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THE SYNANTHROPIC SPREAD OF SOME SALT TOLERANT SPECIES ALONG ROADSIDES IN THE CONTINENTAL PART OF CROATIA

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Our research was carried out in northern Croatia from 2018 to 2022 and we investigated the distribution of salt-tolerant plant species along roads (mainly along motorways) in a total of 51 study sites. We were the first to detect *Cochlearia danica*, a halophyte characterized by an Atlantic distribution, in the Croatian flora. We demonstrated the distinct roadside spread *of Desmazeria marina*, *Parapholis incurva* and *Sagina maritima* in a northerly direction towards the interior of the mainland. We recorded the mass occurrence of several salt-tolerant species already well documented in Central Europe along the surveyed motorways (e.g. *Plantago coronopus*, *Spergularia marina*) and provide data on other weeds that have spread along major roads. Three species found (*Desmazeria marina, Puccinellia distans* subsp. *distans, Parapholis incurva*) are included in the Croatian Red List.

Key words: motorways, road ecology, rest area, salt tolerant species, propagation vector

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Tijekom istraživanja provedenog u sjevernom dijelu Hrvatske od 2018. do 2022. godine, na ukupno 51 lokalitetu duž prometnica (uglavnom uz autoceste), bilježili smo pojavljivanje biljnih vrsta otpornih na sol. Atlantska vrsta *Cochlearia danica* je potvrđena kao nova vrsta u flori Hrvatske. Pokazali smo da se neke vrste, kao npr. *Desmazeria marina, Parapholis incurva* i *Sagina maritima* šire uz ceste prema sjeveru ka unutrašnjosti kopna. Zabilježili smo uz istraživane autoceste masovnu pojavu nekih vrsta otpornih na sol (npr. *Plantago coronopus, Spergularia marina*), što je već dokumentirano u srednjoj Europi. Također dajemo podatke o drugim biljkama (npr. *Dittrichia graveolens, Euphorbia prostrata* i *Vulpia ciliata*) koje se šire uz ceste.

Ključne riječi: autoceste, ekologija ceste, odmorište, halofit vrste, vektor širenja

INTRODUCTION

The modern expressway network, mainly formed by motorways, provides ecological corridors for various organisms (Tikka *et al.*, 2001, Kalwij *et al.*, 2008), addressed by the discipline of road ecology (Forman *et al.*, 2002, Kozár *et al.*, 2013). In Western Europe, it has been observed since the 1980s that certain groups of organisms (plants, insects) use the motorway network and railway lines as secondary dispersal corridors (Clarke, 2002; Török *et al.*, 2003). Many species of spreading plants have a high inva-

sion potential, which poses a high ecological risk (Dean *et al.*, 2019, Pyšek *et al.*, 2002). Due to the general characteristics of climate change (increasingly mild winters, hotter summers, prolonged periods of drought), sub-Mediterranean and even Mediterranean flora elements are expected to spread northwards into Central Europe. In order to protect semi-natural habitats, it is necessary to know the range of these species and to monitor their distribution.

Expressways are closed and similar in structure and thus are subject to ecological conditions that are both coexisting and persistent over long periods of time, creating the potential for persistence and the rapid dispersal of certain organisms (Forman, 1998). Among the many specific environmental effects are soil movement, trampling, increased soil and air pollution, excess heat, air turbulence caused by traffic, regular mowing, road salting (Schmidt, 1989; Rew *et al.*, 2018). Among the factors that promote plant invasion, the effects of road salting, trampling and air turbulence are the most important for the determination of germination and growth (Ross, 1986; Forman, 1998; von der Lippe *et al.*, 2013). In addition, asphalt can heat up to extreme temperatures in sunny conditions. All of these are specifically linked to the extreme habitat types of road banks, especially those of heavily salted (during the winter) main roads with heavy traffic. Road bank habitats are also exposed to trampling and extreme temperatures with consequent droughts during the summer (Jogan, 2017).

De-icing salt has been shown in several studies (e.g. Blomqvist, 1998; Hintz & Relyea, 2019; Fekete *et al.*, 2022) to be deleterious to vegetation adjacent to roads , and to be a source of significant nature conservation problems (Barbosa *et al.*, 2010; McDougall *et al.*, 2018). Salty water and melted snow runoff from vehicle traffic and precipitation onto the roadside causes contamination of soils and associated watercourses (Amrhein *et al.*, 1992) and alters the pH and chemical composition of soils (Davison, 1971). A narrow, salinized band appears parallel to the asphalt strip, providing suitable habitat for halophytes tolerant of high mechanical and osmotic stress (Scott & Davison, 1985; Perkins, 2003). According to Wróbel *et al.* (2006), the proportion of halophyte species in the emergent vegetation is prominent in a 20-30 cm lane from the edge of the bank, decreasing with distance from the surfaced road

Halophytic species in Central Europe used to be characterized by a relatively narrow, regional distribution (e.g. Scott & Davison, 1985; Gerstberger, 2001), but recent studies report a significant increase in the intensity of their spread (Jogan, 2017). Species native to coastal areas of Europe started to spread rapidly along the roads of Central European countries (Fekete *et al.*, 2022), the most striking of which are *Plantago coronopus* (Glasnović, 2007; Friese, 2011; Schmidt *et al.*, 2016), *Cochlearia danica* (Hohla & Raabe, 2012; Fekete *et al.*, 2018), *Dittrichia graveolens* (Király *et al.*, 2014; Kocián, 2014; Takács *et al.*, 2016; Szatmari & Hurdu, 2020). However, the incipient or ongoing expansion of several other species is known (see Fekete *et al.*, 2022). The originally continental *Atriplex micrantha* shows an interesting dispersal pattern, reaching the eastern part of Central Europe from the opposite direction of its former naturalized populations in Western Europe (Hohla & Melzer, 2013; Kocián, 2014; Mesterházy *et al.*, 2017). Species native to a country may also be affected by spectacular roadside migration, where species from native saline areas appear in distant parts of the country through transport. A good example is the remarkable spread of *Spergularia marina* in several countries in Central Europe (Dítě & Dítětová, 2016; Schmidt *et al.*, 2018; Ducháček & Kúr, 2019).

In southeastern Europe, the flora and vegetation associated with linear structures (e.g. roads and railways) are generally significantly understudied topics. In Croatia, several studies have been published on the urban flora of settlements, but only a few studies have investigated railway lines (e.g. Jasprica *et al*., 2017) or roadside verges (e.g. Milović & Pandža, 2014; Borovečki-Voska *et al*., 2021). Therefore, the current distribution of salt-tolerant plant species also present in the roadside flora is not sufficiently known, and up-to-date information is not provided by larger databases (Nikolić, 2005; Nikolić & Topić, 2005).

The main aim of our research was to investigate and map the roadside vegetation on the motorway network in the continental part of Croatia, with a special focus on salt-tolerant and/or potentially invasive species. Our goal was to record the up-to-date situation of the range of species that are likely to occur in the Carpathian Basin and Central Europe in the future.

MATERIALS AND METHODS

Our surveys were carried out in the northern part of Croatia (partly belonging to the Pannonian region), covering a total of 535 km of motorway sections, distributed as follows: the A1 motorway (Lučko - Karlovac): 39 km, A2 motorway (Sveti Križ Začretje - Jankomir): 37 km, A3 motorway (Zagreb - Lipovac): 304 km, A4 motorway (Zagreb - Goričan): 96 km, A5 motorway (Osijek - Svilaj): 59 km (Fig. 1). Forty sampling points were designated, distributed by motorway as follows: A1 motorway: 3; A2 motorway: 4; A3 motorway: 25; A4 motorway: 3; A5 motorway: 4. In addition, in some cases, data collection was also carried out on primary main roads (a total of 11 sampling points): expressway D1 from Karlovac to Zagreb, state road D7 from Osijek to Dubošević border crossing (A5 motorway section north of Osijek is under construction, currently considered as state road), and some high-traffic unmarked roads from the outer and inner areas of larger settlements (Zagreb, Sesvete, Samobor, Varaždin).

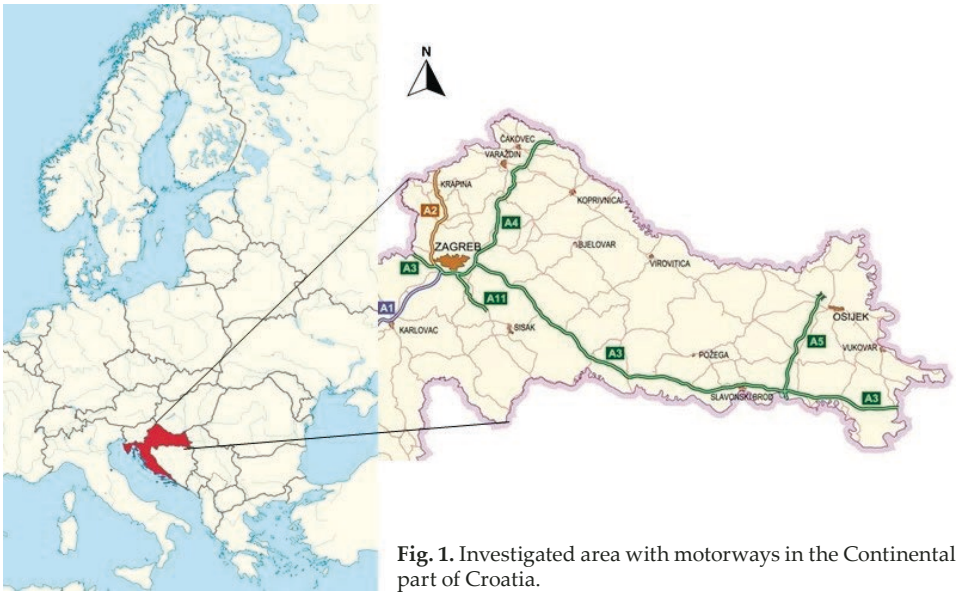

Fig. 1. Investigated area with motorways in the Continental part of Croatia.

Our field surveys were carried out between 2018 and 2022. Sampling points were located at sites considered to be the most favorable for the establishment of species spread in the road network. The most suitable sites for this purpose were rest areas on motorways.

In addition to motorways, four sampling points were located on expressways (D1: two points; D7: two points), while seven sampling points were on lower-ranking roads. Our studies were carried out within the narrow band of the roadside where traffic stress factors were most favorable for the development of halophytic vegetation. In the case of motorway rest areas, this was generally observed on the roadside verges of the single-lane entrance section of the rest area (Fig. 2). The width of this lane was 30–100 cm and its length was determined by the spatial extent of halophytic vegetation, varying from a few tens of meters up to 100 m. Species occurrence within this area was assessed using a simple presence-absence method. The 10 species mapped in detail are all specifically linked to extreme habitat types of road banks, especially main roads with heavy traffic heavily salted during the winter: *Cochlearia danica, Desmazeria marina, Festuca pseudovina, Juncus gerardii, Parapholis incurva, Plantago coronopus, Puccinellia distans, Sagina maritima, Sedum caespitosum, Spergularia marina*.

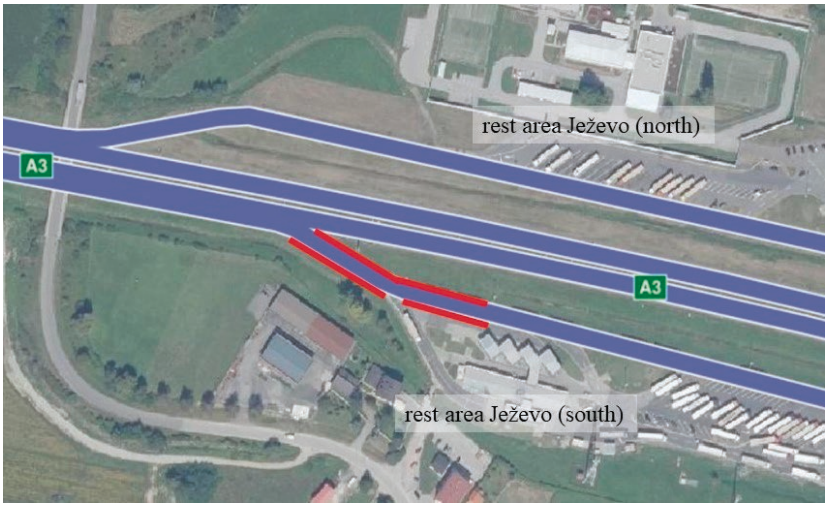

Fig. 2. The surveyed section of motorway rest areas (example - Ježevo rest area, A3 motorway).

In addition, new occurrences of other species with no distinct halophyte character but with a detectable roadside dispersal strategy were recorded (10): *Desmazeria rigida, Dittrichia graveolens, Eleusine indica, Euphorbia prostrata, Helminthia echioides, Rostraria cristata, Sagina apetala, Thlaspi alliaceum, Tragus racemosus, Vulpia ciliata*. For each sampling point, the road identifier, administrative boundary, site name, exact geo-coordinate, date of collection, and names of the collectors were given (Appendix 2). In order to evaluate the occurrence of the studied species, we conducted research at the Herbarium of the Department of Botany, Faculty of Science in Zagreb (ZA).

Taxa were identified using the standard keys of Tutin *et al.* (1993) and Nikolić (2019). The nomenclature of plant taxa mainly follows Flora Croatica Database (Niko-

lić, 2020a), and for taxa not included in Flora Croatica Database, nomenclature follows Euro+Med PlantBase (2022). The threat status of taxa was determined according to the Red Book of Vascular Flora of the Republic of Croatia (Nikolić & Topić, 2005; Nikolić, 2020b).

The collected data are supported by herbarium specimens, the vouchers are deposited in the ZA herbarium in Zagreb. The identification code of the vouchers has been indicated in the text.

We present our data on eight distribution maps (Appendix 1).

RESULTS AND DISCUSSION

(1) *Parapholis incurva* (L.) C.E. Hubb.

A grass species distributed along the Mediterranean coast, but also reaching Great Britain in the west and eastern Europe along the coast of the Black Sea (Euro+Med, 2006-). The species grows in salt marshes in species-rich stands of Salicornion fruticosae in coastal areas of Croatia (Alegro, 2005; Dítě *et al.*, 2018). According to Stančić *et al.* (2008) it has 100 known localities in several vegetation types along the coast, even in ruderal habitats.

During our surveys, we found significant populations; it occurred in 38% of the sampling points (15 sites), making it the third most common salt-tolerant species (Fig. 3, 4). It is present along the entire length of the A3 motorway from the Slovenian to the Serbian border (12 localities), and on the A1 and A2 motorways near Zagreb (on both in just a single locality; voucher: 77197, 77198, 77200) (Appendix 2). It forms stands in the open (probably due to higher salt content) and often trampled strip without competition on the embankment sometimes in monodominant patches. As well as on motorways, it has been observed on the roadside of busy roads in several places: on the D1 motorway near Jastrebarsko and Lučko, on the D528 road in Donji Kneginec (near Varaždin), and in the inner areas of Zagreb, Sesvete, Samobor (Appendix 1).

The roadside spread of *Parapholis incurva* has been documented only from the British Isles (Ireland: Akeroyd, 1984; England: James (2010), Leslie (2017); Outer Hebrides: Smith, 2017), but no locations have been reported from the Mediterranean. It has been reported as an adventive species from Belgium, where it was previously a casual, but recently it is reported as a naturalized species (URL2). Outside of Europe, it is common along the most important highway in Egypt (El-Amier & El-Gawad, 2017).

The occurrence of this species in the Pannonian macroregion of Croatia has not been reported so far, and no herbarium specimens have been found. The circumstances of its roadside occurrence suggest that its distribution in the region may have started several years ago. All of its occurrences in the Zagreb area are located along high-traffic motorways with direct access via the A1 and A6 motorway to Rijeka on the Adriatic coast, where the species' nearest native habitats are found. The distance between Rijeka and Zagreb by motorway is 150 km, while the furthest occurrence from the coast (A3 motorway, rest area Bošnjaci) is 433 km away.

(2) *Puccinellia distans* (Jacq.) Parl.

A salt-tolerant grass that is widespread throughout Europe, and is also found in continental salt marshes as well as on the coast. It is commonly found in the coastal areas of Croatia (Nikolić & Topić, 2005).

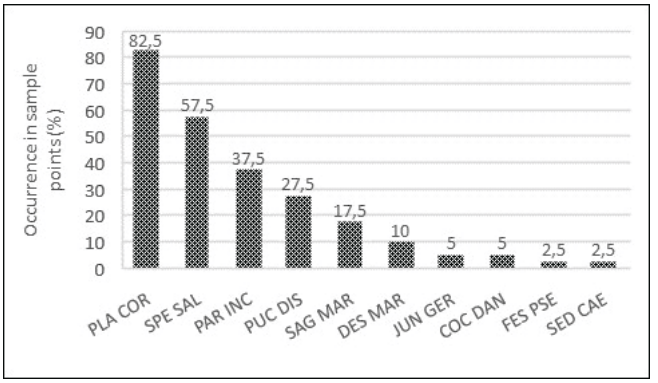

Fig. 3. Probability of occurrence of the mapped halophyte species at the sampling points.

Its secondary occurrence along highways was not frequent, occurring at 28% of the sampling points (11 sites) (Fig. 3). It was found on all roads surveyed except the A5 motorway. The species prefers completely bare, extremely trampled, often saline soil surfaces. It does not form uniform stands, but may become dominant in small patches. It has been found on the embankments of the D1 (Jastrebarsko) and D7 (Švajcarnica) roads, on the D528 road in Donji Kneginec (near Varaždin), and also in the inner area of Samobor.

The roadside spread of this species has long been known in many European countries (e.g. Scott & Davison, 1985; Gerstberger, 2001; Jogan, 2017), and in Hungary it is the most common plant of roadside verges (Schmidt *et al.*, 2018).

(3) *Desmazeria marina* (L.) Druce

A salt-tolerant species native to the coastal zone of southern and western Europe, up to 59° latitude in the north (Orkney Islands), reaching the Middle East and also occurring along the Mediterranean coast of North Africa (Stace, 1980; Euro+Med, 2006). It is also widespread along the northern Adriatic coast (Čarni & Jogan, 1998; Nikolić & Topić, 2005). The species usually appears in coastal habitats, close to the sea, primarily in rocky trampled habitats.

Occurrence of the species was recorded in four localities on motorway sections close to Zagreb (A1: 2 localities, A2: 1 locality, A3: 1 locality; voucher: 77195, 77196). Outside the motorway, it was also recorded in the inner area of Zagreb (Branimirova ulica; voucher: 77199). It prefers open, strongly saline often contaminated gravel surfaces like *Parapholis incurva*.

The roadside spread of this species is a relatively recent phenomenon, with a few known records. Far from the coast, it is known from Switzerland, where Ciardo & Hoffer-Massard (2006) reported it from the shores of Lake Geneva, together with several other halophytes. It has been found in dry shrubby (pseudomaquis) vegetation in southeastern Macedonia (Matevski & Čarni, 2019). Although it is a vulnerable (VU) taxon in Croatia and also listed in the Red Book of Vascular Flora of Croatia (Nikolić & Topić, 2005), roadside appearances are counted as alien, introduced occurrences.

(4) *Plantago coronopus* L.

The native distribution of *Plantago coronopus* in Europe follows the coastline: it grows in maritime areas of Western and Southern Europe (including the southern part of Scandinavia) and along the coasts of North Africa (Hegi & Pusch, 2009).

It is the most widespread salt-tolerant plant in the study area, occurring in great numbers along motorways, but is less common outside them. It was found at 83% of all sampling points (Fig. 3), and was detected at 22 of 25 sampling points on the A3 motorway. There, it is found in long, dense stands on the pavement edge of the dividing strip between the two lanes (e.g. between Okučani and Slavonski Brod). It can further be found on the curbs of the A5 motorway rest areas, which are exposed to less environmental stress. Because it is a new colonizer, individuals are usually observed in the more open parts of the verge, but from there they can rapidly spread to less extreme and more closed vegetation further from the verge.

The secondary expansion of the species, from the Atlantic coast towards the interior of the mainland, started in the last third of the 20th century (Raabe, 1990). In the 2000s, it rapidly invaded western and northern (e.g. Gerstberger, 2001; Diewald, 2011; Hohla, 2012), then eastern and south-eastern parts of central Europe (Sadowska & Żółkoś, 2011; Schmidt *et al.*, 2016; Schmidt & Maslo, 2020; Křenová *et al.*, 2021) via the motorway network from the north-west. It is nowadays considered one of the most successfully spreading roadside halophytes in Central Europe (Fekete *et al.*, 2021).

(5) *Spergularia marina* (L.) Griseb.

A salt-tolerant plant occurring on almost all continents (Hultén & Fries, 1986), but the exact edges of its natural range are not clear (Kaplan *et al.*, 2016). It occurs in most of Europe, in coastal salt marshes in the coastal zone and in continental salt marshes (Euro+Med, 2006-).

It occurs in more than half (58%) of the sampling sites and is found along all motorways, being most common along the A4 where it was present at all rest areas. Along the A3, it was widespread between Lipovljani and Slavonski Brod. It favors microhabitats of roadsides exposed to extreme environmental stress, probably with high salt accumulation often forming large monodominant patches. Furthermore, we found it on the D7 motorway at 2 sites (Darda, Švajcarnica), in the inner area of Samobor and on the D528 road at Donji Kneginec (near Varaždin).

Its secondary distribution in Austria, facilitated by road salting, has been noted since the 1970s (Friedrich, 1979). It has long been known from the Czech Republic (Chocholoušková, 2013), where it now occurs along roads throughout the country (Kaplan *et al.*, 2016). From the Czech Republic it reached the motorways in Slovakia (Goliašová, 2012; Dítě & Dítětová, 2016) and Hungary (Schmidt *et al.*, 2018). In Croatia, there were no previous records outside the coastal strip.

(6) *Sagina maritima* Don

Sagina maritima is a coastal species of Europe occurring from the North Sea to the Mediterranean Sea (Clapham & Jardine, 1993) in open sandy to clayey salt marshes (Jäger, 2011).

It was found at six sites along the surveyed roads: rest area Desinec on the A1 motorway, rest area Križ, rest area Lipovljani, rest area Staro Petrovo selo on the A2 mo-

torway, rest area Ljubešćica and rest area Sesvete on the A4 motorway. The populations are small, often consisting of only a few individuals. Among all the species studied, the most difficult to spot is this small, short-lived species, which often occurs together with *Sagina apetala* (which was also observed to be expanding along roadsides).

The roadside spread of this species is a poorly documented phenomenon in Europe. It has been reported from Scotland in tarmac cracks and sandy roadside verges (URL1).

(7) *Juncus gerardi* Loisel.

Mainly a coastal species in Europe, it also occurs inland in parts of eastern Europe, particularly on saline soils (Hultén & Fries, 1986). In Croatia it is a rare species occurring on coastal saline wetlands (Dítě *et al.*, 2018).

It was recorded in only two of our sampling sites (A3: rest area Novska; A4: rest area Ljubešćica), where it was found on moist surfaces of the road verge, often on the edges of wheel tracks and potholes.

(8) *Cochlearia danica* L.

The species is native to coastal habitats in Western Europe (Hultén & Fries, 1986), and is found in continental territories as a roadside species (Fekete *et al.*, 2018).

During our surveys the species was found at three rest stops along the A3 motorway. On the south side of the motorway from Zagreb towards Slavonski Brod, small populations (a few dozen individuals) were found at Križ rest area (south), on the north side at Lipovljani (north) rest area and Staro Petrovo selo (north) rest area (voucher: 77205). From the Križ (south) rest area to the Popovača exit, dense patches were observed at several points along the edge of the service lane. *Cochlearia danica* is recorded growing along roadsides in eight countries in continental Europe (Fekete *et al.*, 2018), but previously it was not known in Croatia.

(9) *Festuca pseudovina* Hack. ex Wiesb.

A grass species of dry, often saline grasslands of central and eastern Europe, which spreads westwards across the continent to Germany. It has one known roadside occurrence from Austria [referred to as *Festuca valesiaca* subsp. *parvifora*] (Englmaier *et al.*, 2018) and it has several occurrences along Hungarian roads (Fekete *et al.*, 2022).

During our surveys it was found in one place, in the Stupnik rest area on the A1 motorway.

(10) *Sedum caespitosum* (Cav.) DC.

A sub-Mediterranean species that inhabits disturbed, dry gravel grasslands in southern Europe, but often occurs in salt marshes in the Carpathian Basin. It was found at a single sampling site (A3: Staro Petrovo selo rest area) in a dense patch covering a few square meters located a few meters away from the rest area on a bare gravel surface without any competition from other species.

Our research has also involved mapping the distribution of plant species that do not have a pronounced salt-tolerant character, but those that spread are also mainly connected to roadsides in Central Europe.

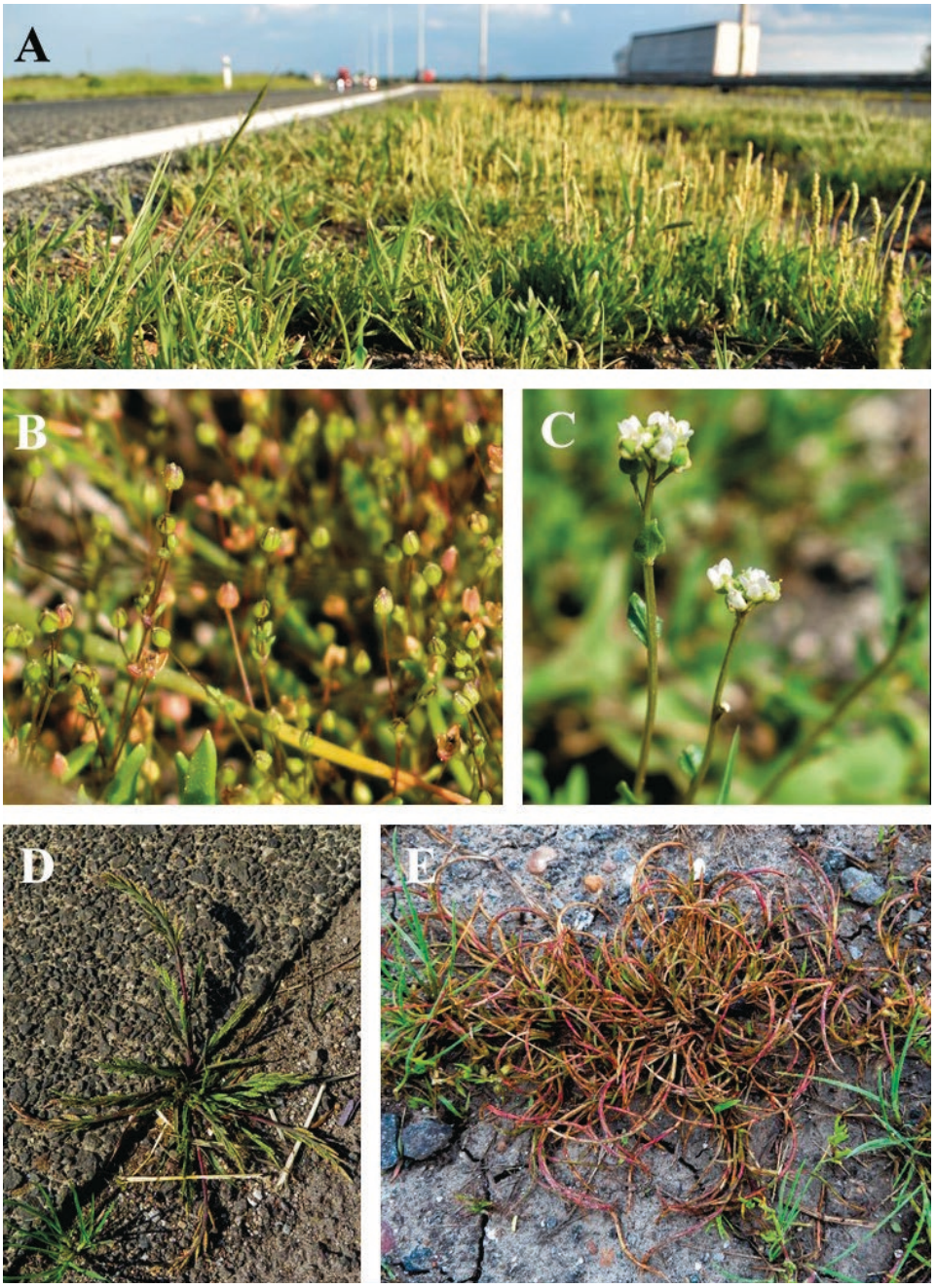

Fig. 4. Salt tolerant species along motorways. A – *Plantago coronopus;* B – *Sagina maritima;* C – *Cochlearia danica;* D – *Desmazeria marina;* E – *Parapholis incurva.*

The elusive, short-lived *Apera interrupta* (L.) P. Beauv. was found on the roadside at the Novska rest stop in a stand of *Vulpia myuros*. Locality: 19 (motorway).

The disturbance- and trampling-tolerant *Desmazeria rigida* (L.) Tutin (syn.: *Catapodium rigidum* (L.) C.E. Hubb.) has been found to spread northwards, appearing along the A1 and A3 motorways, but has also been detected in several places off the motorway. Localities: 6, 12, 17, 22, 26, 28, 29, 36 (motorways); 42, 46, 47, 48 (other roads).

Dittrichia graveolens (L.) Greuter is a coastal plant in Croatia, but was not known from the inland of the country, although in neighboring Slovenia its strong spread has been observed along motorways since 2008 (Frajman & Kaligarič, 2009).

A few specimens were found at rest areas on the A3 and A4 motorways, on the embankments most affected by turbulence from vehicular traffic. Localities: 12, 36 (motorways).

Euphorbia prostrata (Ait.) Small is known from trampled vegetation of mostly urban environments (Milović & Randić, 2001), and was observed during our surveys on roadsides of motorway rest areas as well. Localities: 10, 32 (motorways).

The occurrence of *Picris echioides* L. was observed in the rest areas of the A3 and A5 motorways, where it mainly grows, often in high numbers, in trampled dry lawns and weed communities. Localities: 22, 24, 26, 27, 28, 29, 31, 33, 38, 40 (motorways).

A few stands of *Rostraria cristata* (L.) Tsvelev were found in the agglomeration of Zagreb and south of it along the A1 motorway. Localities: 1, 3 (motorways); 42 (other roads).

Intensive dispersal of *Sagina apetala* Ard. was observed on motorways, present in half of the sampling points. Localities: 1, 3, 5, 12, 13, 14, 16, 17, 18, 20, 21, 23, 24, 25, 28, 34, 35, 36, 38, 40 (motorways); 41, 44, 45, 46, 49 (other roads).

Thlaspi alliaceum L. was recorded at three rest areas along motorway A3, growing in ruderal weed associations of the road embankment. Localities: 13, 14, 15 (motorways).

Tragus racemosus (L.) All. was found only in two sites at motorway A3. The occurrence of the species is not a common phenomenon along roadsides in the Continental part of Croatia, in contrast to Hungary, where it is one of the most common roadside species. Localities: 11, 12 (motorways).

Vulpia ciliata Dumort, a species newly introduced into several European countries in recent decades (Mesterházy *et al.*, 2021), was detected in several sampling sites during our surveys. Localities: 16, 17, 19, 22, 24, 36 (motorways); 42, 43 (other roads).

It can be seen that the distribution of salt-tolerant plant species occurring on roadsides may show different patterns in different countries. While *Festuca pseudovina* and *Puccinellia distans* are the most common species to have taken advantage of the salting of roads, often appearing in a continuous belt in Hungarian roadsides (Fekete et al., 2022), they proved to be rare in the continental part of Croatia. In contrast, in the investigated area several speciesthat are typically elements of Saginetea maritimae in Europe (within this, primarily in Mediterranean upper saltmarshes) show a more definite spread. This association group is distributed mainly in the Atlantic and Western Mediterranean part of the continent. The roadside spread of *Cochlearia danica, Plantago coronopus* and *Spergularia marina* is not a new phenomenon, on the other hand, there were no data or only little information about such observations *of Desmazeria marina, Parapholis incurva* and *Sagina maritima*. The rich stands of the latter coastal species re-

veal their ability to adapt to the continental climate, as has already been observed in the case of *Cochlearia danica* or *Plantago coronopus*, which also belong to the *Saginetea maritimae* association group. However, these species began their conquest from the south, certainly from the base populations located on the coast of the Adriatic Sea. Furthermore, the newly observed stands along Slavonian motorways can also be seen as the initial stage of their wider invasion of Central Europe. In the British Isles, Leslie (2017) mentions *Parapholis incurva* already as a maritime invader, Smith (2017) presents *Sagina maritima* as a "classical roadside halophyte"; taking into account the similar ecological backgrounds of *Cochlearia danica* and *Plantago coronopus*, they will easily be able to achieve a similar rate of spread in the continent.

CONCLUSIONS

We can see, that the emerging road network and road traffic play a major role in the spread of plant species, for which roadsides can create suitable habitats. Both native and alien species can use roadsides as dispersal corridors as we could see from our records. Coastal species possibly would never be able to leave their original habitats, the coastal zone, without the the facilitation of cars. In the case of the spread of alien species, such as *Cochlearia danica,* it should also be noted that a conservational problem may emerge if the species reach the coastal regions of the Adriatic Sea threatening maritime plant communities. It is important to note that all roadside data of the species listed in the Red Book of Vascular Flora of Croatia (Nikolić & Topić, 2005) can be evaluated as non-native, introduced occurrences. The monitoring of this species would be important to prevent its colonization of native habitats.

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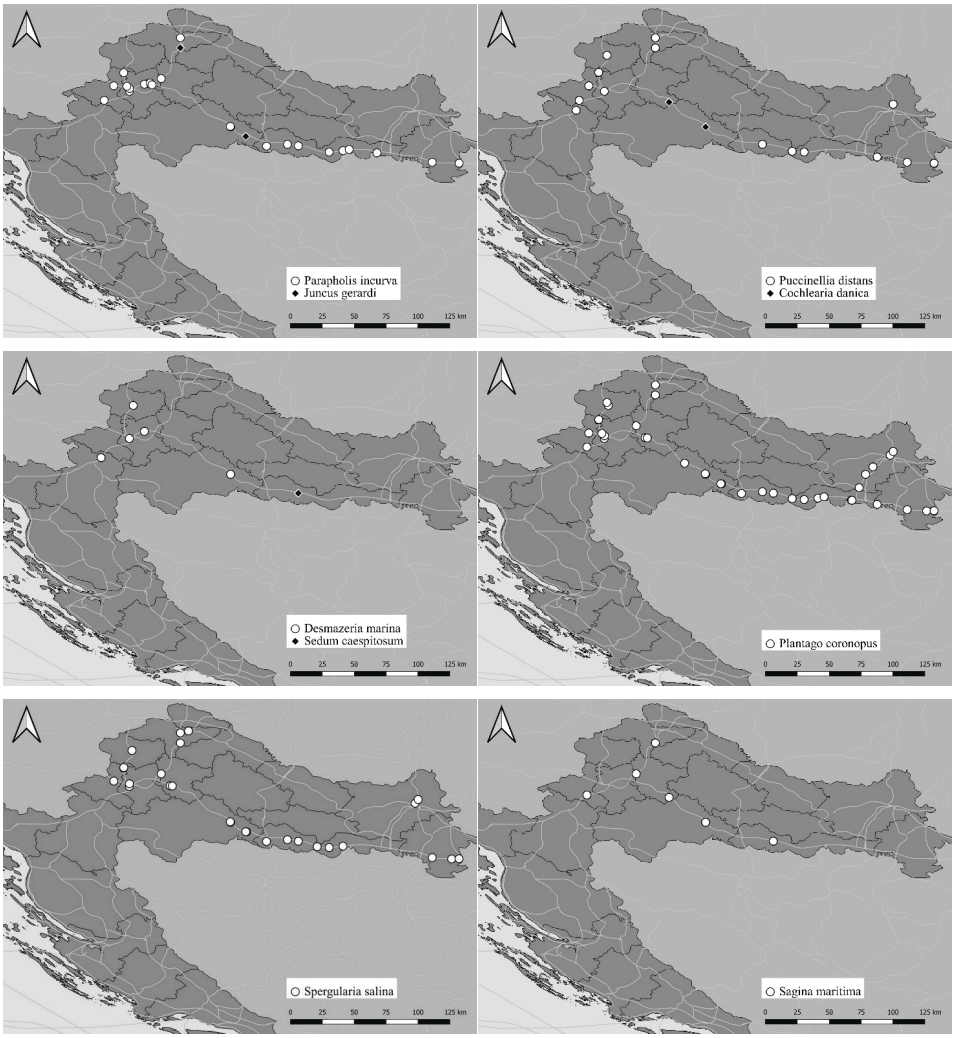
URL1: https://www.assyntwildlife.org.uk/2019/07/halophytes-roadsides/

URL2: https://alienplantsbelgium.myspecies.info/content/parapholis-incurva

APPENDIX 1.

Distribution of the mapped species along roadsides in the Continental part of Croatia.



APPENDIX 2.

List of data-collecting locations.

nr.	road	settlement	location name	wgs84 x	wgs84 y	date	collector
1	A1	Donji Stupnik	Stupnik rest area	45°44′45.8″N	15°52′54.4″E	12.05.2022	D.Schmidt, S.Kis
2	A1	Donji Desinec	Desinec rest area	45°39′48.2″N	15°42′48.4″E	12.05.2022	D.Schmidt, S.Kis
3	A1	Draganić	Draganić rest area	45°33′39.5″N	15°36′33.5″E	12.05.2022	D.Schmidt, S.Kis
4	A2	Jakovlje	Jakovlje rest area	45°55′33.1″N	15°49′39.8″E	20.07.2021	D.Schmidt
5	A2	Jakovlje	Jakovlje rest area	45°55′46.1″N	15°49′41.6″E	20.07.2021	D.Schmidt
6	A2	Ciglenica Zagorska	Sveti Križ Začretje rest area	46°03′58.3″N	15°55′11.5″E	20.07.2021	D.Schmidt
7	A2	Ciglenica Zagorska	Sveti Križ Začretje rest area	46°04′05.9″N	15°55′08.5″E	20.07.2021	D.Schmidt
8	A2	Vrankovec	Sveti Križ Začretje exit	46°05′43.1″N	15°54′27.2″E	20.07.2021	D.Schmidt
9	A3	Gradna	Gradna rest area	45°49′31.7″N	15°44′15.8″E	19.07.2021	D.Schmidt
10	A3	Zagreb	Plitvice motel sjever rest area	45°46′22.7″N	15°52′58.2″E	01.07.2020	D.Schmidt
11	A3	Donja Greda	Zagreb-east (Ivanja Reka) toll gate	45°45′12.0″N	16°16′34.9″E	01.07.2020	D.Schmidt
12	A3	Ježevo	Ježevo rest area	45°45′03.6″N	16°17′52.4″E	01.07.2020	D.Schmidt
13	A3	Vezišće	Križ rest area	45°38′25.5″N	16°30′31.9″E	10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
14	A3	Vezišće	Križ rest area	45°38′09.1″N	16°30′52.0″E	19.07.2021; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
15	A3	Donja Gračenica	Gračenica rest area	45°30′27.3″N	16°39′32.9″E	10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
16	A3	Lipovljani	Lipovljani rest area	45°23′58.2″N	16°51′43.1″E	19.07.2021; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
17	A3	Lipovljani	Lipovljani rest area	45°24′16.5″N	16°51′30.0″E	01.07.2020; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
18	A3	Paklenica	Novska rest area	45°18′27.2″N	17°00′58.6″E	19.07.2021	D.Schmidt
19	A3	Paklenica	Novska rest area	45°18′29.8″N	17°00′32.7″E	01.07.2020; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
20	A3	Gređani	Okučani toll gate	45°12′50.9″N	17°12′33.0″E	04.06.2019	D.Schmidt
21	A3	Rešetari	Nova Gradiška toll gate	45°13′50.4″N	17°24′42.4″E	04.06.2019	D.Schmidt
22	A3	Staro Petrovo Selo	Staro Petrovo Selo rest area	45°12′59.3″N	17°31′01.3″E	19.07.2021; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
23	A3	Lužani	Lužani rest area	45°09′49.0″N	17°41′59.4″E	01.07.2020	D.Schmidt
24	A3	Brodski Stupnik	Brodski Stupnik rest area	45°09′20.8″N	17°48′54.2″E	01.07.2020; 10.05.2022	D.Schmidt, S.Kis, Z.Ulbert
25	A3	Gromačnik	next to toll gate Slavonski Brod west	45°10′09.0″N	17°56′56.6″E	08.06.2019	D.Schmidt
26	A3	Slavonski Brod	Marsonija rest area	45°10′52.5″N	18°00′30.9″E	08.06.2019, 01.07.2020	D.Schmidt
27	A3	Slavonski Brod	Marsonija rest area	45°10′52.8″N	18°00′27.8″E	19.07.2021	D.Schmidt
28	A3	Sredanci	Sredanci rest area	45°08′56.8″N	18°16′15.2″E	08.06.2019, 01.07.2020	D.Schmidt
29	A3	Sredanci	Sredanci rest area	45°08′52.4″N	18°16′38.9″E	19.07.2021	D.Schmidt
30	A3	Babina Greda	Babina Greda rest area	45°06′30.8″N	18°31′16.5″E	01.07.2020	D.Schmidt
31	A3	Bošnjaci	Bošnjaci rest area	45°03′26.4″N	18°48′43.3″E	01.07.2020	D.Schmidt
32	A3	Lipovac	Spačva rest area	45°02′42.7″N	19°00′00.8″E	01.07.2020	D.Schmidt
33	A3	Lipovac	off road to D57	45°02′50.1″N	19°04′18.4″E	01.07.2020	D.Schmidt
34	A4	Štefanec	Varaždin rest area	46°17′02.3″N	16°27′17.6″E	21.07.2021	D.Schmidt
35	A4	Ljubešćica	Ljubešćica rest area	46°10′03.9″N	16°22′31.2″E	21.07.2021; 13.05.2022	D.Schmidt, S.Kis

nr.	road	settlement	location name	wgs84 x	wgs84 y	date	collector
36	A4	Donja Zelina	Sesvete rest area	45°52′07.5″N	16°11′26.5″E	21.07.2021; 13.05.2022	D.Schmidt, S.Kis
37	A5	Beketinci	Beketinci rest area	45°28′18.7″N	18°28′53.2″E	21.07.2021	D.Schmidt
38	A5	Novi Perkovci	Ivandvor rest area	45°16′11.6″N	18°20′49.4″E	08.06.2019	D.Schmidt
39	A5	Tomašanci	Strossmayerovac rest area	45°23′56.2″N	18°24′35.6″E	08.06.2019	D.Schmidt
40	A5	Donji Andrijevci	Andrijevci rest area	45°10′58.1″N	18°19′36.0″E	08.06.2019	D.Schmidt
41	D1	Jastrebarsko	Trešnjevka street	45°39′27.5″N	15°38′19.7″E	12.05.2022	D.Schmidt, S.Kis
42	D1	Lučko	Puškarićeva ulica	45°45′35.2″N	15°53′44.5″E	12.05.2022	D.Schmidt, S.Kis
43	-	Zagreb	Branimirova ulica	45°49′15.2″N	16°03′46.0″E	12.05.2022	D.Schmidt, S.Kis
44	-	Zagreb	Branimirova ulica	45°48′54.0″N	16°01′40.3″E	11.05.2022	D.Schmidt, S.Kis
45	-	Zagreb	Zagrebačka ulica	45°49′35.3″N	16°05′01.9″E	12.05.2022	D.Schmidt, S.Kis
46	-	Sesvete	ulica Ljudevita Posavskog	45°48′32.7″N	16°06′03.7″E	12.05.2022	D.Schmidt, S.Kis
47	-	Zagreb	Ljubljanska avenija, next to King Cross Jankomir shopping center	45°47′40.3″N	15°51′32.9″E	20.07.2021	D.Schmidt
48	-	Samobor	Svetonedeljska ulica, near crossroad with ulica I. Gundulića	45°47′55.3″N	15°43′55.3″E	20.07.2021	D.Schmidt
49	-	Donji Kneginec	528. ulica, roundabout next to Lumini Centar	46°15′54.8″N	16°22′33.2″E	13.05.2022	D.Schmidt, S.Kis
50	D7	Darda	E73 street, south of Drava bridge	45°35′02.7″N	18°38′47.7″E	08.06.2019	D.Schmidt
51	D7	Švajcarnica	E73 street, off road to Darda	45°37′12.7″N	18°40′35.2″E	08.06.2019	D.Schmidt