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Update on the distribution of freshwater crayfish in Croatia

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ABSTRACT

Key-words: *distribution, indigenous, non-indigenous, crayfish, Croatia*

Four indigenous European and two non-indigenous American freshwater crayfish species inhabit Croatian freshwater habitats. Generally, the noble crayfish (*Astacus astacus*), the narrow-clawed crayfish (*Astacus leptodactylus*) and the stone crayfish (*Austropotamobius torrentium*) are distributed in the water bodies of the Black Sea drainage while the white-clawed crayfish (*Austropotamobius pallipes*) inhabits rivers of the Adriatic Sea drainage. However, a few records of the noble and the stone crayfish populations in the Adriatic Sea drainage exist. Non-indigenous species the signal crayfish (*Pacifastacus leniusculus*) and the spiny-cheek crayfish (*Orconectes limosus*) are distributed in northern Croatia, in the water bodies of the Black Sea drainage. Recently, the distribution of Croatian crayfish populations has been studied more intensely within the frame of Natura 2000. In this paper we present results of field work conducted from 2005 till 2010, and compare them with previous data. Approximately 520 sites were investigated. Results indicate that non-indigenous crayfish are spreading and displacing the noble and the narrow-clawed crayfish. No mass mortalities in the contact zone have been reported. This survey also revealed the spread of the narrow-clawed crayfish westwards and southwards displacing the noble and the stone crayfish from their habitats. The stone and the white-clawed crayfish populations have undergone the biggest decline in numbers. The main reasons for this are disturbance of their habitats and intensive droughts which have been pronounced of late. Collected data are helpful as a starting point for development of management strategies by state institutions dealing with protection of endangered crayfish species.

RÉSUMÉ

La distribution actuelle des écrevisses en Croatie

Mots-clés : *distribution, indigène,*

Quatre espèces européennes d'écrevisses d'eau douce indigènes et deux non-indigènes d'Amérique habitent les eaux douces croates. En règle générale, l'écrevisse à pattes rouges (*Astacus astacus*), l'écrevisse à pattes grêles (*Astacus leptodactylus*) et l'écrevisse des torrents (*Austropotamobius torrentium*) sont présentes dans les masses d'eau du bassin de drainage de la mer Noire tandis que les écrevisses à pattes blanches (*Austropotamobius pallipes*) occupent les rivières du bassin de la mer Adriatique. Cependant, quelques signalements de populations d'écrevisses nobles et d'écrevisses des torrents dans le bassin de la mer

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Adriatique existent. Les espèces non indigènes, l'écrevisse signal (*Pacifastacus leniusculus*) et l'écrevisse américaine (*Orconectes limosus*), sont distribuées dans le nord de la Croatie, dans les plans d'eau du bassin de drainage de la mer Noire. Récemment, la distribution des populations d'écrevisses croates a été étudiée plus profondément, dans le cadre de Natura 2000. Dans cet article nous présentons les résultats du travail de terrain mené de 2005 à 2010, et les comparons avec les données précédentes. Environ 520 sites ont été étudiés. Les résultats indiquent que les écrevisses non indigènes se répandent et déplacent les écrevisses nobles et les écrevisses à pattes grêles. Aucun cas de mortalité importante dans la zone de contact n'a été rapporté. Cette étude a également révélé la propagation vers l'Ouest de l'écrevisse à pattes grêles et le déplacement vers le Sud des écrevisses nobles et des écrevisses des torrents. Les populations d'écrevisses des torrents et d'écrevisses à pattes blanches ont subi la plus forte baisse en nombre. Les raisons principales en sont la perturbation de leurs habitats et des sécheresses intenses qui ont été prononcées ces derniers temps. Les données recueillies sont utiles comme point de départ pour le développement de stratégies de gestion par les institutions publiques traitant de la protection des espèces d'écrevisses en voie de disparition.

INTRODUCTION

Recent updates on the distribution of freshwater crayfish in Europe revealed presence of five indigenous European crayfish species (ICS) and ten non-indigenous American and Australian crayfish species (NICS) (Holdich *et al.*, 2009). Presently all of the ICS have undergone a decline in the number and size of their populations. They are mainly threatened by presence of NICS, habitat deterioration, water quality impoverishment and climate changes (Holdich *et al.*, 2009); consequently three out of five ICS are listed in the Bern convention, EU Habitat directive and IUCN Red List of Threatened Species (Edsman *et al.*, 2010; Füreder *et al.*, 2010a, 2010b).

Croatian freshwater habitats harbour four ICS and two American NICS (Maguire and Gottstein-Matočec, 2004; Maguire *et al.*, 2008). In general, the noble crayfish (*Astacus astacus* (Linnaeus, 1758)) is distributed in the water bodies belonging to the Black Sea drainage. However some noble crayfish populations were also recorded in the Adriatic Sea drainage (Maguire and Gottstein-Matočec, 2004). Their presence in the water bodies of the Adriatic Sea basin is of anthropogenic origin (Maguire and Gottstein-Matočec, 2004). The narrow-clawed crayfish (*Astacus leptodactylus* Eschscholtz, 1823 species complex) inhabits water of the Black Sea drainage the same as the stone crayfish (*Austropotamobius torrentium* (Schrank, 1803)). The presence of the latter was also recorded in a few streams of the Adriatic Sea drainage (Karaman, 1929; Albrecht, 1982; Maguire *et al.*, 2006). The white-clawed crayfish (*Austropotamobius pallipes* (Lereboullet, 1858) species complex) inhabits rivers belonging to the Adriatic Sea drainage (Maguire and Gottstein-Matočec, 2004). Non-indigenous species, namely the signal crayfish (*Pacifastacus leniusculus* (Dana, 1852)) and the spiny-cheek crayfish (*Orconectes limosus* (Rafinesque, 1817)) are distributed in the water bodies of the Black Sea drainage (Maguire and Gottstein-Matočec, 2004; Maguire *et al.*, 2008). The signal crayfish was introduced in 1970s to Austria (Pöckl, 1999), from where it has spread through the Mura River into Slovenia (Bertok *et al.*, 2003, Govedič, 2006; Govedič *et al.*, 2007) and Croatia (Maguire *et al.*, 2008; Hudina *et al.*, 2009). The spiny-cheek crayfish spread into Croatia from the Hungarian part of the Danube River (Maguire and Gottstein-Matočec, 2004), and it continued spreading downstream through the Danube River into Serbia (Pavlović *et al.*, 2006) and Romania (Pârvulescu *et al.*, 2009).

The noble crayfish, the stone and the white-clawed crayfish are all treated as endangered, and are protected by Croatian law (Narodne novine, 1999, 2005, 2008).

The aim of this study is to update the knowledge on the current distribution of ICS and NICS in Croatia and to compare recent findings with the previous data (Grube, 1861; Šoštarić, 1888; Car 1901; Entz, 1914; Karaman, 1929, 1961, 1963; Bott, 1950, 1972; Albrecht, 1982; Maguire

Table I
Number of localities in which crayfish were recorded for each crayfish species in Croatia.

Tableau I
Nombre de localités dans lesquelles les écrevisses ont été rencontrées pour chaque espèce d'écrevisse en Croatie.

Species	Number of localities
Astacus astacus	95
Astacus leptodactylus	30
Austropotamobius pallipes	59
Austropotamobius torrentium	116
Orconectes limosus	9
Pacifastacus leniusculus	2

and Gottstein-Matočec, 2004). Quantification of decline rates per species from the available data is given and main reasons of decline are outlined.

MATERIAL AND METHODS

To assess present day distribution of crayfish field trips to different water bodies across Croatia were performed in the period from 2005 to 2010. Intensity of field surveys was higher in the period from 2008 to 2010 when data on the distribution of crayfish were collected within the frame of Natura 2000 project. During the field work crayfish were hand caught, trapped (baited LiNi traps (Westman *et al.*, 1978) or handmade traps (Maguire *et al.*, 2002)), electro fished, or a combination of these methods was applied. All of the crayfish caught were determined to species (Holdich *et al.*, 2006). After determination ICS were released back to the water, and NICS were removed from the system. GPS coordinates of each studied site were taken.
Collected data were compiled and processed with statistical program Microsoft Excel 2007, and geographical presentations of species distribution were performed by ArcGis 9.1 program package.

RESULTS

Throughout this research presence of four ICS (the noble, the narrow-clawed, the stone and the white-clawed crayfish) and two NICS (the signal and the spiny-cheek crayfish) was confirmed. During the research period 513 localities were investigated, from which 311 (61%) were positive (presence of crayfish was recorded) and 202 (39%) were negative (presence of crayfish was not recorded). Number of localities inhabited by certain species is presented in Table I.
Astacus astacus presence was recorded in water bodies of the continental part of Croatia that belong to the Black Sea drainage but some populations were also recorded in the Adriatic Sea drainage (Figure 1). In Table II we presented results of the analyses of the historical (Šoštarić, 1888; Entz, 1914; Karaman, 1929, 1961, 1963; Albrecht, 1982) and recent data (Maguire and Gottstein-Matočec, 2004) compared to the data obtained in this survey. Of twenty-two localities described in the historical sources to harbour *A. astacus* populations we surveyed fourteen, and found that 36% of previously existing populations had disappeared (Table II). A 15% loss in the number of populations was also found when we compared present day data with data obtained in early 2000's (Maguire and Gottstein-Matočec, 2004) (Table II). This research revealed new localities that harbour *A. astacus* populations (Table II), and visiting the same locality at the beginning and the end of the research (2005 and 2010 respectively) enabled us to detect a further 5% loss of populations. Possible reasons of populations' loss are given in Table II.

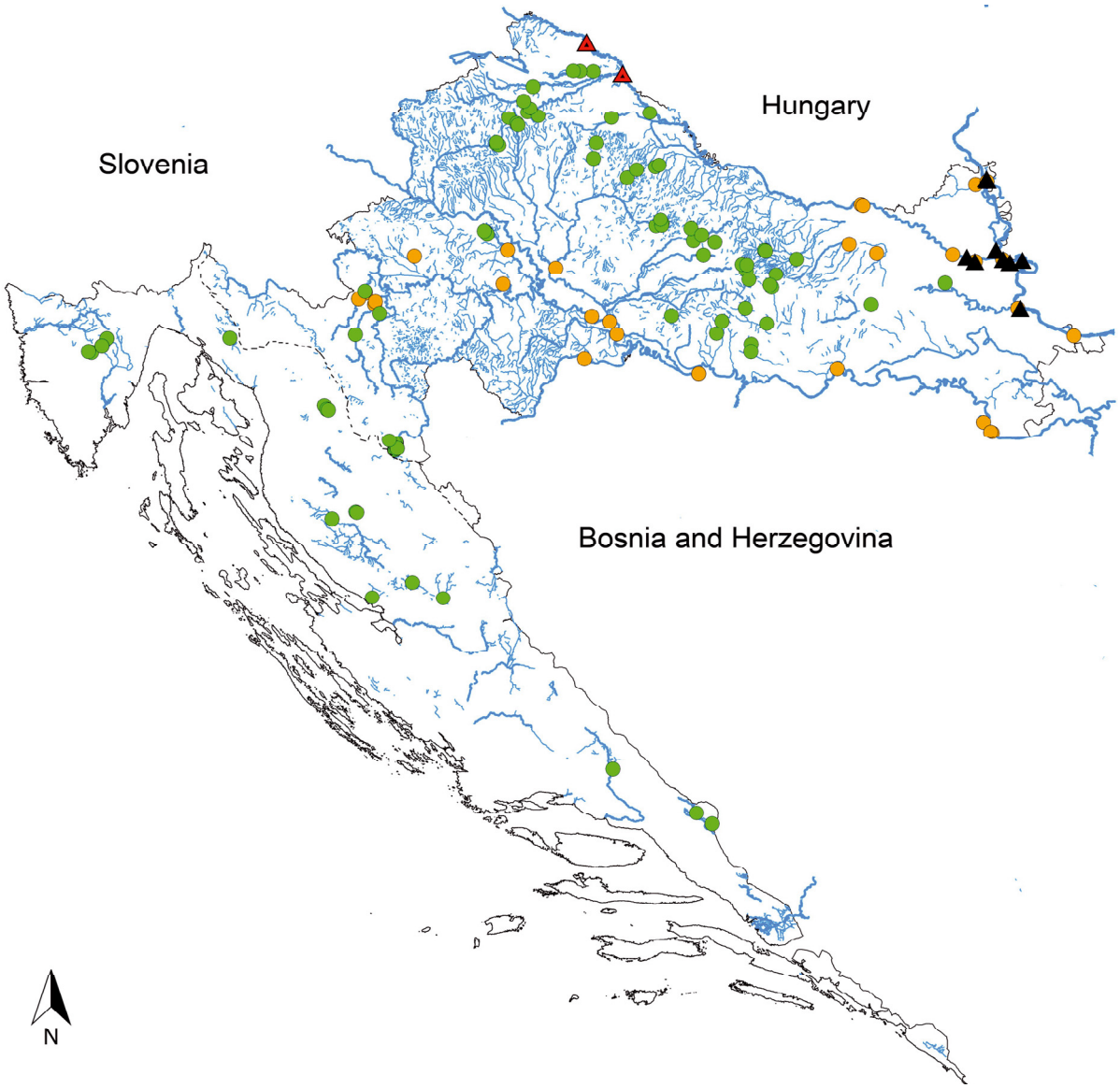

Figure 1
Geographical presentation of Astacus astacus *(green dots),* A. leptodactylus *species complex (orange dots),* Orconectes limosus *(black triangles) and* Pacifastacus leniusculus *(red triangles) distribution (dotted line is a border between the Adriatic Sea and Black Sea drainages).*

Figure 1
Distribution géographique d'*Astacus astacus* (points verts), du complexe d'espèces *A. leptodactylus* (points oranges), d'*Orconectes limosus* (triangles noirs) et de *Pacifastacus leniusculus* (triangles rouges) (la ligne pointillée est la frontière entre les bassins versants de la mer Adriatique et de la mer Noire).

Distribution of *Astacus leptodactylus* was recorded only in the water bodies of the Black Sea drainage (Figure 1). Compared to the previous findings when presence of this species was recorded in only five localities (Maguire and Gottstein-Matočec, 2004) there are 25 new localities where the narrow-clawed crayfish presence is currently recorded (Table II).
Distribution of *Austropotamobius pallipes* species complex is limited to the rivers of the Adriatic Sea drainage (Figure 2). During this research we studied all of the localities that harboured the white-clawed crayfish according to the historical (Grube, 1861; Entz, 1914; Karaman, 1929, 1961; Bott, 1950, 1972; Albrecht 1982) and previous data

Table II

Number of localities, for each species, where crayfish were recorded according to historical, previous and current data (present). Within each data set (historical, previous) we presented number of currently confirmed populations (now) and gave reasons for loss (with number of lost populations). For currently collected data we gave number of surveyed localities and reasons of absence or loss in the last five years (with number of lost or absent populations). (T.L. – total number of localities surveyed; % pos – percentage of positive localities; % neg – percentage of negative localities.)

Tableau II

Nombre de localités, pour chaque espèce, où les écrevisses ont été localisées selon les données historiques, antérieures et actuelles. Au sein de chaque ensemble de données (historiques, antérieures), nous avons présenté le nombre de populations retrouvées aujourd'hui et donné des raisons de la perte (avec le nombre de populations perdues). Pour les données actuellement recueillies, nous avons donné le nombre de localités prospectées et les raisons de l'absence ou de la perte au cours des cinq dernières années (avec le nombre de populations perdues ou absentes). (TL – nombre total de localités enquêtées ; % pos – pourcentage de localités avec présence ; % neg – pourcentage de localités avec absence.)

Species	Historical			Previous			Current			T.L.	% pos	% neg
	Present	Now	Reasons of loss	Present	Now	Reasons of loss	Surveyed	Present	Reasons of loss or absence			
A. astacus	22 14 surveyed*	9	Water body engineering (2); drought (1); replacement by *A. leptodactylus* (2)	27	23	Water body engineering (3); drought (1)	81	67 (4 populations disappeared in last 5 years)	Water body engineering (3); NICS (1)	122	78	22
A. leptodactylus	–	–	–	5	5	–	25	25	–	30	100	0
A. pallipes	16	5	Water body engineering (9); drought (2)	18	6	Water body engineering (9); drought (1); unknown (2)	122	51 (3 populations disappeared in last 5 years)	Water body engineering (3) Water body engineering, drought & direct municipal waste water influx (41)	156	38	62
A. torrentium	14	10	Water body engineering (4)	32	28	Spillage from chemical factory (1); unknown (3)	148	78	Drought (2); water body engineering & direct municipal waste water influx (24)	194	60	40
O. limosus	–	–	–	1	1	–	8	8	–	9	100	0
P. leniusculus	–	–	–	–	–	–	2	2	–	2**	100	0

* Historical data are not always reliable – contradictory cases with regard to geographical names (Maguire and Gottstein-Matočec, 2004) were confronted so only 14 out of 22 localities were surveyed.

** Two localities were surveyed – the most upstream and the most downstream points of the Mura River in Croatia, and they were positive, so we can conclude that the whole length of the Mura River is invaded by the signal crayfish.

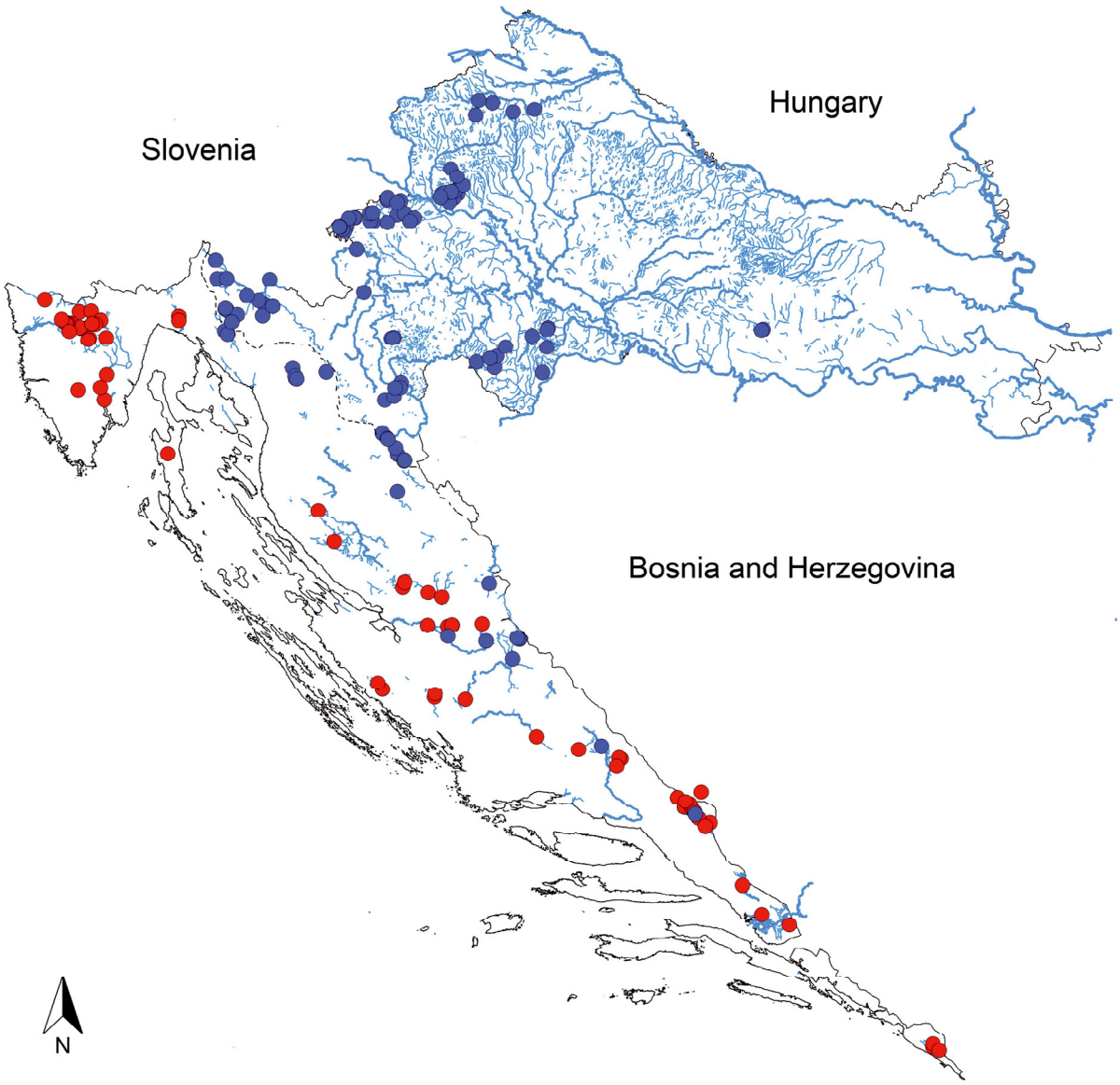

Figure 2
Geographical presentation of Austropotamobius pallipes *species complex (red dots) and* A. torrentium *(blue dots) distribution (dotted line is a border between the Adriatic Sea and Black Sea drainages).*

Figure 2
Distribution géographique des espèces du complexe *Austropotamobius pallipes* (points rouges) et *A. torrentium* (points bleus) (la ligne pointillée est la frontière entre les bassins versants de la mer Adriatique et de la mer Noire).

(Maguire and Gottstein-Matočec, 2004). According to our analyses 68% of previously existing populations have disappeared (Table II).

In this research we included 122 additional localities in the water bodies that belong to the Adriatic Sea drainage and that could potentially harbour the white-clawed crayfish. 42% of localities were positive (presence of crayfish was recorded), and 58% were negative (presence of the white-clawed crayfish was not recorded) (Table II). Visiting the same locality at the beginning and the end of the research (2005 and 2010 respectively) enabled us to detect a further disappearance of 6% of populations (Table II).

Austropotamobius torrentium is distributed in water bodies of the Black Sea drainage, but a few populations also exist in the Adriatic Sea drainage (Figure 2). During this research we studied all of the localities that harboured the stone crayfish according to historical (Šoštarić, 1888; Car 1901; Entz, 1914; Karaman, 1929, 1961; Albrecht 1982) and previous data (Maguire and Gottstein-Matočec, 2004). According to our analyses 17% of previously existing populations have disappeared (Table II).

During this research we included 148 additional localities that could potentially harbour the stone crayfish populations. 53% of surveyed localities were positive while in 47% the stone crayfish were not recorded (Table II).

Orconectes limosus entered Croatia *via* the Danube River and since first recorded in the marshes of "Kopački rit" Nature Park (Maguire and Gottstein-Matočec, 2004) it has continued to spread upstream into the Drava River (Figure 1, Table II).

Pacifastacus leniusculus entered Croatia through the Mura River from Slovenia (Maguire *et al.*, 2008) and it is currently distributed along the whole length of this river in Croatia and we are expecting its spread into the Drava River (Figure 1, Table II). To date there were no recorded mass mortalities of ICS in contact zones with NICS.

DISCUSSION

The main objective of this study was to update data on the distribution of freshwater crayfish in Croatia and to evaluate the current situation in comparison with previous findings.

The noble crayfish is indigenous to Croatia and it is naturally distributed within the tributaries of the Sava and Drava Rivers (the Danube catchment, the Black Sea drainage) (Šoštarić, 1888; Entz, 1914; Karaman, 1929, 1963; Holdich *et al.*, 2006). The presence of this species has also been established within freshwater systems of the Adriatic Sea drainage (Albrecht, 1982; Maguire and Gottstein-Matočec, 2004). Currently the noble crayfish is protected by national legislation and therefore it should not be disturbed or relocated from their natural habitats (Narodne novine, 1999, 2005, 2008). However, the situation in the past was different. Due to their economical and consumption value the noble crayfish were frequently moved from one water body to another. Thus their occurrence in the rivers of the Adriatic Sea drainage is of anthropogenic origin (Maguire and Gottstein-Matočec, 2004). This research revealed a decline in the number of populations mainly caused by water body engineering, droughts and displacement by NICS (Table II). A further decline in the number of noble crayfish populations is therefore expected, and especially in the contact zones with NICS (Hudina *et al.*, 2009) and *Astacus leptodactylus*.

There are no historical records on the narrow-clawed crayfish presence in Croatian freshwaters. Its occurrence within water bodies of the Black Sea drainage was recorded only relatively recently (Maguire and Gottstein-Matočec, 2004), and since then, throughout this survey, new positive localities have been established. Taking into consideration historical data on the distribution of the noble crayfish (Karaman, 1929, 1962) and the stone crayfish (Entz, 1914; Karaman 1961, 1963), as well as personal observations, it is obvious that the narrow-clawed crayfish has spread westwards and southwards displacing both the noble and the stone crayfish from their original habitats, while at the same time *Orconectes limosus* is slowly displacing it from its habitats on the far east of Croatia (Hudina *et al.*, 2009).

This research revealed a significant decline in the number of the white-clawed crayfish populations. Reasons for the small number of records are most likely due to the degradation of the white-clawed crayfish habitat (water body engineering, water quality impoverishment) that was observed during field work which is similar to the situation in other European countries (Füreder, 2006). Extreme droughts that have been pronounced during the last few years in coastal Croatia have also had a negative impact on the presence of the white-clawed crayfish within the water bodies of the Adriatic Sea drainage. Negative impacts of water level reduction onto the number of the white-clawed crayfish populations have been well documented (Grandjean *et al.*, 1997; Füreder, 2006).

The stone crayfish in Croatia inhabits smaller fastrunning streams on higher altitudes belonging to the Black Sea drainage, but it was also recorded in a few water bodies of the Adriatic Sea drainage (Karaman, 1929; Albrecht, 1982; this survey). As the stone crayfish was never of economic importance, it is unlikely that it was introduced from the water bodies of the Black Sea into the water bodies of the Adriatic Sea drainage, but most probably they had spread into this area during the geological past when the two drainages were connected (Žganec, 2009). Comparing historical and previous data (Šoštarić, 1888; Car, 1901; Entz, 1914; Karaman, 1929, 1961; Albrecht 1982; Maguire and Gottstein-Matočec, 2004) with recent findings, the decline in the number of the stone crayfish populations is apparent, but not as pronounced as it is for the white-clawed crayfish. During the survey of the negative stone crayfish localities, a strong negative anthropogenic influence (canalization, riverside vegetation removal) onto habitats as well as consequences of extreme droughts were observed (Table II). There is a reasonable concern that future negative human impact onto the positive stone crayfish localities could still further reduce their number (Füreder, 2006).

NICS presence in Croatian freshwaters was recorded relatively recently (Maguire and Gottstein-Matočec, 2004; Maguire *et al.*, 2008). Since 2004 the spiny-cheek crayfish have entered the Drava River and it has slowly continued upstream spreading and displacing *A. leptodactylus* populations (Hudina *et al.*, 2009). Its presence has still not been recorded in the Sava River, but we expect that this river will be a future corridor allowing it to spread upstream into the water bodies of the Sava River basin in Croatia and Bosnia and Herzegovina. The signal crayfish has spread rapidly throughout the Mura River and it progresses quickly towards the Drava River displacing *A. astacus* (Hudina *et al.*, 2009). At a national level an invasive non-native crayfish species strategy has not yet been prepared, but scientists and activists from different NGOs are making an effort to increase awareness of local communities of the threat that NICS bring with them (Faller, 2010, pers. comm.; Hudina, 2010, pers. comm.).

As a conclusion based on the analysed data we may say that Croatian ICS populations are undergoing a decline. The white-clawed crayfish have suffered an alarming reduction in number of populations, followed by the stone and the noble crayfish. Data collected through this research will be used as a starting point for the development of management strategies by state institutions dealing with the protection of endangered native crayfish species.

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