EXPERT BASE FOR CREATING THE ACTION PLAN OF MANAGING THE STRICTLY PROTECTED NATURA 2000 SPECIES OF FISH – EUROPEAN MUDMINNOW (*UMBRA KRAMERI*) IN VIROVITICA – PODRAVINA COUNTY

General notes:

This expert base is created within the project "Transboundary management program of pantalateral preserve of the Mura-Drava-Dunav biosphere" (acronym: coop MDD), Interreg Danube Transnational Programme, whose implementation was allocated to BIOTA j.d.o.o. and key expert dr. sc. Dušan Jelić by the Public institution for management of protected parts of nature and ecological network of Virovitica-Podravina County via public procurement "Development of an Action plan for managing the strictly protected Natura 2000 species of fish - European mudminnow (Umbra krameri)" (EV: 01/17-MV).

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Abbreviations:

AP -action plan

MPAP –Management plan with action plan

PI VPC - Public institution for management of protected parts of nature and ecological network of Virovitica-Podravina County

VPC – Virovitica – Podravina county

MNPE – Ministry of nature protection and energetics

1. ABSTRACT

The european mudminnow (*Umbra krameri*) is a small freshwater fish that inhabits swamp and wetland areas of large European rivers. In Croatia it can be found near river Drava, Sava and Dunav. It's endangered because of anthropogenic influences like waterway regulation, embankment creation, the interception of flooding areas of big rivers, draining swamp habitats as well as introducing foreign invasive species and pollution of water bodies. It prefers still or slow running waters with lush vegetation that do not contain other species of fish. Waters with lower oxygen concentrations are favoured by the mudminnow, which additionally limits the number of other fish species that can survive in the habitat. For that reason, it can be found in mildly polluted waters because those condition cause a lack of oxygen or create completely anoxic conditions. Polluted waters are still suboptimal conditions for the mudminnow. In Virovitica – Podravina county the mudminnow inhabits canals and streams in the Županijski and Lendava canal basin. Its optimal habitat are deep canals with lush vegetation where at least 1m of water can be found during summer months. On the surface there is a thick layer of duckweed and the vegetation looms over from the bank which stops the water from heating up or evaporating. There are seven known localities of the mudminnow in VPC. With this research 18 new localities were found. During the participative process 4 general and 13 specific goals were determined for the conservation of the european mudminnow on VPC territory. As a means of achieving those goals 33 activities were defined for a 10-year period (2019. – 2029.)

2. INTRODUCTION

2.1. Methods of creating the expert base

This expert base is made for the Interreg project "Transboundary management program of pantalateral preserve of the Mura-Drava-Dunav biosphere" (acronym: coop MDD), whose implementation was allocated to BIOTA j.d.o.o. and key expert dr. sc. Dušan Jelić by the Public institution for management of protected parts of nature and ecological network of Virovitica-Podravina County via public procurement "Development of an Action plan for managing the strictly protected Natura 2000 species of fish - european mudminnow (Umbra krameri)" (EV: 01/17-MV).

Analysis of the stakeholders was conducted in the preparational phase of the project and three main regional centres of the count were identified, according to that the stakeholders were included in the first three preparational workshops. The stakeholder analysis showed that a large percentage of the stakeholders are also agriculturists and/or employed which will present a problem when they are asked to participate in centralized workshops. To gain their attention and interest the first preparation workshops were conducted locally in the towns of Noskovci, Pitomača and Suhopolje. The expert base was made based of literature data, unpublished data of the authors and their associates and contributions of the included stakeholders. Two more workshops (out of five possible) were organized within the project where stakeholder representatives and experts worked together to identify possible threats, conservation measures and the activities contained in the action plan for conservation of the European mudminnow.

The stakeholder analysis is supplied in this document (ANNEX 1.).

3. THE BASIS FOR CREATING THE EXPERT BASE.

3.1. Biology and species description

European mudminnow, *Umbra krameri* WALBAUM, 1792

Foreign names: crnka (cro.), Europäischer Hundfisch (germ.)

Other Croatian names: rapa

Systematics:

Vertebrata
Gnathostomata
Pisces
Osteichthyes
Actinopterygii
Neopterygii
Halecostomi
Teleostei
Euteleostei

Protacanthopterygii

Esociformes

Esocoidei (Haplomi)

Umbridae

Synonyms:

Gobius caninus MARSILI, 1726

Umbra Kramer GRONOVIUS, 1763

Umbra Krameri WALBAUM, 1792

Aphyra lacustris GROSSINGER, 1794

Cyprinodon umbra CUVIER, 1829

Umbra Crameri MOLLER, 1844

Umbla (pro *Umbra*) *Krameri* BONAPARTE, 1846

Umbra Nattereri (in. lit.)+ *U. Krameri* CUVIER & VALENCIENNES, 1846

Umbrina Krameri STEINDACHNER, 1870

Umbra canina KAROLI & HERMANN, 1882

Umbra umbra BERG, 1916

Umbra lacustris HANKO, 1923

Umbra krameri krameri KUX & LIBOSVARSKY 1957

Umbra krameri pavlovi KUX & LIBOSVARSKY, 1957

Figure 1. Adult specimen of the European mudminnow, Umbra krameria, from channel Paninac (photo: Dušan Jelić)

Etymology

Umbra (lat.) = shadow, *krameri* – in honour of Wilhelm Heinrich Kramer, who first described the fish as *Umbra*, even before Linne.

Morphology

It's a little fish with a total body length of 5 to 9 cm, sometimes growing to 11,5 cm (Wanzenböck, 1995; Kottelat i Freyhof, 2007). It was recorded that females can sometimes grow up to 17 cm (Povž, 1995). Body mass is mostly 5 to 8 grams, the largest recorded mass for the species being 27 grams (Wanzenböck, 1995). The body is long, cylindrical form that is laterally lightly flattened. Males are usually smaller and thinner than females (Wanzenböck, 1995). The head is rather large and make up a third of the total body length, with a mouth lightly facing upwards (Wanzenböck, 1995).

The maxilla is shorter than the mandible and it reaches the middle of the eyes (Wanzenböck, 1995). Aside from the snout and chin the entire body is covered with large, smooth, spherical cycloid scales which easily fall off the body (Wanzenböck, 1995). The scales don't have radial lines but concentric circles (Wanzenböck, 1995). There is no lateral line and 31 – 36 scales span the lateral side of the animal, over and under which are 5 – 7 rows of scales (Wanzenböck, 1995). The body colour is mostly dark brown on the dorsal part of the animal, while the underbelly is a grey, almost white colour (Wanzenböck, 1995).

Irregular black dots are distributed all over the body and there is a white line extending along the body, from the operculum (gill cover) all the way to the caudal peduncle (Wanzenböck, 1995). The black maculation can be seen on the dorsal and tail fins (Wanzenböck, 1995). The dorsal fin is located on the second half of the body, and it starts directly above the base of the pectoral fins spanning al the way to the base of the anal fin (Wanzenböck, 1995). Seeing as the fin spines are almost the same length the dorsal fin is shaped like a rectangle (Wanzenböck, 1995). Unpaired fins are rounded (Wanzenböck, 1995).

Aside from size and body shape it there are morphometric differences between males and females (Kux i Libosvárský, 1957). Males are characterised by loner ventral fins and a shorter distance between them and the anal fin (Wanzenböck, 1995).

Biology of the species

Its lifespan is up to two years in the western part of its range (Wanzenböck, 1995) and up to five years in the Dunav, Dnjepar and Dnjestar deltas (Wanzenböck, 1995; Kottelat i Freyhof, 2007). It reaches sexual maturity early. Males and females can reproduce at 1+ years of age. There have been individuals that were observed mating at 10 months in aquariums (Wanzenböck, 1995). In natural populations the male female ratio slightly favours females (Wanzenböck, 1995). The number of eggs females deposit varies from population to population and is affected by the age of the individual. The number off eggs can reach 2710 eggs per female as described by Berg, 1980. The spawning period is early spring, between March and April, when water temperature reaches between 12,5 and 16,5°C (Wanzenböck, 1995). Females choose the deposit site for the eggs. They deposit the eggs on plants

or they build nests from plant matter. The females guard the nests until the brood hatches. During that period, they are very aggressive (Wanzenböck, 1995).

Species ecology

It can be found in still waters, mainly swamp and pond areas (Wanzenböck, 1995). It can be found in densely overgrown parts of large bodies of water, but it mostly prefers, smaller, complexly structured waters like backwaters and oxbows (Povž, 1984), ponds and ditches (Wanzenböck, 1995). The common characteristic of the habitats where the mudminnow is found is a rich habitat structure provided by plants (dry trunks, submerged trunks, macrophytes and water moss) which are characteristic of swamp areas (Wanzenböck, 1995) and complexs plant communities comprised of species: Elodea sp. - Hydrocharitaceae; Typha sp. - Typhaceae; Carex sp. - Cyperaceae; Nymphaea sp. - Nymphaeceae; Potamogeton sp. - Potamogetonaceae; Nuphar sp. - Nymphaeaceae; Nymphoides sp. - Menyanthaceae; Salix sp. - Salicaceae; Lemna sp. - Lemnaceae; Myriophyllum sp. - Haloragaceae; Ceratophyllum sp.- Ceratophyllaceae; Phragamites sp. - Poaceae; Trapa sp. - Trapaceae; Myosotis sp. - Borraginaceae; Mentha sp.- Lamiaceae; Salvinia sp.- Salviniaceae; Utricularia sp. - Lentibulariaceae; itd. (Bănăduc, 2008).

One of the main adaptations to living in habitats like these is tolerance to very low levels of oxygen which enables the organism to breathe in a special way (Wanzenböck, 1995). Geyer I Mann (1939a, b) and Berg (1948) state that the European mudminnow is a very resilient fish and can survive outside of water for up to two days during winter.

They prefer diverse food. European mudminnow spawn usually feed on small crayfish like ostracods, cyclopoids and chironomid larvae. After that they switch to larger food, especially benthic like Gammaridae crustaceans, isopods and even snails. They feed on food in the middle and surface layer of the water like water beetles but other insects as well. (Wanzenböck, 1995). They can feed on water plants as well (*Lemma sp*.) (Wanzenböck, 1995), as well as fish spawn (Berg, 1948).

In Croatia the mudminnow inhabits stagnant and slowly running waters with lush vegetation in flood plains near large rivers (Drava, Sava, Dunav, Odra). It in habits mesotrophic and eutrophic constant (NKS A.1.1.1.2., A.1.1.1.3.) and periodic (NKS A.1.2.1.3., A.1.2.1.4.) stagnant waters, middle

and lower parts of slow watercourses (NKS A.2.3.2.2.) as well as canals with constant and periodic flow (NKS A.2.4.2.). A small number of other freshwater fish species is characteristic of European mudminnow habitats. It can survive in habitats characterised as occasional bodies of water because the individuals can survive droughts in wet mud under layers of decomposing leaves or artificially created depressions (an exceptional number of individuals was found in a hole created beneath the roots of an overturned tree in Grobižalj, BIH). A large number of individuals was noticed in Bistrec and Rakovica streams in Međimurje that dwell in riparian vegetation along a very fast watercourse and in sintopy with 12 other fish species (Jelić, D., unpublished data). This habitat is completely opposite with habitats in Žutica forest where the species exclusively inhabits closed ponds in the forest (Mrakovčić et al., 2007).

3.2. The role and significance of the species

This species is not interesting from an economic perspective because of its small mass. It is not attractive for cultivation or sports fishing. Sports Fishermen recognize it because it can sometimes, albeit very rarely, be caught via fish hooks. Due to its preferred habitats it rarely comes into contact with fishermen. Even though it lives in the same habitats as mudfish its not recognised as good live bait for predatory fish species. It's role in the ecosystem is that of a predator since its primary food are insect larvae, water insects, tadpoles etc. In ex situ cultivation state, it was observed to be feeding on mosquito larvae in extreme quantities thus effectively cleaning the water body from the aforementioned. Its importance lies in the potential for ecological repression of mosquitoes.

3.3. Analysis of the state of the species and habitat (historical view/current state)

The distribution of the species

The European mudminnow is endemic to the Dunav and Dnjestar basin (Sehr and Keckeis, 2017). It is the only representative of the genus in Europe. It inhabits Austria, Bosnia and Montenegro, Bulgaria, Croatia, Hungary, Moldova, Romania, Serbia, Slovakia, Slovenia and Ukraine (Sehr i Keckeis, 2017; Kottelat i Freyhof, 2007).

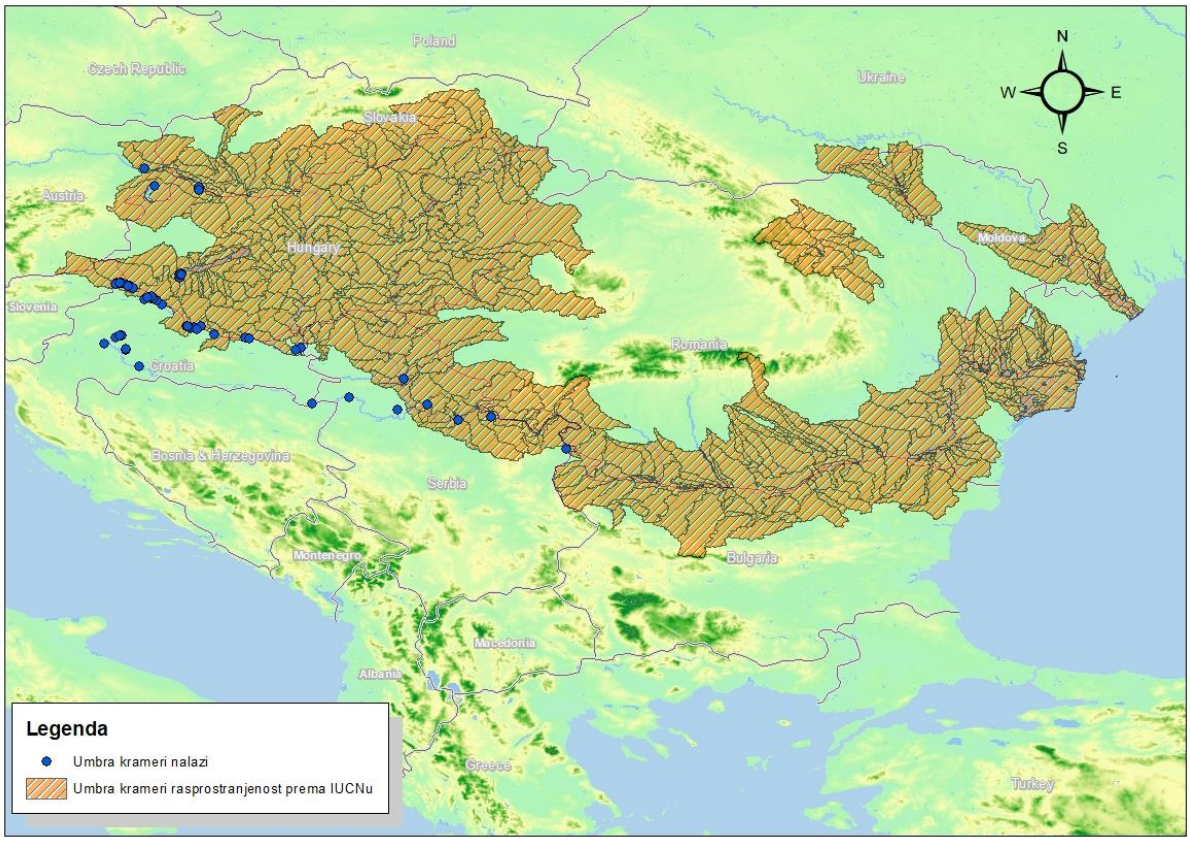

Figure 2. Global distribution of the European mudminnow according to IUCN data and scientific literature.

There is no record of big connected populations in Croatia, instead it is clumped in several localities like in the rest of the Europe (Mrakovčić et al., 2006). We can find it in distributary channels of the rivers Drava and Mura and in the west border area of Lonjsko polje in Žutica forest which is considered to be a characteristic habitat for this species (Mrakovčić et al., 2006). The species is known through literature at only 8 localities in Virovitica – Podravina County (Delić et al., 1997; Mrakovčić et al., 2006; Freyhof 2012) in canals and waterways related to Županijski and Lendava canals (Figure 3.).

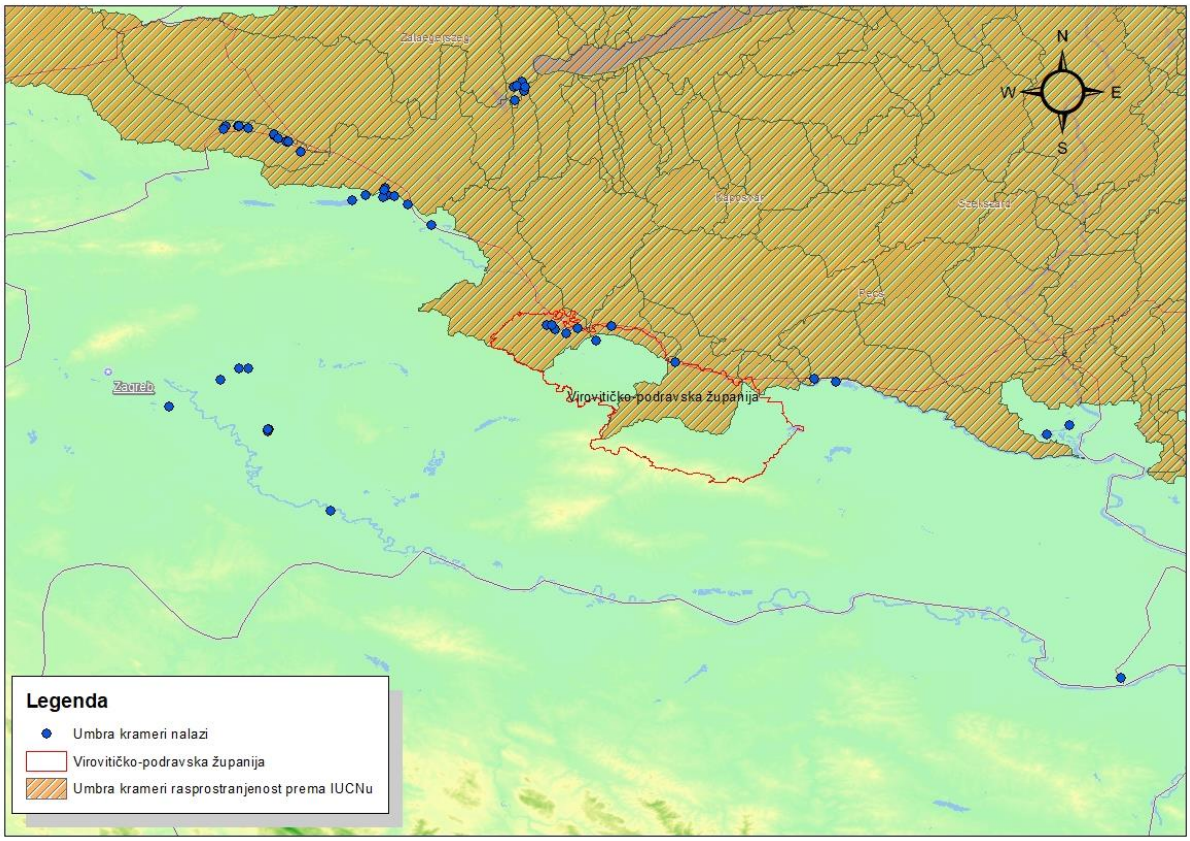

Figure 3. Distribution of the European mudminnow in Croatia and neighbouring countries (literature data).

The first findings and the only review paper on european mudminnow distribution in VPC was made by Delić et al. (1997). The authors have confirmed the presence of this species during 1996. in this part of Croatia and in Lendava stream (locality Liman: 2 individuals), Gakovac canal (in between Lendava and Ođenica: 15 individuals), Šušulić canal (tributaries of Lendava: 15 individuals) and the artificially excavated site near Starogradački Marof (near Lendava: 15 individuals). The next year (1997.) the findings at Šušulić stream were confirmed (3 individuals) as well as Gakovac stream (10 individuals). A new locality was found on the Županijski canal near Gornje Bazije (7 individuals).

Jelkić et al (2016.) 2913. add new data of new findings in the southern parts of the Županijski canal basin; more accurately Mlinski canal near Vaške, that show that the species can be found to the south near Drava. There is no published data about systematic research on the European mudminnow distribution nor the general distribution on VPC ichthyofauna.

During the research for the preparation of the action plan in 2017. and 2018. new potential localities were mapped in the close vicinity of existing literature records. 84 potential localities were researched in the field with special emphasis on the central and lower part of the Županijski canal because those areas were indicated as interesting in previous publications (Delić et al. 1997 I Jelkić et al., 2016). The european mudminnow was confirmed at a total of 18 localities mostly concentrated around the upper basin of Županijski canal (canal Paninac, Krešimirovac, Ritić, canal in Noskovci, Veliko polje etc.). The middle and the lower parts of the Lendava and Županijski canal basin are the most important parts for the conservation of the European mudminnow in VPC.

Habitat

In Croatia the European mudminnow inhabits stagnant and slowly running rivers with lush vegetation in flood plains near big rivers (Drava, Sava, Dunav, Odra). It inhabits mesotrophic and eutrophic constant (NKS A.1.1.1.2., A.1.1.1.3.) and occasional (NKS A.1.2.1.3., A.1.2.1.4.) stagnant waters, middle and lower flows of slow watercourses (NKS A.2.3.2.2.) as well as channels with constant (NKS A.2.4.1.) and occasional (NKS A.2.4.2.) waterflow. All other habitats are characterised by a low amount of other freshwater fish species. It can survive in habitats defined as occasional waterbodies because the individuals can survive drought in damp mud under deposits of decomposed leaves or artificially created depressions (on Grobižalj in Bosnia and Herzegovina an extraordinary number of individuals was registered in a hole under an overturned tree root system). In Međimurje in streams Bistrec and Rakovnica large populations were registered in water vegetation near an extremely fast waterflow in a sintopy with 12 other species of fish. This habitat is the polar opposite of the habitats in Žutica forest where the species exclusively inhabits closed ponds in the forest.

European mudminnow habitats in Virovitica – Podravina County (Županijski canal) represent some sort of inter-stage. It is a longitudinal water body which occasional has faster waterflows (in places of steeper angles and less vegetation) and in other parts the water completely slows down and creates limnophilic habitats (with an abundance of vegetation). Hornwort (Ceratophyllum demersum) and Eurasian watermilfoil (*Myriophyllum spicatum*) plant communities are present in canals with visible water flow which was mentioned in previous studies on Milinski stream (Jelkić et al. 2016). In deeper parts of the canal small communities of the yellow water – lily (*Nuphar luteum*) and broad waterweed

(*Elodea canadensis*) can be located while the curled pondweed (*Potamogeton crispus*), water – starwort (*Callitriche sp.*), yellow iris (*Iris pseudacorus*), common reed (*Phragmites australis*) and the narow - leaved cattail (*Typha angustifolia*) inhabit the canal banks (Delić et al. 1997). During the 2017. – 2018. habitat analysis the same types of habitats and dominant vegetation were observed and were in accordance to previous literature descriptions. In the localities where the water slows down eutrophic conditions form, coupled with demersal lack of oxygen (evident by malodorous anoxic mud and gas generation) and reduced ichytiofauna that can survive such conditions (European mudminnow, European weatherfish, crucian carp). Delić et al. (1997) mention that the european weatherfish (M. fossilis) and the loach (*C. elongatioides*) were the most common species found next to the european mudminnow. Our research showed that the loach (38% of localities), pike (33%), and european weatherfish and the prussian carp (16%) were the most common species found with the european mudminnow. In almost 78% of localities (habitats) where the mudminnow was found there was only one other fish species present, or there were none. Only in Županijski canal near Gaćište the mudminnow was recorded (only one specimen) in syntopy with 7 different species of fish.

The fact that Županijski canal and its tributaries are regurarly cleaned points to the fact that the ecosystem can regenerate in the meantime. The waters in VPC are managed by Croatian waters VGO Osijek. During the workshops in the shareholder process the representatives of the Croatian waters stated that the canals of the first and second order are maintained every 4 years.

There is no detailed data on the historical state of the area of interest so it's hard to compare the changes that occurred through the last decade of intensive use. The state of water bodies before the creation of the Županijski canal is also unkwnown. It's likely that the mudminnow was present in the area of naturally occurring floods near the river Drava and its smaller tributaries. After the canal was dug it probably found suitable habitats in some parts of the system.

Number of individuals

In Croatia sub populations have been recorded along river Mura up to the confluence into Drava, alongside Drava in the basin of Županijski canal, in canals along Bosut, in Žutica forest near Ivanić Grad, in river Odra near Velika Gorica. Smaller populations were recorded in canals and waterflows that flow into Sava (right tributaries) from Jagodno to Žutica forest, and sole individuals

were recorded in Lonjsko polje (Svinjičko) and the peripheral channel in HE Dubrava (near Varaždn). It disappeared from a lot of locations where it was present in the past (Freyhof, 2011). The total number in all populations has fallen by 30% in between 2000. and 2010. (Freyhof, 2011).

Jelkić et al. (2016) have presented new data in 2013 about the localities in the south part of the Županijski canal basin, more accurately in Mlinski canal near Vaška. In the same paper they state the first quantitative data about the relative numbers of the mudminnow at about 0,1 individual/m^2.

To asses the quality of the habitat 85 different water bodies were searched and the mudminnow was found in 18 of them. The assessment about the number of the individuals was given based on the relative number of individuals that was sampled. Five localities were given a grade for large populations (grade 3 or 3+; Figure 4.,), the most noticeable one being canal Paninac near Gaćište where an extremely large population was found (two separate localities). On two locations on that canal 2 – 3 mudminnows can be caught via electrofishing per m^2 of the habitat.

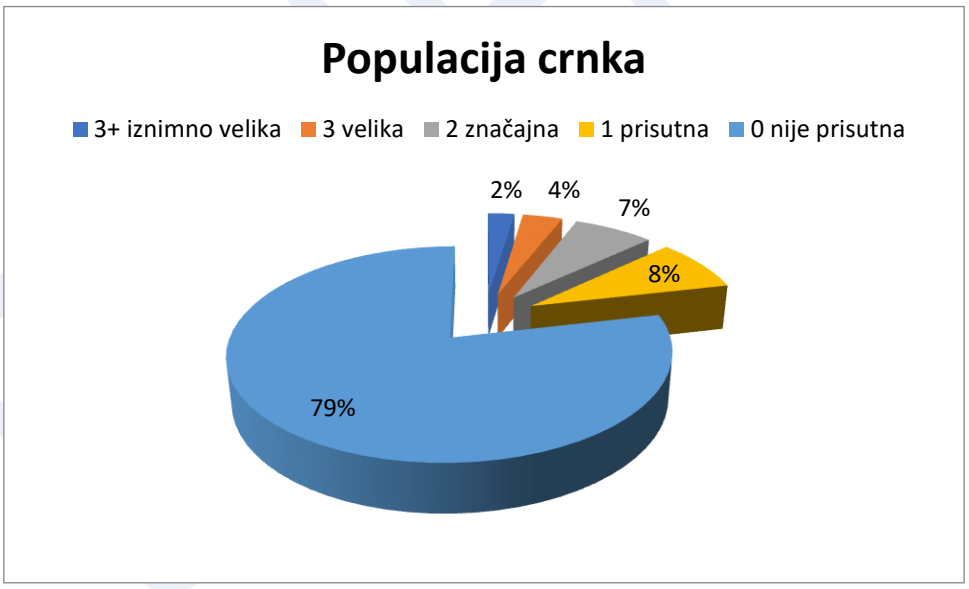

Figure 4. Analysis of the size of the european mudminnow population of assessed localities (N=84)

On the lower part of the canal, at the mouth of Županijski canal a significant population of the mudminnow was recorded. For this and 5 other localities, the population of the mudminnow was deemed significant (2), and its presence was confirmed or there were only a couple individuals at

seven other localities. That doesn't mean those localities are not important by any means. It means that the european mudminnow comes in smaller population densities due to competition with other species or the suboptimal habitat type. In some cases (eg. Županijski canal in Rušani) those habitats are exceedingly large (parts of the canal with similar conditions) and they contain a collectively large population of the mudminnow (as opposed to the canal Paninac which is short).

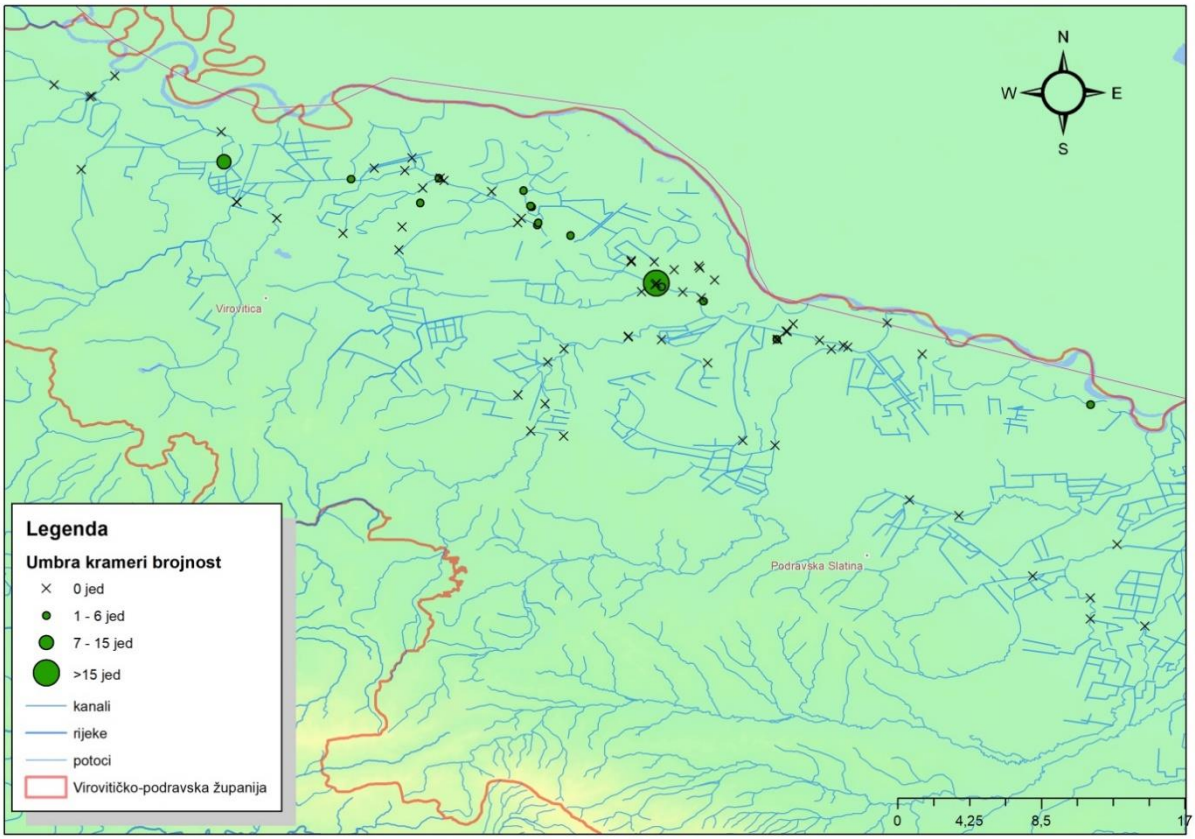

Figure 5. Relative numbers of the european mudminnow on the assessed localities.

The numbers and density of the mudminnow at VPC are not assessed in previous studies. All localities described in older literature (Delić et al. 1997; Jalkić et al. 2016) were confirmed with new research 82017. – 2018.) within the making of this expert base of management of the european mudminnow. Other referable historical data does not exist, and it is impossible to compare numbers and define the trends of individual populations.

The populations can be considered stable, even expanding, due to human influence over the last 50 years. By digging Županijski canal and its side canals and connecting it to existing streams new suitable habitats were created for the european mudminnow. It seems like the largest factor for inhabiting a system is the fact that it's inaccessible to other fish species (except syntopic ones like the european weatherfish). The state before the canal was dug is not known.

Genetic structure

The European mudminnow is the representative of the genus Umbra and the family Umbridae in Europe. Along with the European mudminnow there are 4 species in the family worldwide: *Umbra limi*, *Umbra pygmaea*, *Novumbra hubbsi* and *Dallia pectoralis*, that inhabit northern America and east Siberia (Kuehne and Olden, 2014). Genetic studies on the family Umbridae are rare and not detailed enough, seeing as molecular phylogeny was done on bigger taxonomic groups like orders Esociformes and Salmoniformes (López et al., 2000; López et al., 2004). Recent genetic studies in Europe point at great genetic diversity of the European mudminnow along the entire area of distribution (Marić et al., 2016). In Croatia the Sava populations are genetically separate from the Dunav populations, while the Drava population (Županijski canal) doesn't differ from the Hungarian populations in Balaton lake and Tisa river (Marić et al., 2016). This type of filogeography of the European mudminnow in Croatia is a direct result of Pleistocene glaciations and tectonic movements that happened at the same time, thus forming the basins we know today (Marić et al., 2016).

Future research should be aimed at further genetic analysis of this subpopulation which can then be compared to data from other regions. It's important to find out how closely connected the subpopulations from Lendava and Županijski canal are, and determine their connection to the populations of Varaždin and Međimurje counties.

3.3.1. Habitat description and evaluation

3.3.1.1. Field studies

Field studies were conducted from the second half of April to the end of October 2018. in an attempt to cover all the annual seasons. The detectability of the European mudminnow changes during the year and it depends on the temperature of the water, the presence of vegetation and other fish species. Flood periods should be avoided due to accidental captures that wouldn't otherwise happen at those location (migrating individuals). Before the research started the existing literature was analysed and 7 known localities in VPC were discovered where the european mudminnow was observed. Delić et al (1997) observed the species in Gakovac and Šušulić canals, the river Lendava (near Liman), and Županijski canal near Gornje Bazje. Freyhof (2012) published his own data with observations near Suhopolje "close swamp areas". Jurkić et al. (2016) publish a new localitiy in Mlinski stream (tributary of the Županijski canal) (Figure 4.). Mrakovčić et al. (2007) report the general distribution of the species from the mouth of Mura into Drava to Donji Miholjac, without specific localities. This literature data were the starting points for defining localities that are going to be covered with this research.

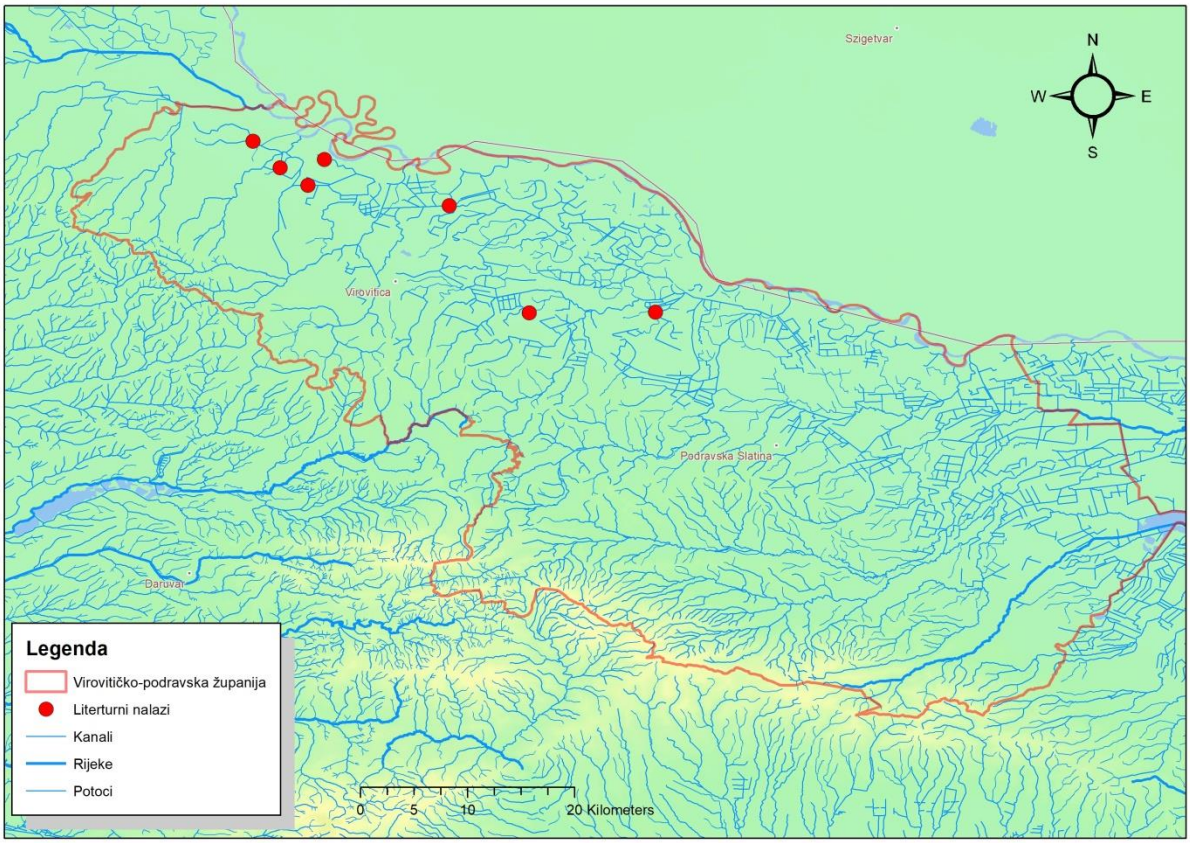

Figure 6. Localities from literature with known locations of the European mudminnow and the network of water habitats in Virovitica – Podravina County.

On the localities where there was no record of the European mudminnow but were assessed as potential habitats a repeated habitat search was conducted. That way two additional localities were confirmed; Županijski canal near Gornje Bazje and Ritić canal near Budrovac Lujački. Those localities obviously contain populations that are harder to detect. Ritić canal is also very shallow, so during the dry part of the year there is not a lot of water inside. It is filled with lush vegetation which complicates electrofishing.

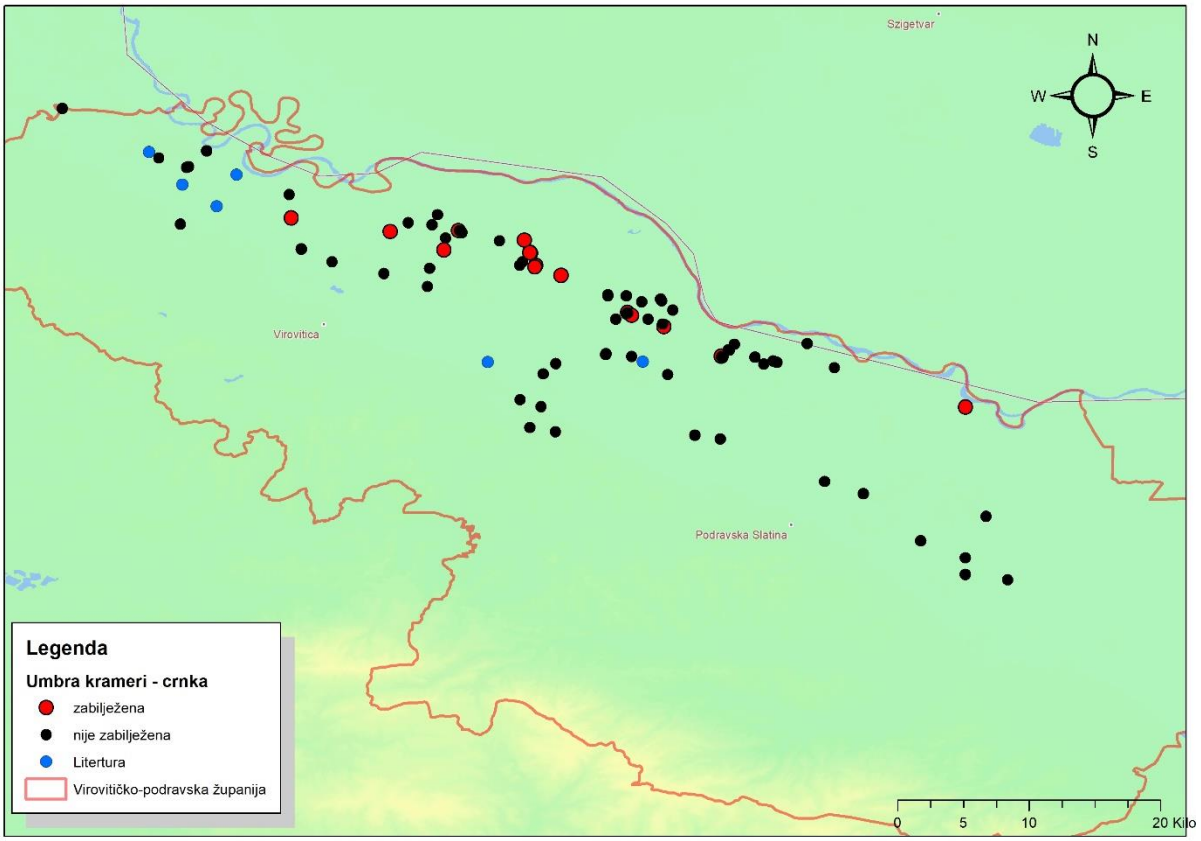

Figure 7. Overview of reserch localities on the territory of the Virovitica – Podravina County with a display of European minnow spatial distribution. A tendency of records in the upper part of the Županijski canal flow can be observed.

Figure 8. Channel Paninac in Gaćište, directly before flowing into the Županijski canal. This channel presents the ideal habitat for the European mudminnow and a very large population of the species was recorded within it.

Figure 9. The european mudminnow in its natural habitat. The coloration serves as camouflage, so it can merge with the lush vegetation in the background.

3.3.1.2. Assessment of habitat quality

With the aim of assessing habitat quality 85 water bodies were inspected; only in 18 of those has the presence of the European mudminnow been verified (Figure 8.; full list available in ANNEX 2).

The assessment of habitat quality was based on the adequacy of the observed state of the habitat for the mudminnow; how the general characteristics like the vegetation, depth and water flow, suit the optimal ecological needs of the species. The current state of the localities was taken into consideration as well because certain localities ecologically fit the mudminnow even if they are currently in a bad state due to mowing of the vegetation, digging the canal or pollution. It's important because the localities could be greatly improved with minor adjustments.

All localities were assessed based on the degree of mudminnow habitat pollution. In most cases it was water pollution where organic pollution dominates and is clearly visible. It's likely that it is the case of

chemical pollution (not tested) as well. The sources of pollution were not detected since it was not a subject of this research.

Figure 10. Overview of the localities where the presence of the European mudminnow was recorded with the quality grade of the habitat.

Settlement	Locality	Population	Habitat quality	Pollution	Habitat type
Gaćište	Paninac channel above the floodgate	3+	excellent	non-existent	Deep canal, vegetation
Gaćište	Paninac channel under the floodgate	3+	excellent	non-existent	Deep canal, vegetation
Rušani	Mouth of Krešimirovac in Županijski canal	3	excellent	non-existent	Deep canal, vegetation
Rušani	Krešimirovac, canal 100m from the bridge	3	excellent	polluted	Deep canal, vegetation
Bušetina	Bupetina canal	3	good	faint	Shallow canal with lush vegetation
Rušani	Županijski canal, Rušani2	2	good	faint	Deep canal, vegetation
Rušani	Krešimirovac, stream	2	excellent	polluted	Deep canal, vegetation
Gaćišta	Mouth of Paninac into Županijski canal	2	excellent	faint	Deep canal, vegetation
Veliko polje	Canal in Veliko polje	2	excellent	non-existent	Shallow canal with lush vegetation
Vaška	Vaška canal near the fishpond	2	good	non-existent	Shallow canal with lush vegetation
Brezovica	Županijski canal	2	good	non-existent	Wide, deep channel with riparian vegetation
Gornje Bazje	Županijski canal	1	suitable – but in bad condition	extremely polluted	Deep canal, vegetation
Noskovci	Canal in front of Dravska prica	1	excellent	non-existent	Deep canal, vegetation

Budrovac Lujački	Canal Ritić	1	good	non-existent	Shallow canal with lush vegetation
Veliko polje	Side canal	1	excellent	non-existent	Shallow canal with lush vegetation
Krešimirovac	Krešimirovac/Manduševac	1	excellent	non-existent	Shallow canal with lush vegetation
Rušani	Krešimirovac stream	1	good	polluted	Shallow canal with lush vegetation
Gaćište	Županijski canal	1	good	faint	Wide, deep channel with riparian vegetation

Optimal habitats, where the largest number of the European mudminnow was recorded, were assessed as great in majority of the cases (habitat quality) or with mild pollution. Only the Županijski canal near Gornje Brestje was assessed as an extremely polluted locality, while three more localities are assessed as polluted (all localities in Krešimirovac stream). Taking into account all surveys localities its abundantly clear that the higher flows of the Županijski canal are the most polluted along with smaller channels near Virovitica (eg. Ođenica).

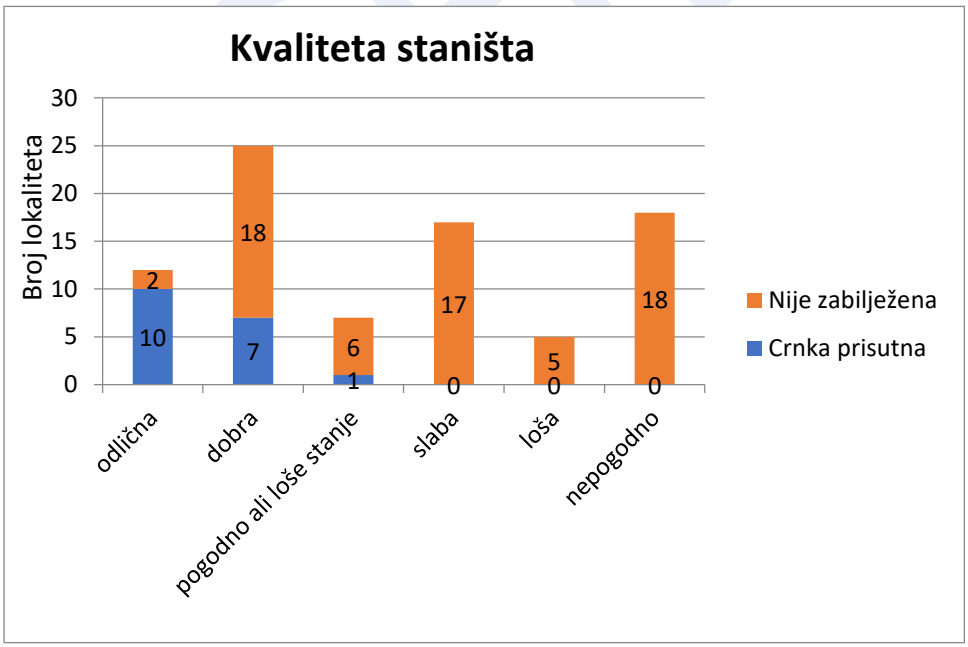

Figure 11. Overview of the localities where the European mudminnow was found and where it was not.

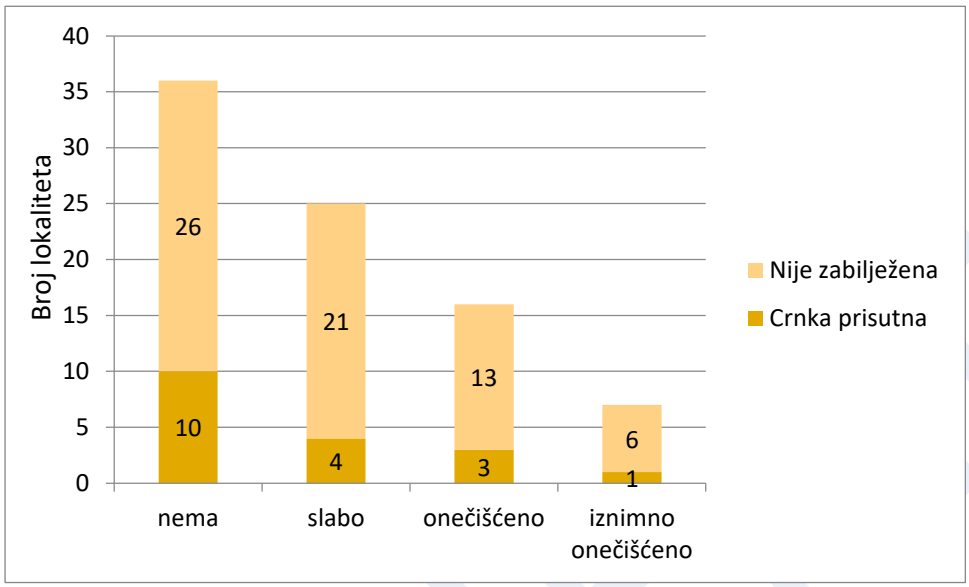

Figure 12. Analysis of the detected localities in relation to the detected pollution.

Defined habitat types:

Fishpond without vegetation – sport fishponds with very little vegetation, big open water surface, greater depth and presence of large quantities of fish for consumption; additional feeding of fish by fishermen is present.

Fishpond with lush vegetation - larger sport fishpond or repurposed oxbows with natural vegetation in shallow parts of the water body, so some areas are adequate for the European mudminnow; fish for consumption and additional feeding present in a part of the water body.

Pond, vegetation – closed water body, pond or pool with a relatively small water column, but large build-up of fine mud, rooted and floating water vegetation present (duckweed), low water oxygenation, anoxic conditions in deeper layers of mud.

Dry canal – canals rich with rooted vegetation displaying torrential characteristics, the rest of the ear they are dry, or a thin film of water flows through them; artificially dug and well kept.

Shallow canals with lush vegetation – canals that endure a large amount of water during springtime, but only 10 – 30 cm of water remain during summer months, very rich with water vegetation (rooted vegetation, in places with deposits of duckweed), they contain deeper areas that retain water even in the driest years; flow is present

Deep canal, vegetation - low canals that retain water, of greater depth with weak flow, very develop ed vegetation which shades the water and prevents the water from heating up (cold water).

Flow, not a lot of vegetation – streams with faster waterflow which prevents plants from sprouting roots (especially during springtime), riparian vegetation poorly developed, very good oxygen saturation and diverse rheophile and limnophile fish species.

Wide canal, deep, riparian vegetation – flatland parts of deeper canals (primarily lower parts of the Županijski canal) that are accessible for ichthyofauna from Drava river, vegetation present either on the edges of the canal (sometimes the vegetation zone is wide and can span up to 10 m near each bank) or spanning the entire width of the canal (where the whole profile is up to 1 m in depth).

River – large rivers, without water vegetation, aside from very rare cases in riparian areas, with great water speed and ichthyofauna adapted to those conditions (e.g. Drava)

From Figures 8. and 12. it's visible that the European mudminnow was found in three basic habitat types: 1) Deep canal, vegetation (50 %); 2) Shallow canal with lush vegetation (39%); 3) Wide canal, deep, edge vegetation (11%). Based on the assessment of the size of the population it could be deduced that the optimal habitat type for the European mudminnow are deep canals with lush vegetation. It's likely that the reason behind it is that those types of canals are resistant to extreme droughts because they are deep enough to retain a certain amount of water and lush vegetation provides noticeable shade which doesn't allow the water to heat up. During drought conditions the surface of those canals is completely covered with vegetation and the water is not visible, which decreases the rate of water evaporation. Species like the European mudminnow, that can survive in such conditions, can survive long-term and develop dense populations. Other fish don't venture into such canals during spring and cannot survive dry periods during the summer, thus cannot establish permanent populations.

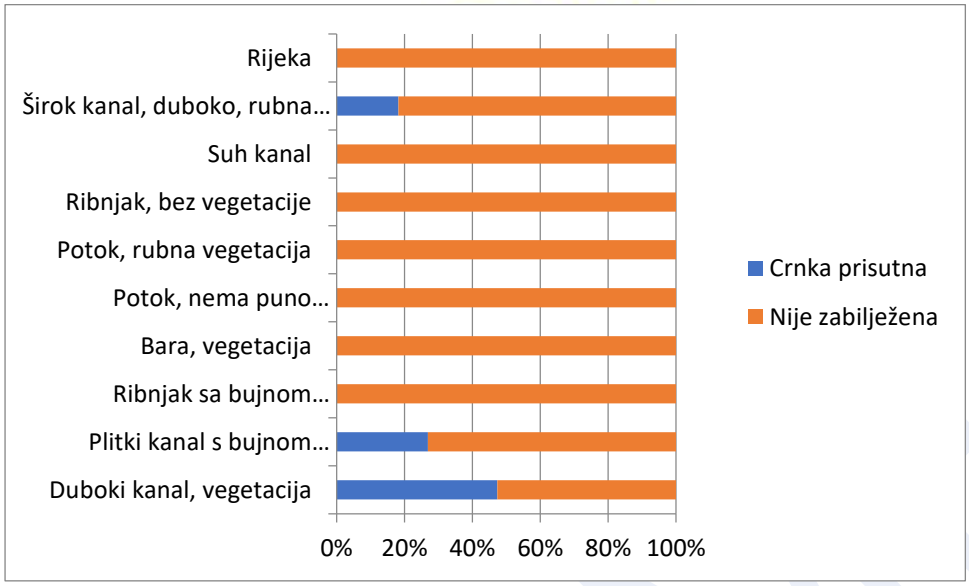

Figure 13. Analysis of habitat types at localities where the European mudminnow was and was not recorded.

Figure 14. During summertime canal Paninac (Gaćište) is completely covered in vegetation under which there is still a 0,5 m column of water.

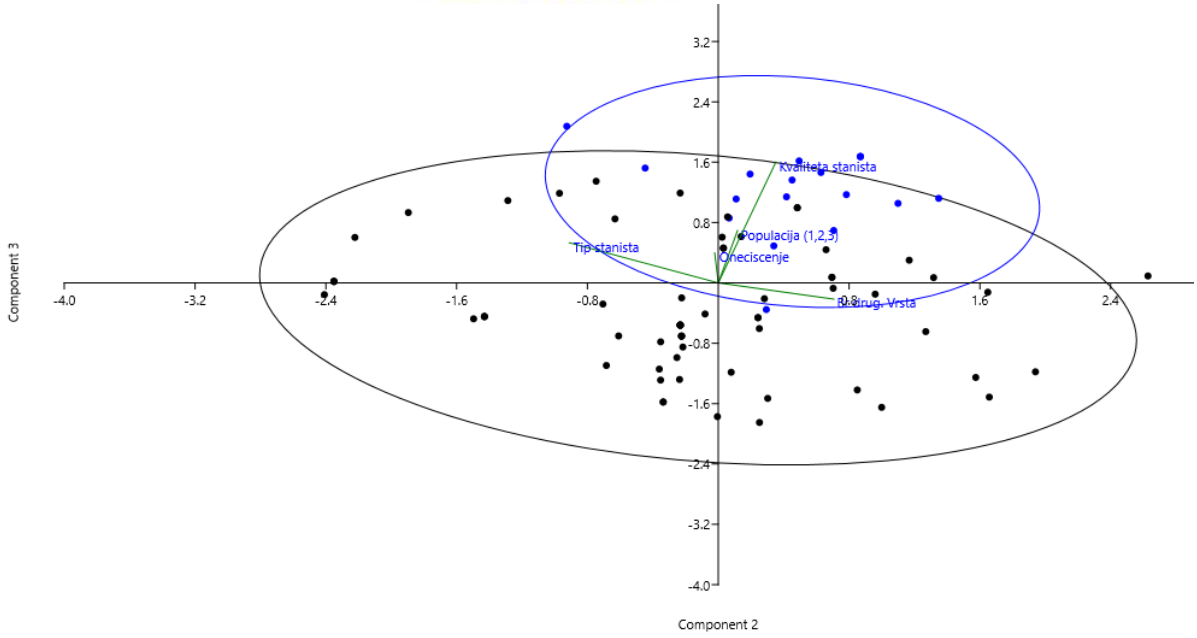

Figure 15. PCA analysis of the overall habitat quality on the localities where the European mudminnow was recorded (blue dots) and where it was not (black dots). An extraordinary habitat influence can be observed (85% of Component 3) and its correlation to the size of the population (Population 1, 2, 3, makeup 36% of Component 3)). The presence of other species in the habitat is also a large influence (58% of Component 2).

The overall habitat quality on each locality doesn't just depend on the quality of the habitat in itself (as it was graded based on the review of the habitat conducted in the field) rather it takes into account broader factors that have been assessed (size of the population, pollution, number of other fish species in the habitat). The PCA analysis was conducted for the purpose of analysing all available data in order to determine which are the crucial factors that have impacted the presence of the European mudminnow, or lack thereof, in a certain locality. Figure 15 shows significant separation of localities where the European mudminnow is present and where it is not, primarily based on the assessment of habitat quality, size of the population and the number of other present fish species. Component 1 (PCA1) was not used because it was not informative enough for separating two groups of localities. The largest percentage in PCA1 were number of other present species (80%) and habitat type (58%).

It's possible to conclude that the European mudminnow on the territory of Virovitica – Podravina County prefers slowly flowing canals, overgrown with rich vegetation with no regard to the degree of pollution in them (except in extreme cases). It's important that there aren't many other fish species present and its specifically intolerant to invasive species. It doesn't prefer ponds, pools or other stagnant water bodies, regardless of the present water vegetation.

3.3.1.3. Potential habitats in the territory of Virovitica – Podravina County.

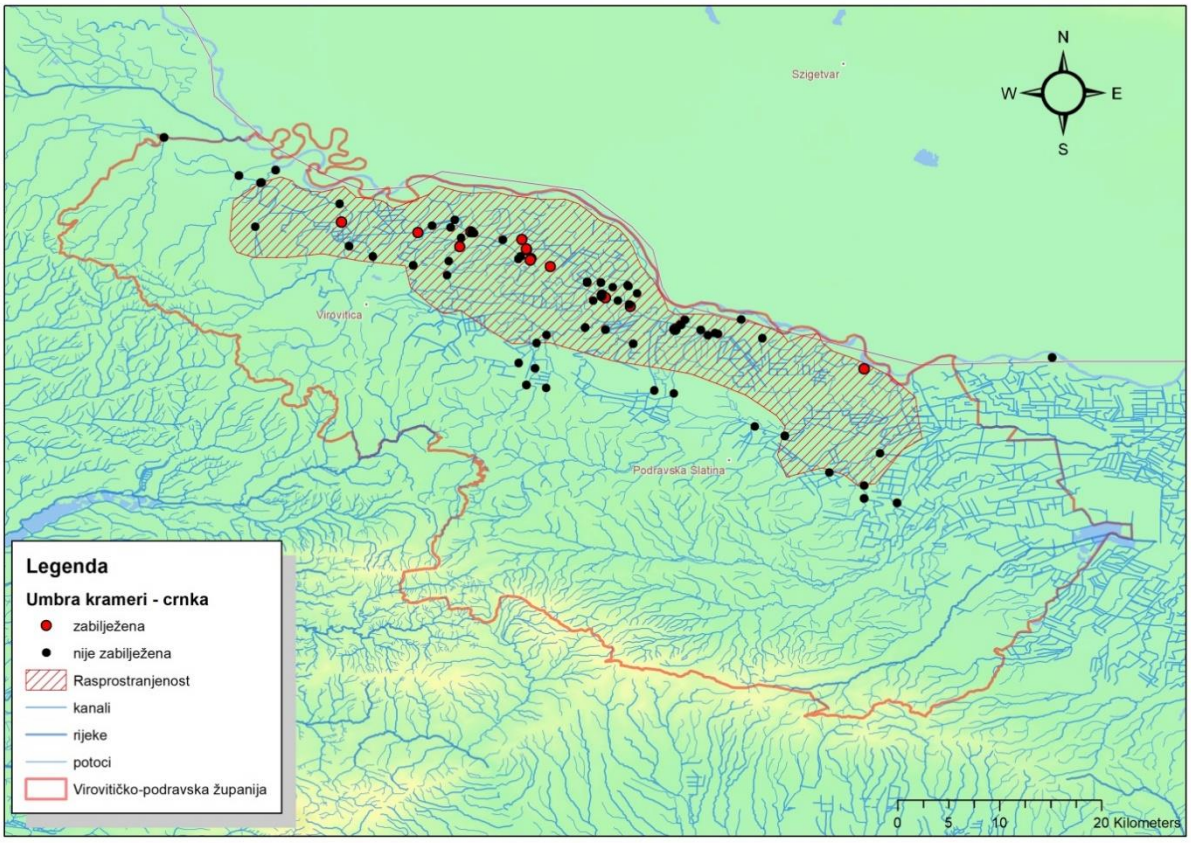

Figure 16. Overview of the potential habitats of the European mudminnow in flowing waters in Virovitica – Podravina County and the defined area of distribution in relationship to the available water bodies.

By researching the characteristics of European mudminnows habitat preferences on the territory of Virovitica – Podravina County the general distribution of the species was determined (Figure 15.). All streams in that area (polygon)can be potential habitats for spawning or migrating populations of the European mudminnow. Even though no individuals were recorded during field surveys in 2017. and 2018. it's highly likely that the European mudminnow would be found in some other locations if long-term research was conducted during all seasons of the year (in only during migration or after flood season). The measures issued by the action plan for conservation must be implemented in the potential areas as well (defined by the polygon on Figure 15.). This polygon was drawn based on the expert judgement of the expert team and the analysis of 3 parameters: 1) elevation, 2) observed types of water habitats in the assessed localities, 3) hydrological characteristics of the assessed localities (incline, waterflow speed). The polygon was drawn to cover the optimal and suboptimal life conditions for the European mudminnow.

The areas located outside of the distribution designated in Figure 16. can be adequate habitats for the species and such localities should still be marked, and distribution maps should regularly be updated (through a tracking program). Water flows that are located on higher elevations and bigger inclines mostly don't create adequate habits for the European mudminnow because of the faster water flow, higher oxygen saturation and many other fish species. Natural water flows of Virovitica – Podravina County flow down from hill areas of Bilogora and Papuk and develop into a network of canals from Figure 16. when they reach the plains. Only in the lowest part, generally between the Podravina highway and Drava river, do they reach the flood plains where we find adequate conditions of the European mudminnow.

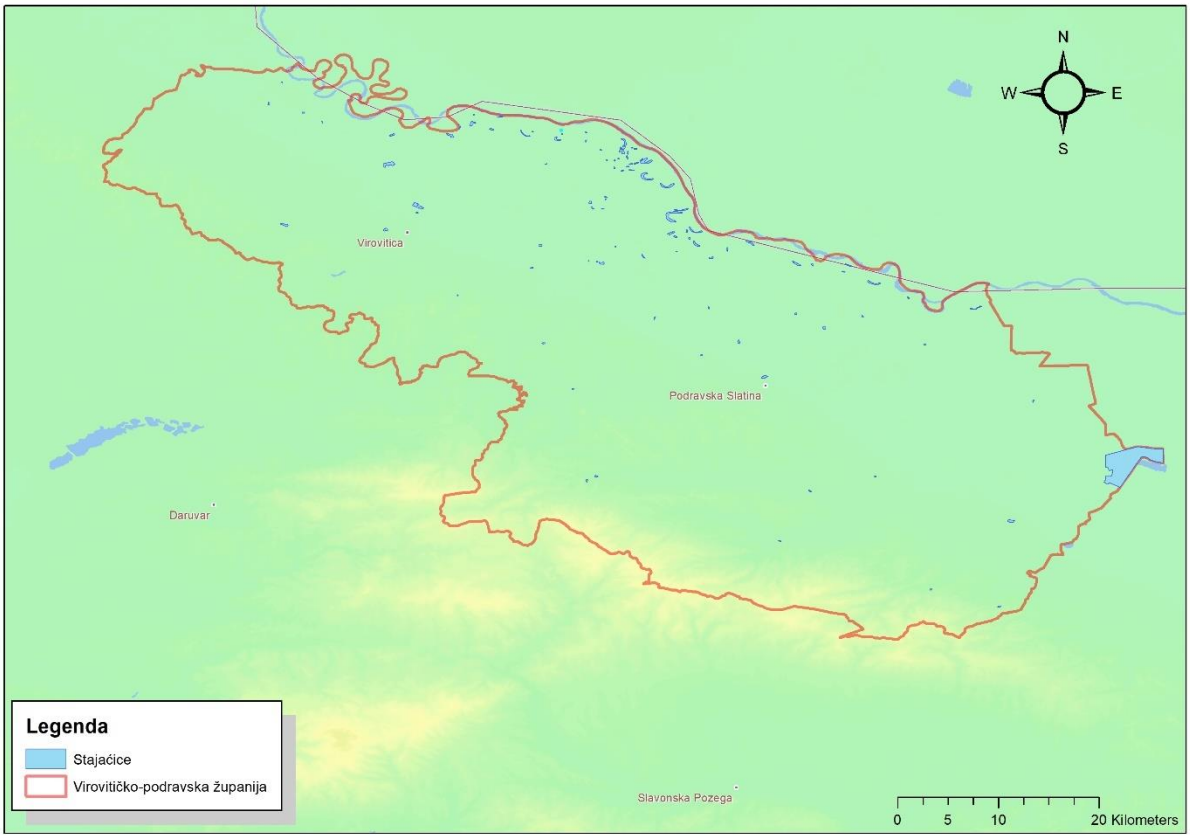

Figure 17. Overview of the potential habitats for the European mudminnow in closed stagnant waters of Virovitica – Podravina County.

Stagnant waters have very similar microhabitat conditions regardless of their elevation and incline. It is possible to find the European mudminnow in one of the stagnant water bodies in any part of the Županijski if it was transported there by humans (Figure 17.). By reviewing the field and topographic maps 101 stagnant water bodies were found, only a few of which were larger than 10 ha (economic fishponds Grudnjak and a couple other sport fishponds). The total area of the stagnant wasters in Virovitica – Podravina County is estimated at around 1250 ha (based on the GIS analysis of the water bodies from Figure 17).

The European mudminnow wasn't recorded in the northern parts of the Virovitica – Podravina County in the border area near Koprivnica – Križevci Županijski (surrounding area of Podravske Sesvete) in which we can expect the presence of the European mudminnow. Those are Sirova Katalena, Kopanjek, Čivićevac, Rogstrug canals and their tributaries. The species wasn't found in the northern canals of Koprivnica – Križevci or Varaždin counties and there is no proof that the Međimurje

and Virovitica – Podravina County populations are linked. If the population in the canals near Drava is continuous it would be the largest known population of the European mudminnow in Europe.

3.3.2. Recommended measures for improving habitat status

To conserve the European mudminnow active conservation measures need to be implemented because it is a stenovalent specialist. In addition, it is imperative to protect wetland and swamp areas, as well as limnophilic habitats along Drava river. To achieve adequate protection for the European mudminnow habitats measures for controlling entry and spread of herbivorous foreign fish species (e.g. the grass carp, silver carp etc.) are needed, as well as restauration of natural limnophilic habitats. Sources of organic and inorganic pollution in the upper part of Županijski canal need to be identified and a plan for their remediation should be made. The aforementioned pollution is dangerous for the entire ecosystem because of bioaccumulation of toxic substances. There is a real threat to the residents that bathe in that water and consume the fish from the contaminated waters.

3.4. Threats

3.4.1. Endangered species status

According to the Red book of freshwater fishes of Croatia (Mrakovčić et al., 2006) the European mudminnow is considered an endangered (EN) species according to the IUCN status. On the global level of the IUCN red list the European mudminnow is considered vulnerable (VU) since 1996. According to the assessment from 2008., the species retained the status of a vulnerable (VU) species (Freyhof, 2011). It is internationally protected by the Bern convention and is located in Appendix II. The main dangers for this species are habitat fragmentation and the continuous decrease of habitat quality (criteria: B2ab (iii)) (Mrakovčić et al., 2007).

No decline in population numbers has been recorded in Virovitica – Podravina County rather the populations can be considered as stable, even expanding due to human influence. By digging the Županijski canal and its side channels and connecting it to extant streams new suitable habitats were created for the European mudminnow. It seems like the main factor for the European mudminnow's

residing inside this system is the fact that many parts are unsuitable for other species (except syntopic species like the European weatherfish).

3.4.2. Causes of species/population endangerment

The main stressors for the European mudminnow are habitat destruction via water body regulation, drainage and overgrowth of swamp habitats, habitat degradation and competition with foreign and invasive species. One of the bigger stressors on the species is communal water pollution and agricultural production due to the use of mineral fertilisers, herbicides and pesticides.

3.4.2.1. Regulation of water bodies

Water flow regulation for river transports and regulation and drainage of swamp habitats for agriculture have decreased the number of offshore waters (oxbows, ditches, offshoots) where this species can be found during the last stages of habitat succession (Freyhof, 2011). The European mudminnow prefers habitats with dense, diverse water vegetation, slow flowing or stagnant water and unregulated natural banks without human influence (Sehr and Keckeis, 2017). Considering it has a large tolerance for water quality (low concentrations of oxygen) the main cause its endangerment is the disappearance of suitable habitats via drainage and degradation (Sehr and Keckeis, 2017). At some places in the Županijski and Lendava canal system it has been observed that they were recently cleared of vegetation and sludge in detail, and the banks were constructed neatly and at a very high angle. During cleaning some individuals remain in the vegetation or sludge which leads to direct decrease in mudminnow numbers. After cleaning the population should be replenished with individuals from parts of the canal that weren't cleaned. This could have a cumulative effect because the canals are often cleaned in planned actions where the cleaned segments can be several kilometres long. A mosaic approach with small segment cleaning could enable faster habitat population by the mudminnow and other native species, in turn lowering the inhabitation rate of invasive species. Vegetation renewal is also a lot faster with the mosaic approach. Additional supplementary measures could be added to the Program of measures in the plan of water management which could lower the negative effect on the most important localities (populations graded with 2 and 3).

3.4.2.2. Pollution

Pollution in open waters connected to Županijski canal can be divided into two basic types: 1) organic pollution of urban areas and industry; 2) organic pollution from agriculture

During the shareholder workshops some larger cities in VPC were defined as sources of large urban and industrial pollution that, through smaller channels (e.g.Ođenica), ends up in Županijski canal. Smaller inhabited areas along Županijski canal contribute to the pollution by discharging household waste water into the canal.

Due to the complex nature of the pollution problem an analysis was conducted on the source of pollution as well as systems for preventing direct discharge of pollution into open waters that is currently in use. Summary results of this analysis were included into this action plan. During the workshops legal processing of individuals responsible for polluting was discussed with the shareholders. Communal workers and the inspection should go to the field based on reports from the citizens, fishermen and legal entities. It was suggested that the cunty office of VPŽ and NVOi organize a public debate or round table with the representatives of the amenable institutions to work out where to report illegal polluting when it's discovered so that the responsible parties can be treated according to the law.

As the largest city in the County, Virovitica has mechanisms for water purification of waste waters in function (source Virovitica water supply: http://virkom.hr/):

- 2016. A ceremony was conducted regarding the beginning of implementation of the project "Improvement of the water utility infrastructure of the agglomeration Virovitica" with a total value of 147.246,575 kn. The project is financed with the operative program "Environment protection 2007. – 2013.", and it refers to the construction of a new waste water purifier and 35 additional kilometres of the sewer network in Virovitica, Špišić – Bukovica and Brezik
- In 2018. on Monday, May 28th during the assembly of Virkom company the work report of 2017. was adopted, according to which the company's revenue for the year was 18.972.542,00 kn while 40.854.944,00 kn were invested through various investment activities. In the words of director Margareta Ptiček during 2017. 166 new connections were added to the water supply system which

then holds 15.191 connections in total. The drainage system added 338 new connections which now counts 8.904 connections in total.

- Drainage and purification: : http://virkom.hr/odvodnja-i-prociscavanje/
- EU projects Virkom participates in: http://virkom.hr/eu-projekti/
- Project of communal infrastructure improvement, 2017: http://virkom.hr/tehnicki-pregledi-aglomeracija/
- Waste water collectors in construction from 2017: http://virkom.hr/zeleno-svjetlo-za-nove-kolektore/

Water purification and drainage:

The current state of drainage and purification of waters does not satisfy all needs of the Virovitica – podravina county residents. Public drainage is organised in cities and suburban areas while rural parts of the county and smaller settlements don't have access to it in most cases. In addition to existing drainage systems in cities and suburban areas there are processes in motion for obtaining files for construction, or the construction has already started for a new drainage system in Pitomača, Špišić Bukovica, Lukač, Suhopolje and Gradina counties. The reconstruction of the extant drainage system is underway in Slatina with Mednici, Sladojevci, Kozice, Bakić, Markovo suburbs, as well as Zdenci and Čačinci counties.

- Documents from 2008. show the complete communal infrastructure of Virovitica: http://www.vpz.com.hr/wp-content/uploads/2010/08/infrastruktura2008.pdf
- An ecological elaborate for the Pitomača agglomeration in the east of Virovitica – podravina county: https://mzoip.hr/doc/elaborat_zastite_okolisa_734.pdf
- Ecological elaborate for Špišić Bukovica, Gradina and Suhopolje: https://mzoip.hr/doc/elaborat_zastite_okolisa_572.pdf

CONCLUSION:

can be concluded that collectors and purifiers are used as measures for protection from urban pollution in Virovitica – Podravina county even so, visible pollution in Županijski canal still exists. Some pollution comes from urban areas not covered by purifying systems, the other from rural areas were no sewer systems are present.

For the survival of the European mudminnow the most important areas are the waterways and canals in Špišić Bukovica, Kukač, Gradina and Sopje (according to the territory breakdown of VPC) where the urban pollution drains directly into the localities where large populations of the species were recognised. In addition to direct pollution, waters draining from distant areas to parts of the Županijski canal with significant population also have an adverse effect on the species (e.g. Virovitica, Suhopolje, Slatina etc.) It was observed that the water in the lower part of the County canal largely manages to get purified through the auto - purification effect of water ecosystems (lush vegetation stretching the length of the canal). A large portion of organic matter and nutrients is purified from the water, but that leaves the problem of purifying the inorganic pollutants. That raises the question whether any harmful substances accumulate in fish tissues or other predators in the food chain (bioaccumulation)?

Pollution from agricultural land

The structure of land use in Virovitica – Podravina county:

Out of 2.024 km^2 → approx. 1.153 km^2 is farmland

32% of it are forests → 647 km^2

9% is construction land → 182 km^2

2% water surfaces → 40km^2

Vitovitica – Podravina county has the largest percentage of agricultural land per capita in Croatia, where 991 km^2 is agricultural land (mainly arable land). The arable land of the county takes up 99.420 ha or 6,8% of total arable land in Croatia. Agriculture is the base of this county's future

economy. General information about the water supply and irrigation practices on agricultural land can be found in the water management plan of the Virovitica – Podravina county (detailed at: https://www.voda.hr/sites/default/files/dokumenti/04_sazetak_0.pdf). This document outlines the effect of agriculture on water systems of the county.

Agricultural crop structure in the county:

Agriculture is of strategical importance for Virovitica – Podravina county because of the favourable climate and resource base, flatland and hill landscape that enables high arable, fruit and vegetable crop yields. According to the ARKOD system there are 84.128.65 ha of arable land and they make up 58% of the total surface area of the county and 8% of total arable land in Croatia. Most of the agricultural production is done through family farms.

The largest percentile of agricultural land is arable land and vegetable gardens (92.7%), where the county tendency for arable crops is evident, while the remaining percentile (7.29%) is used for other crops according to ARKOD – greenhouses (2,38%), meadows (2.30%), pasture (1,80%), vineyard (0.54%), stubbed vineyard (0,01%), fruit trees (2,38%), culture of short-term fertilization (0,04%), nursery gardens (0,02%), mixed permanent crops (0,01%) and other types of use (0,07%). Agricultural production is based on conventional cultures while the focus should be on modern technology implementation and intensive agriculture which demands more engagement and investment, but the yield is incomparably bigger than traditional agriculture can produce.

The use of agriculture land according to ARKOD in Virovitica – Podravina county shows that in 2017. most of the land was arable 92,71 % (77.993,59 ha) which means that arable crops are prevalent in the county. Out of the traditional crops the most common are areas covered in corn and wheat. Tobacco and camomile (medicinal herbs) production is worthy of noting as well. Out of all produced cereal crops corn dominates with 28,17% (21.975,25 ha) followed by wheat 13,36% (10.422,01 ha).

Camomile production is important, taking up 6,55% (5.108,04 ha) of arable land. The county is widely known for its traditional tobacco production which comprises 3,88% (3.030,90 ha) of total arable crop production. Out of the total 84.128,65 ha of arable land, 2,22% (1.867,85 ha) is covered in fruit trees. The most important fruit tree is hazel with 38,6 % (720,28 ha). The other species of

cultivated trees in the county are: aronia 30,43 ha, a fruit species attractive to manufacturers due to its adaptability and low cultivation costs, blueberry 3,73 ha, peach 66,21 ha, melon 0,64 ha and apple 201,76 ha.

The total surface area of vegetable cultivated areas is 1.531,68 ha according to the data from the Croatian centre for agriculture, food and rural affairs in 2017. Paprika comprises 40% (615,12 ha) of all vegetable cultivation areas. The remaining 29,4% of vegetable production is divided amongst other crops, most notably tomatoes, beets, cauliflower, eggplant, kale and onion.

Intense agriculture like this demands large quantities of artificial fertilizers that only partially incorporate into the cultivated crops and the rest washed away into the open water with rainfall. During shareholder workshops some individuals suggested the concentration of dissolved substances substantially rises in the Županijski canal after every rainfall, which could be the result of washing away from agricultural land. There is no data available on how much organic fertilizer washes away into the Županijski canal and consequently into Drava river, this further research is needed.

Guidelines for decreasing the amount of fertilizer runoff exist in international practices. By following said guidelines most of the fertilizers stay in agricultural surfaces and reduce the cost of fertilization (and with it the price of the produce) as well as protecting the natural environment and habitats. Large quantities of fertilizers cause damages worth millions of dollars because they heighten the production in drainage canals (e.g. Županijski canal) which increases the demand and frequency of cleaning.

Decreasing fertilizer runoff

Bioreactors: the simplest bioreactor is comprised of a 100-foot-long, 10-feet-wide and a approx. 40-inch-deep ditch filled with wood chaff, corn leftovers and other carbon rich foods for bacteria, all covered with a layer of dirt. Field drainage canals are rerouted through the bioreactors before the water drains into open waters. Bacteria convert nitrogen into gas through nitrification in order to decrease eutrophication and harmful algal growth. These practices are in accordance with the Water policy and national guidelines for concentrations of priority substances of waters discharged

into open waters. Further details about bioreactors: https://www.fluencecorp.com/bioreactors-could-reduce-fertilizer-runoff-protecting-waterways/.

Recommended measures for decreasing fertilizer runoff:

- Systematic cooperation between people that work around the watershed to constantly monitor the state of the water
- Applying fertilizer in the right amount, in the right way, at the right time of year can significantly decrease runoff
- Cover crops: planting certain grasses, clovers or crops can decrease runoff due to recycling nutrients and decrease of soil erosion
- Planting trees, shrubs and similar vegetation in areas that border water to increase resorption and filtration of nutrients before they reach open water bodies
- Reducing soil treatment decreases erosion and soil compactness, improves nutrient build-up and decreases runoff
- Management of waste created by farm animals
- Reducing the amount of waste waters that flow into water bodies

3.4.2.3. Connectivity of mudminnow habitats

The presence of a continuous distribution of the European mudminnow is clearly visible in VPC, distributed along the Lendava and Županijski canal systems (unique subpopulation). The connection between the subpopulation of the Županijski canal and the Međimurje (confluence of Mura and Drava), the the Kopački rit subpopulation, even the Sava river subpopulations is not proven. Those are geographically isolated subpopulation that should have contact via natural drift along large river systems (Drava, Sava, Dunav). That means that the subpopulations of the VPC are partially isolated and the flow of individuals and genes is difficult. The communication is further limited by the absence of a wide flood zone around Drava (disappeared when the embankment was built) which the

species could use to widen their distribution range. The communication is limited to the main river body. For a poor swimmer like the mudminnow that could be a big problem and there is a big risk of complete isolation. Renewing connections between separated European mudminnow subpopulations and establishing connections to new, potential habitats by deepening the canal and increasing groundwater levels enables the survival of the species (Sehr and Keckeis, 2017). Drava river is still one of the best-preserved large rivers in Europe so it's imperative to stop further riverbank and flood zone regulations. Natural flooding cycles the European mudminnow needs to survive, disappear when rivers are regulated and the European mudminnow along with them (Mrakovčić et al., 2006). A part of the subpopulations near Mura, Drava and Dunav is potentially in contact with Hungarian subpopulations on the other side of the rivers during high floodwater periods. The same applies to the subpopulation from VPC that is in contact with the Hungarian, subpopulations at least through drift and gene exchange. The subpopulations near Drava (Žutica, Odra etc.) can be connected to subpopulations in Bosnia and Herzegovina, but they aren't connected to the subpopulations in the Drava river. There is no verified record of the species north of Lendave stream or southeast of Čađavica river. Those areas outside of the bounds of VPC need to be inspected in detail to ensure the survival of the species.

The geographic data points to the isolation of this population but molecular testing is needed in order to confirm the validity of the hypothesis. If the isolation or even weak connection is confirmed it is possible to carry out measures of intentional mixing of the subpopulations (imitating natural gene and individual exchange).

3.4.2.4. Introduction of foreign invasive species

The European mudminnow is a species that doesn't prefer interactions with other fish species and it is a weak competitor. It is a top-notch specialist and it inhabits habitat types that are unaccommodating for most of the other native species. Introducing foreign species, especially the ones that can survive in the same habitat, presents a big problem for the European mudminnow. Those are species like the pumpkinseed (*Lepomis gibbosus*), black bullhead (*Ameiurus melas*), stone moroko (*Pseudorasbora parva*) and the Prussian carp (*Carassius gibelio*), that dominate any water they find themselves in. As very good competitors they push out native fish species, in this case the European mudminnow (Mrakovčić et al., 2006). In some localities the European mudminnow was

found in great numbers despite the presence of many other fish species (e.g. canals in Međimurje; the native species dominate, but invasive species are present), which points to holes in our knowledge of ecology of the species. Habitat analysis on the territory of the VPC points to a large preference for habitats without other fish species. The factor of the number and presence of other fish species has proven to be the most significant when determining the presence of the European mudminnow (no matter if they were native or invasive). It was more important then pollution and overall habitat quality (for more details search section 3.3. Assessing habitat quality). In smaller, deep canals with lush vegetation there was a large presence of the Prussian carp, stone moroko and black bullhead which have a significantly adverse effect on the presence of the European mudminnow (competition for food and habitat, even predation). Removal of the invasive species would free the habitat for the mudminnow, so their populations could increase in size.

3.4.3. Knowledge deficiency (Needed research, needed species data)

The European mudminnow inhabits a variety of scattered localities in different swamp and wetland habitats and canals. The size and state of different populations is unknown, there is no monitoring of the size of the subpopulations, demographic structure or long-term population trends. Data gathered through habitat analysis shows that the mudminnow is abundant in some micro locations while rare in others, although no clear reason is visible from the available parameters. Research should focus on active protection, solving current problems and as a result, define needed additions to the management plan of the species. We are lacking knowledge of the connection between the number of mudminnows in a certain habitat and the parameters that dictate its quality (organic load, vegetation, environment parameters, microzoobenthos structure etc.), to easily define the parameters for habitat restauration in the future. In some locations the mudminnow was recorded despite pollution being present, furthermore it seems a certain degree of pollution is favourable for the species (causes anoxic conditions other species cannot survive in). Larger degrees of pollution a are detrimental to the species so it wasn't recorded in highly polluted localities. The genetic structure and taxonomy of the mudminnow in VPC is unknown. Phylogenetic relationships to other mudminnow subpopulations need to be researched (especially the ones in Međimurje and Hungary) to determine whether genetic exchange is present. Border canals with Koprivnica – Križevci county need to be checked (Podravske Sesvete surrounding area) because the presence of the mudminnow

can be expected in them. The canals in question are: Sirova Katalena, Kopanjek, Čivićevac, Rogstrug and their tributaries. Detailed research of canals along the Drava river in Koprivnica – Križevci and Varaždin is needed to prove the connection between VPC and Međimurje subpopulations. This research is needed to confirm the existence of the continuous mudminnow population in canals around the Drava river. In that case it would be the largest continuous population of the European mudminnow in Europe. With that the responsibility and focus of species conservation at the European level would be directed to this area. The VPC must be active in this field and actively implement measures of conservation. There is a lack of knowledge of heterozygosis and the health of the subpopulation., as well as level of isolation compared to other subpopulations (population genetics). That would help define important conservation units and their status. Based on them the urgency of taking action and implementing conservation methods could be decided.

During habitat analysis it was determined that there is a lack of macrozoobenthos structure and water invertebrate communities in Županijski canal. Those species are the basis for the functioning of the ecosystem (and its energetics), not to mention that they are a food source of the European mudminnow. During shareholder workshops it was suggested that the mudminnow could be present in fishing waters since fishermen transferred fish between open water bodies. Stagnant waters have much more stable conditions and they are similar regardless of the elevation and incline (as opposed to flowing waters), thus our expert opinion is that the European mudminnow could have survived in some of those closed water bodies. This research didn't cover such bodies of water, but they were reviewed in chapter 3.3.1.3. Potential European mudminnow habitats on the VPC territory (101 water body with the collective surface area of 1250 ha). It would be beneficial to check microhabitat conditions in all mentioned stagnant waters, and in the case of existing favourable habitats (lush vegetation), the area should be investigated for mudminnow presence (with electrofishing method).

3.4.4. The state of the species on a regional and/or global scale

According to Freyhof (2011), the number of individuals in all the populations is in significant decline. From 2000. to 2010. it has declined by 30% with a trend of further decline. It is considered the most endangered stagnophilic fish species in Austria (Sehr and Keckies, 2017). It was considered

extinct in Austria since 1975. but was later rediscovered in the late 90-ties on the border with Slovakia (Sehr and Keckies, 2017). Habitat destruction caused a decline in mudminnow numbers in all known European populations – Balaton lake basin, Szigetköz floodplain area, Mura and Drava basin in Croatia and floodplain areas of Danube in Austria (Sehr and Keckies, 2017). It has disappeared from a lot of places it used to inhabit (extinct) (Freyhof, 2011).

3.5. Social aspect

While creating the expert base for the management plan for the European mudminnow in VPC shareholder workshops were held on the 21. and 22. May 2018. in Noskovci, Pitomača and Suhopolje, where the residents and fishermen are informed on the status of the species and the goals of the management plan. One more meeting was held in the public administration of VPC on 22. October 2018. with the title "Activities and conservation measures for the species and habitat with the goal of improving its status – the role of local inhabitants in European mudminnow (*Umbra krameri*) protection" to present real dangers and conservation measures to interested shareholders.

Eighteen different shareholders contributed in the workshop: Public administration VPC, BIOTA j.d.o.o., Geonatura d.o.o., fishing societies "Šaran Sopje", "Šaran Bakić", "Tvin Virovitica", "Smuđ Vaška", "Štuka Žlebina", "Klen Slatina", County road administration of VPC and Croatian water management agency for Županijski canal area.

The workshops yielded potential activities such as: ban on using machinery for habitat arrangement, where the European mudminnow is present, for maintenance (mowing etc.); cleaning the canal with special care towards the population and favourable habitats (removing pollution that is potentially threatening to human health); restocking Virovitica's fishponds with goldfish and tench;, restocking Vranaševačka pond, ponds near Bakić and the Turkish city, near Španat and the canal near Zidina with European mudminnow; reinforce game keeper activity and procuring the means for paying the extra work to gather more people to monitor the waters (e.g. Donji Miholjac), they added it would be favourable to hire unemployed people so they can commit to the work; promoting species (swordfish, sturgeon, crucian carp); introducing new cycling tours, especially 3 – 4 km along Žlebina

where there are ponds which are possible localities for the European mudminnow and incorporate educative materials about the mudminnow along the tour; arrange extant waters (lakes) for sport fishing and tourism but leave certain parts of the lakes overgrown for spawning sites for other fish species and habitats for the mudminnow; use smaller ponds for mudminnow habitats and leave a part of them for spawning sites for other species which would be used for restocking, enable natural regimes of river flooding, organising public events (Field festival from a hypothetical situation) to interest the public for less popular waters; organize maintenance of ponds and oxbows; artificial habitat creation for the mudminnow.

They list the strong pollution as the main habitat problem in Županijski canal which they deem Virovitica responsible for. Allegedly it drains organic and inorganic waste into the canal. Even though elevated levels organic material contributes to habitat loss for the European mudminnow, they are worried about the pollution that threatens the health of people that consume the fish from Županijski canal. Regarding the cultivation and reintroduction of the species with declining populations the fishermen list the authorised organisations, in this fishing society "Šaran" Bakić whom are the only authorised ones to restock fishponds and manage waters in VPC, they think it's impossible to acquire licenses for cultivations at club level, which is directly prohibited by the law of freshwater fisheries.

3.5.1. Workshops for sport fishermen and interested residents during the making of the Action plan

The project has five planned workshops, three of which were held locally (one in Pitomača, three in Noskovci and one in Suhopolje) to gather as many interested parties to the remaining two workshops. The fourth and fifth workshops were held together for all shareholders in Noskovci where detailed elements of the plan were developed. Local preparation workshops "The importance of the European mudminnow species (*Umbra krameri*) and the habitats where we can find it with emphasis on the current status of the species and activities for status improvement" were held on the 21. and 22nd of May 2018 in Pitomača, Noskovci and Suhopolje. The goals of the preparatory workshops were resident sensibilisation, shareholder defining and gathering data from local fish club members and interested community members. There were 29 participants in total, mostly consisting of fish club representatives from Suhopolje, Noskovci and Pitomača municipalities and representatives of the fishing alliance of VPC. After a brief introduction into the project "coop MDD" (Transboundary

management programme for the planned 5-country UNESCO Biosphere Reserve "Mura-Drava-Danube") by the director of the public administration of VPC, Tatjana Arnols Sabo, dr. sc. Dušan Jelić from BIOTA j.d.o.o. held a lecture about the ecology, conservation and habitats of the European mudminnow (*Umbra krameri*). After the lecture the participants explained their viewpoints on the state of the species in VPC, the dangers threatening the species and ideas on managing the species and waters in lives in in a sustainable manner through questions and debate. Through the debate we found out a couple locations that seem ideal by the description of the conditions in them, and those locations were covered through field surveys later. Most fish club members don't think the mudminnow is an active fishing species so the conservation would be easy to implement; education being the critical tool to achieve it.

Figure 18. Members of the fish clubs from Suhopolje municipality during he workshop on 22. May 2018.

Figure 19. Dr. sc. Dušan Jelić holding a lecture about the European mudminnow ecology, conservation and habitat.

The fourth workshop under the name "Activities and conservation measures for the species and habitats with the aim of status improvement – the role of residents in protecting the European mudminnow (*Umbra krameri*) was held on 22nd October 2018 in the informative and educative centre Dravska priča PAVPC. Representatives of local fish clubs, the sport fishing alliance of VPC, local water supply, area branches of Croatian water management agency, Croatian forests and Croatian motorroads, VPC tourist board and development agency were invited to the workshop. The goals of the workshop were introducing the shareholders to the species and its habitat, the results of inventarisation and gathering all active shareholders. Through the workshop attitude towards dangers to the species and its habitat were determined. Pollution of open waters, introduction of invasive species, waterway regulation and habitat fragmentation were defined as the main threats to the species.

The fifth workshop was conducted on 23rd March 2019 in the informative and educative centre of the public administration for managing protected nature areas and the ecological network of Vitovitica – Podravina county in Noskovci. Before the workshop the experts hired for this project and the represenatives of the PUVPC visited a few locations where the field surveys were conducted: Paninac and Županijski canals in Gaćište, pond in Budakovci and swimming area in Sopje on the river Drava. The workshop started at 3pm with shareholder registration. Out of all the invited shareholders the ones that responded were: representatives of Croatian water management agency, Županijski canal, Natural society Drava, fishing societies "Šaran Bakić", "Karas Čađavica", "Klen Slatina", Faculty of science, Biology division in Zagrebu, Town museum in Varaždin, PUVPC and BIOTA j.d.o.o. There were 16 shareholders present. The main focus was finding measures for conservation and activities for recovery of the mudminnow in VPC. The shareholders are divided into two groups, so that in both groups there were mixed representatives of all the administrations and associations. The groups were divided by themes: invasive species and canal maintenance. Group work was conducted in 30 minutes after which there was a short presentation of results. The produced activities have been incorporated into the action plan.

SUMMARY INVASIVE SPECIES:

1. The amount of grass carp released into fishing waters needs to be controlled
2. A part of the water needs to be left under vegetation
3. Added control measures are needed for invasive species as well as financing for those measures
4. The sport fish clubs should remove the invasive species in association with the public administration of VPC
5. Proposal of cultivation of: goldfish, European weatherfish, tench and the European mudminnow

SUMARRY OF CANAL MAINTENTANCE

1. The ministry of agriculture should give incentives to farmers not to remove vegetation in borderline areas of their land near canals
2. Enforced work and transparency of inspections

3. Defining the time frame and locations of canal cleaning and making refugees for the European mudminnow
4. Educating the residents on the importance of clean canals
5. Commercialising the European mudminnow for touristic purposes (as a mascot or trademark of the County)

3.6. Extant mechanisms and conservation capacity

According to the rulebook for strictly protected species (NN 144/13, 73/16) the Management plan for directing strictly protected species with an action plan is passed primarily for species that are subject to significant anthropocentric, or other, influence which demand taking measures or activities in hopes of decreasing that influence. The same type of plan can be devised regionally if it's in accordance with national strategies. While devising activities the participative approach is favoured, which means including all key shareholders and identifying key problems and defining goals, activities and priorities needed for effective conservation of priority species together. BIOTA j.d.o.o. is contracted by the PA VPC for the implementation of the participative approach, consulting business and writing the expert base for creating the action plan for the European mudminnow on the Virovitica – Podravina county territory.

The species is included in Annex II of the Habitat directive, Appendix II of the Bern convention. Nature 2000 areas from the ecological network HR2000364 Mura, HR2000465 Žutica, HR2001004 Stari Gradac – Lendava, HR2001005 Starogradački Marof, HR2001006 Županijski canal (Gornje Barje - Zidina), HR5000014 Upper river flow of Drava (from Lower Dubrava to Tereza's field) and HR5000015 Middle flow of Drava (from Tereza's field to Donji Miholjac) have been singled out for the mudminnow protection. The listed areas from Natura 2000 ecological network on the territory of VPC belong to the regional park Mura – Drava and the biosphere preserve Mura – Drava – Dunav. The species is strictly protected with the law of nature protection (NN 80/13, 15/18) and is listed in the rulebook for strictly protected species (NN 144/13, 73/16). The species inhabits freshwater habitats of lowland waterways, and those habitats are encompassed in the general water utility directive (2000/60/EC) and the protective mechanisms it entails (quality control, monitoring of the state). The European mudminnow isn't interesting for fishing and is not considered an economically exploited species.

3.7. Protection of the species up until now

Until now there were no specific activities related to the protection of the European mudminnow in VPC territory. Through the shareholder process we found out that Nature society "Drava" mapped the presence of the mudminnow in the 90ties. Based on that they published two papers:

Delić, A. (1999): European mudminnow (*Umbra krameri* Walbaum 1792): the resident of swamps and podnds in Virotivica – Podravina county. Priroda 2: 43-43.

Delić, A., Grlica, D. i Razlog-Grlica, J. (1997): New localities for the European mudminnow (*Umbra krameri* Walbaum 1792) in Croatia. Ribarstvo 55 (3): 93-98.

During the same time the trial *ex situ* cultivation in Virovitica was underway. It has been a success. Adults and juveniles have been re – released at their respective sampling locations (source: Darko Grlica, personal communication).

4. VISION, GOALS, ACTIVITIES

4.1 Vision

A PRESERVED, STABLE POPULATION OF THE EUROPEAN MUDMINNOW (*Umbra krameri*) IS LOCATED IN VIROVITICA – PODRAVINA COUNTY AND THE CITIZENS PERCIEVE IT AS AN ICONIC SPECIES OF THE SWAMP HABITATS.

4.2. General goal/ specific goals

The preservation of healthy populations of the mudminnow in Virovitica – Podravina county over the next 10 years through applying an integrated and multidisciplinary management of the Županijski canal basin. Preservation of favourable ecological conditions and habitat quality as a base for maintaining a stable number of adult individuals of the European mudminnow.

4.2. General goal/ specific goals

(GG – general goal; SG – specific goal; I – indicators)

GG1: Raising mudminnow habitat quality

SG1.1. Defining the main source of water pollution and creating guidelines for water autopurification

I1.1. Decreased the number of pollution sources draining into open waters

SC1.2. Decreasing the influence of intensive agriculture on water habitats through promotion of positive agricultural practices amongst agriculturalists.

I1.2. Two campaigns for the promotion of positive agricultural practices were carried out

SC1.3. Promotion of good practices in maintenance of sport fishing waters and strengthening ecoturism

I1.3. Guidelines were created for strengthening ecoturism on sport fishing surfaces along with setting uo platforms for birdwatching

SC1.4. Adapted maintenance of canals at significant locations with the goal of conserving mudminnow populations

I1.5. Significant populations were covered, and three experimental surfaces were created

GG2: Strengthening the mechanism of nature protection in Virovitica – Podravina county

SG2.1. Establishing a protocol of reporting pollution sources in open waterways

I2.1. A protocol was produced that is being applied in the field

SG2.2. Knowledge transferral and incorporation of the action plan into PUAPP

I2.2. The constructed PUAPP incorporates the activities predicted by the AP

SG2.3. Protection of transboundary basins and divided mudminnow populations

I2.3. At least three meetings held, and cooperation contracts signed with at least three partners

GG3: Restoration and maintenance of healthy mudminnow populations in Virovitica – Podravinca County

SG3.1. Preventing the entry of foreign and invasive species (especially grass carp) by closing dissemination pathways to new locations

I3.1. Two-day education was held for game wardens, lectures held at minimally 10 fishermen gatherings

SG3.2. Removal and control of foreign invasive species at important localities for the mudminnow

I3.2. At least 4 invasive species removal activities were held in cooperation with fishing societies

SG3.3. Establishment of a system of cultivating rare and endangered species

I3.3. One centre for cultivation was established at the border waters of the distribution area and in still waters of VPC

GG4. Filling the gaps in knowledge

SG4.1. Filing the gaps in data about the border areas of the distribution range and still waters of VPC

I4.1. A new map of the european mudminnow distribution was made with supplemented data.

SG4.2. Precisely pinpointing the codependance of pollution sources in different parts of the canal in relation to the state of the water body.

I4.2. An analysis was made on the presence of organic pollutants at different areas of the canal in relation to the state of the water body

I4.2. A report was made on the presence of heavy metals in the water and living organisms; a report was made on the structure of the invertebrate communities at 30 stations along the Županijski canal and its tributaries; a population estimate was created for the mudminnow at five different localities, as we as the approximation of their numbers in VPC

SG34.3. Tracking the state (monitoring) of the european mudminnow state in VPC

I4.3. A long – term plan was created for monitoring the state of the mudminnow in VPC; at least one cycle of monitoring was conducted in accordance with the long – term plan

4.3. Activities for accomplishing the specific goals

Detailed action plan can be found in ANNEX II.

5. LITERATURE

Bănăduc D. (2008): *Umbra krameri* WALBAUM, 1792 a Natura 2000 protected fish species in Romania. Acta Ichthiologica Romanica III, 33-44.

Berg LS. (1948): Freshwater Fishes of the USSR and adjacent countries. - Acad. Nauk SSSR Zool. Inst., Vol. 1, 4th ed., 493 pp.+ App. (Translation by Israel Program for Scientific Translation, 1962).

Biro, P. & G. Paulovits (1995): Distribution and status of *Umbra krameri* WALBAUM, 1792, in the drainage of Lake Balaton, Hungary. Ann. Naturhist. Mus. Wien 97 B: 470 - 477.

Bohlen, J. (1995): Laboratory studies on the reproduction of the European mudminnow, *Umbra krameri* WALBAUM, 1792. Ann. Naturhist. Mus. Wien 97 B: 502 - 507.

Delić, A. (1999): Crnka (*Umbra krameri* Walbaum 1792): stanovnik močvara i bara virovitičke Podravine. Priroda 2: 43-43.

Delić, A., Grlica, D. i Razlog-Grlica, J. (1997): Nova nalazišta crnke (*Umbra krameri* Walbaum 1792) u Hrvatskoj. Ribarstvo 55 (3): 93-98.

Freyhof J. (2011): *Umbra krameri*. The IUCN Red List of Threatened Species 2011: e.T22730A9380477. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T22730A9380477.en. Downloaded on 15 October 2018.

Freyhof J. (2012): Threatened freshwater fish and moluscs of Balkan.Geyer F, Mann H (1939a): Beiträge zur Atmung der Fische I. Die Atmung des Ungarischen Hundsfisches (*Umbra lacustris* GROSSINGER). Zoologischer Anzeiger, 127: 234-245.

Geyer F, Mann H (1939b): Beiträge zur Atmung der Fische I. Weiteres zur Atmung des Ungarischen Hundsfisches (*Umbra lacustris* GROSSINGER). Zoologischer Anzeiger, 127: 305-312.

Guti, G. (1995): Ecological impacts of the Gabcikovo River Barrage System with special reference to *Umbra krameri* WALBAUM, 1792, in the Szigetkoz flood plain. Ann. Naturh ist. Mus. Wien 97 B: 466 - 469.

Jelkić, D., Opačak, A., Ozimec, S., Vukajlović, N., Kralj, E. (2016): Novo nalazište crnke (umbra krameri) u Hrvatskoj. U Pospišil, M., Vunčec, I. (ur.): Zbornik sažetaka/Book of abstracts 51. Hrvatski i 11. međunarodni simpozij agrgonoma, Opatija 2016. / Zagreb : Agronomski fakultet, 2016, 131-132.

Kottelat M, Freyhof J. (2007): Handbook of European freshwater fishes. Kottelat, Cornol, Switzerland and Freyhof, Berlin, Germany.

Kováč, V. (1997): Experience with captive breeeding of the European mudminnow, *Umbra krameri* Walbaum, and why it may be in danger of extinction. Aquarium Sciences and Conservation 1: 45-51.

Kraljević, Sandra (1997): Biološke i taksonomske značajke vrste *Umbra crameri* Walbaum. 1792 – Pisces. Diplomski rad, PMF Biološki odsjek, Zagreb.

Kux Z, Libosvárský J. (1957): Zut Verbreitung und Rassentugehörigkeit der europäischen Hundfishe (*Umbra krameri* WALBAUM 1792 = *lacustris* GROSS. 1794). Zoologicke Listy, 6: 215 – 225.

Kuehne, M. L.&D. J. Olden (2014): Ecology and conservation of mudminnow species worldwide. Fisheries 39: 341–351.

Leiner, S. (1995): The status of the European mudminnow, *Umbra krameri* WALBAUM, 1792, in Croatia. Ann, Naturhist. Mus, Wien 97 B: 486 - 490.

López, A., P. Bentzen & W. Pietsch (2000): Phylogenetic relationships of Esocoid fishes (Teleostei) based on partial cytochrome b and 16S mitochondrial DNA sequences. Copeia 2: 420–431.

López, A., W. Chen & W. Ortí 2004): Esociform phylogeny. Copeia 3: 449–464.

Marić S., Stanković D, Wazenböck J, Šanda R, Erös T, Takács P, Specziár A, Sekulić N, Bănăduc D, Ćaleta M, Tombitsky I, Galambos L, Sipos S, Snoj A. (2016): Phylogeography and population genetics of the European mudminnow (Umbra krameri) with a time-calibrated phylogeny for the family Umbridae. Hydrobiologia 792(1): 151-168.

Mikschi, E., Wanzenböck, J. (1995): Proceedings of the First International Workshop on *Umbra krameri* Walbaum, 1792. Annalen des Naturhistorischen Museums in Wien, Serie B, Botanik und Zoologie 97B: 437-508.

Mikschi, E. & J. Wanzenbock (ed) (1995): First International Workshop on *Umbra krameri* WALBAUM, 1792. Ann. Naturhist. Mus. Wien 97 B: 437 - 508.

Mrakovčić, M., Kerovec, M. (1990): *Umbra krameri*. Ekološki glasnik 5-6, 68-69.

Mrakovčić, M., Brigić, A., Buj, I., Ćaleta, M., Mustafić, P., Zanella, D. (2006): Crvena knjiga slatkovodnih riba Hrvatske, Ministarstvo kulture, Zagreb, 253 str.

Pavletić J. (1954): Rijetka riba – crnka ili rapa. Ribarstvo Jugoslavije, 9: 62-64.

Povž, M. (1995): Threatened fishes of the world: *Umbra krameri* Walbaum, 1792 (Umbridae). Environ. Biol.

Povž, M. (1995): Discovery, distribution, and conservation of mudnlinnow *Umbra krameri* WALBAUM, 1792, in Slovenia. Ann. Naturhisl. Mus. Wien 97 B: 478 - 485.

Povž, M. (1984): Areal velike Sencice *Umbra krameri* Walbaum, 1772 (Osteichthyes) v Sloveniji. ICHTHYOLOGIA, Vo1.16, No.1-2: 43-48.

Sehr M, Keckeis H. (2017): Habitat use of the European mudminnow *Umbra krameri* and association with other fish species in a disconnected Danube side arm. J. Fish Biol., 91(4): 1072-1093. doi: 10.1111/jfb.13402

Wanzenböck, J. (2004): Europen Mudminnow (*Umbra krameri*) in the Austrin floodplain of the river Danube: conservation of an indicator species for endangered wetland ecosystems in Europe. Pp. 200-207 U: Akcakaya H.R., Burgman M.A., Kindvall O., Wood C.C., Sjögren-Gulve P., Hatfield J.S., McCarthy M.A. (ur.): Species conservation and management – case studies. Oxford University Press, New York.

World Conservation Monitoring Centre (1996): *Umbra krameri*. U: IUCN 2007. 2007 IUCN Red List of Threatened Species. World Wide Web electronic publication. www.iucnredlist.org. (Učitano 20.05.2008.)

Zanella, D. (1997): Rasprostranjenost i zaštita vrste *Umbra krameri*, Walbaum, 1792 Pisces) u republici Hrvatskoj. Diplomski rad, PMF Biološki odsjek, Zagreb.Wanzenböck J. (1995): Current knowledge on the European mudminnow, *Umbra krameri* Walbaum, 1792 (Pisces: Umbridae). Ann. Naturhist. Mus. Wien, 97B: 439-449.

6. ANNEXES

ANNEX I. Shareholder analysis

ANNEX II. Asessment of habitat quality

ANNEX III. Analysis of the sources of pollution and purification of waste water sin Virovitica – Podravina county

ANNEX IV. Deatailed activity overview

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