Halophytes in roadside habitats: a survey of salt-tolerant vascular plant species along roads in Luxembourg

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Abstract. Traffic-related disturbances along networks of roads facilitate the dispersal of halophytes. In order to assess the salt-tolerant roadside flora of Luxembourg and its possible distribution patterns, 52 relevés have been made from 2017 to 2018. On the verges and median strips of different road types (16 sampling plots on motorways, 36 on national and B roads) 205 vascular plant species were recorded (32 grass and grass-like, 151 herbaceous and 22 woody species). *Plantago coronopus* was first observed on roadside habitats in Luxembourg, while several halophytes already present in neighbouring countries were expected, but not found. The species composition of the surveyed road types was notably different, e.g. *Senecio inaequidens* and *Atriplex micrantha* were more frequent along motorways, whereas *Puccinellia distans* was present along all road types.

Keywords. Halophytes, neophytes, vascular plants, invasive alien species, dispersal, roadside flora, Luxembourg

1. Introduction

The number of neophyte plant species in Europe is constantly growing (Petrischak 2014). While watercourses function as a major dispersal vector for non-native plants on riverbanks (Čuda et al. 2017), networks of railways and roads promote the distribution of neophytes in terrestrial environments (Brandes & Oppermann 1995, von der Lippe & Kowarik 2007).

Along roadsides, a variety of abiotic stress factors can lead to the development of habitats with a limited suitability for the native flora. Within the road-effect zone, microclimatic changes, an increased level of pollutants, particularly de-icing salt, or maintenance works are likely to impair the competitive strength of indigenous plants. Therefore, verges of busy roads (median and marginal strips) have a high probability of being invaded by alien plant species that are tolerant to traffic-related disturbances (Brandes 2009a).

In a human-mediated dispersal process diaspores are transported across countries on wheels and other parts of motorized vehicles. According to von der Lippe & Kowarik (2007) the share of neophyte seeds dispersed over long distances by traffic is significantly higher than that of native species. In addition to its function as dispersal corridor, roadsides have a high value for the development of species richness. Because of the interconnectedness of various small-scale biotope features, urban and other anthropogenic spaces often develop high levels of biodiversity (Brandes 2016).

Despite its potential as research area for plant dispersal, particularly the distribution movements of non-native species, few systematic surveys of the Luxembourgish roadside flora have been published so far. Most observations of non-native plants appearing next to roads have been made by coincidence. The objective of the study described here is to provide a representative survey of

the roadside flora of Luxembourg. As most of the sample plots (vegetation relevés) are roadsides exposed to a regular use of deicing salt during the winter season, one thematic priority of the study is to document the occurrence of halophytes. Another purpose of this research is to scan for the possible occurrence of neophytes that have been found in the neighbouring countries (Belgium, France, Germany) but remain undocumented within the Grand Duchy – e.g. *Hordeum jubatum* (Hand et al. 2016).

2. Material and Methods

The study is based on vegetation relevés gathered in plots on the verges and median strips of controlled-access motorways (Fr.: autoroute, A), national roads (Fr.: route nationale, N), B roads (Fr.: chemin repris, CR). Other types of roads, e.g. dirt roads, have not been investigated. We collected our data in relevés listing each species cover-abundance values according to the Braun-Blanquet rating scale (Braun-Blanquet 1964) as adapted by Reichelt & Wilmanns (1973).



Fig. 1. Map of the research area showing sampling sites.

For a representative assessment of the current status of the roadside flora, the plots were chosen to be evenly distributed throughout the country and to cover different types of roads (Fig. 1). While roadsides and median strips of motorways have only been accessed during roadblocks (for maintenance and construction works) because of obvious safety reasons, national and B roads were surveyed during times of regular road traffic.

A total of 52 sampling plots along 40 different road sections were investigated in 2017 and 2018: 16 plots were sampled along motorways (one site at A6 and A13, two sites at A1; between four and five plots per site) and 36 plots along national and B roads (CR145, CR149, N2, N4, N5, N6, N7, N10, N11, N12, N13, N14, N15, N22, N23, N27, N31; between one and six sites per road, one plot per site). The sampling sites next to motorways vary from a certain extent from those next to other roads. On motorway sections, the vegetation was surveyed along the median and marginal strips, on other road types only along the marginal strips (verges). For examples of investigated median strips, see Fig. 2-4, sampling sites on marginal strips can be seen in Fig. 5-7. As salt-tolerant neophytes / halophytes are most likely to be found



Fig. 2. Sparse vegetation on the Jersey barrier on median stripes of the A6 (Croix de Gasperich). Photo: 01.09.2018, T. Frankenberg.



Fig. 3. Median stripe vegetation along the A1 (Kirchberg, near the slip road from the A7). Photo: 07.07.2018, K. Mildenberger



Fig. 4. Raised bed with *Rosa rugosa* in the median stripe along the A13 (Mondorf-les-Bains). Photo: 18.07.2018, T. Frankenberg.

within the range of only a few centimeters from the asphalt surface, the spatial design of the plots ensures that relevant species data will be included. Hence, the sampling plots measured between 0.1 to 0.5 m in width and respectively between 20-200 m in length.

The nomenclature of the vascular plant species follows Lambinon & Verloove (2015).

In order to provide a clearer presentation, we aggregated our relevés in a synoptic table (Table 1) presenting the constancy of the species in habitats along both road types, motorways and national / B roads. We used the standard Braun-Blanquet constancy classes (Dierschke 1994).

3. Results

205 vascular plant species were recorded, amongst which were 22 woody species, 32 grass and grass-like plants and 151 herbaceous plants (Table 1). Within the latter, we list species from the Goosefoot-family (Chenopodiaceae) separately, as several of these are halotolerant.

Elymus repens and *Senecio inaequidens* were the most frequent species along motorways

Table 1. Compilation of vegetation surveys on motorways and national / B roads in 2017 and 2018. Bold species names: halophytes with strong salt tolerance (S ≥ 4).

Plants marked in light grey occur only in one of the two categories, plants in dark grey have a difference of at least 3 constancy classes between the two categories, i.e. a species in one category could be found significantly more often than in the other. S = Ellenberg's salinity indicator values (Ellenberg et al. 2001): 0 = no salinity; 1 = saline, mostly occurring on low-salt to salt-free soils, occasionally on slightly saline soils (0-0.1% Cl^-); 2 = oligohaline, more often on very low chloride soils (0.05-0.3% Cl^-); 3 = mesohaline, mostly on low chloride soils (0.3-0.5% Cl^-); 4 = mesohaline, mostly on soils with low to moderate chloride (0.5-0.7% Cl^-); 5 = mesohaline, mostly on soils with moderate chloride content (0.7-0.9% Cl^-); 6 = meso- / polyhaline, mostly on soils with moderate to high chloride content (0.9-1.2% Cl^-); 7 = polyhaline, on high chloride soils (1.2-1.6% Cl^-); 8 = euhaline, on very high chloride soils (1.6-2.3% Cl^-); 9 = euhaline to hyperhaline, on soils with very high salinity (> 2.3% Cl^-) in dry seasons; BR: X = Halotolerant species (Brandes 2009a, 2009b). Constancy classes according to Braun-Blanquet (1964): r = 0 – 5 %, + = >5 – 11 %, I = >10 – 20 %, II = >20 – 40 %, III = >40 – 60 %, IV = >60 – 80 %, V = >80 – 100 %.

Further species occurring with low constancy:

Motorways - Constancy +: *Aethusa cynapium, Allium vineale, Epilobium lanceolatum, Eupatorium cannabinum, Euphorbia exigua, Euphorbia peplus, Fagopyrum esculentum, Geranium dissectum, Inula conyzae, Linaria repens, Medicago ×varia, Mycelis muralis, Papaver rhoeas, Scrophularia nodosa, Securigera varia, Sedum acre, Senecio erucifolius, Solanum dulcamara, Solidago virgaurea, Verbascum thapsus* and *Vicia tenuifolia*. Woody species (mostly spontanous): *Acer pseudoplatanus, Betula pendula, Cornus* sp., *Euonymus europaeus, Ligustrum vulgare, Prunus avium, Quercus robur, Robinia pseudoacacia* and *Ulmus minor*.

National roads and B roads - Constancy +: *Aegopodium podagraria, Agrimonia eupatoria, Alliaria petiolata, Arctium tomentosum, Centaurea jacea* subsp. *nigra, Chaenorrhinum minus, Chelidonium majus, Equisetum arvense, Erigeron annuus, Euphorbia cyparissias, Fumaria officinalis, Galeopsis tetrahit, Geum urbanum, Knautia arvensis, Leucanthemum vulgare , Lysimachia nummularia, Medicago arabica, Medicago falcata, Melilotus officinalis, Myosotis arvensis, Ononis spinosa, Origanum vulgare, Oxalis corniculata, Phacelia tanacetifolia, Pimpinella saxifraga, Ranunculus acris, Reseda lutea, Sanguisorba minor, Sisymbrium officinale, Symphytum officinale, Torilis japonica, Trifolium dubium, Trifolium medium* and *Vicia hirsuta*.

All road types - Constancy r*: Holcus lanatus, Hordeum murinum* and *Panicum miliaceum*.

			Constancy			
S	BR	Columns / Categories	Motorways	National and B roads	Overall abs.	Overall in %
		Number of relevés	16	36	52	52
		Range vegetation cover (%)	5-95	25-95		
		Average vegetation cover (%)	75	85		
		Range number of species	6-51	20-47		
		Average number of species	24	33		
		Grasses and grass-like plants				
0		*Arrhenatherum elatius*	III	V	38	73
0		*Dactylis glomerata*	III	IV	32	62
7	**X**	***Puccinellia distans***	**III**	**III**	**24**	**46**
0		*Festuca rubra*	III	II	21	40
1		*Poa trivialis*	I	III	17	33
0		*Setaria viridis*	I	II	11	21
0		*Eragrostis minor*	I	II	10	19
1		*Bromus hordeaceus*	+	II	10	19
0		*Agrostis capillaris*	+	I	8	15
0	X	*Elymus repens*	**V**	I	17	33
2		*Festuca arundinacea*	**II**		5	10

0		*Calamagrostis epigejos*	I		3	6
0		*Carex muricata* subsp. *muricata*	I		3	6
0		*Bromus arvensis*	I		2	4
0		*Bromus sterilis*	I		2	4
0		*Agrostis stolonifera*	+		1	2
0		*Alopecurus myosuroides*	+		1	2
		Avena sativa	+		1	2
		Festuca ovina	+		1	2
		Hordeum vulgare	+		1	2
0		*Poa compressa*	+		1	2
		Triticum aestivum	+		1	2
0		*Poa pratensis*	I	**V**	36	69
1		*Poa annua*	+	**V**	37	71
0		*Lolium perenne*	+	**V**	32	62
0		*Trisetum flavescens*		**IV**	23	44
0		*Alopecurus pratensis*		I	7	13
0	X	*Echinochloa crusgalli*		I	6	12
0		*Festuca pratensis*		I	5	10
		Herbs				
		Plants of the Goosefoot family				
0		*Chenopodium album*	III	V	41	79
0	X	*Atriplex prostrata*	I	+	4	8
	X	*Atriplex micrantha*	**III**		9	17
0		*Atriplex patula*		**IV**	24	46
0	X	*Chenopodium polyspermum*		I	4	8
		Other herbaceous plants				
1		*Polygonum aviculare*	IV	V	48	92
0		*Plantago major*	III	V	43	83
0	X	*Daucus carota*	III	III	28	54
0		*Artemisia vulgaris*	III	IV	36	69
0	X	*Matricaria maritima* subsp. *inodora*	III	IV	33	63
1		*Sonchus asper*	III	II	17	33
0	X	*Lepidium ruderale*	II	II	14	27
0		*Cirsium vulgare*	II	I	12	23
1		*Sonchus arvensis*	II	I	11	21
0		*Fallopia convolvulus*	II	+	9	17
1		*Achillea millefolium*	II	IV	33	63
0		*Lactuca serriola*	II	III	20	38
0		*Spergularia rubra*	II	II	15	29
		Brassica napus	II	I	11	21
0		*Pastinaca sativa*	II	r	6	12
1	X	*Cirsium arvense*	II	II	13	25
0		*Picris hieracioides*	II	I	11	21
0		*Potentilla reptans*	I	III	21	40
0		*Senecio jacobaea*	I	III	20	38
0		*Senecio vulgaris*	I	II	15	29
1		*Potentilla anserina*	I	II	14	27
0		*Galium mollugo* subsp. *erectum*	I	II	13	25
0		*Tanacetum vulgare*	I	II	11	21
0		*Persicaria maculosa*	+	II	10	19
0		*Linaria vulgaris*	I	II	11	21
0	X	*Urtica dioica*	I	II	11	21

1		*Cerastium fontanum* subsp. *vulgare* var. *holosteoides*	+	II	9	17
0		*Lapsana communis*	I	I	9	17
0		*Lotus corniculatus*	+	I	8	15
0		*Anagallis arvensis*	I	I	9	17
0		*Convolvulus arvensis*	I	I	8	15
0		*Malva moschata*	+	I	7	13
0		*Silene latifolia* subsp. *alba*	I	I	8	15
0		*Euphorbia helioscopia*	I	I	7	13
0		*Heracleum sphondylium*	I	I	7	13
0		*Lamium purpureum*	I	I	7	13
0		*Calystegia sepium*	+	I	6	12
0		*Echium vulgare*	+	I	6	12
0		*Stellaria media*	+	I	6	12
0		*Trifolium hybridum*	+	I	6	12
0		*Tragopogon pratensis*	I	I	6	12
0		*Bellis perennis*	+	I	5	10
0	X	*Melilotus albus*	+	I	5	10
0		*Rumex obtusifolius*	+	I	5	10
0		*Senecio viscosus*	I	+	6	12
1		*Hypochaeris radicata*	I	+	5	10
0		*Centaurea jacea*	+	+	4	8
0		*Geranium pyrenaicum*	+	+	4	8
0		*Hypericum perforatum*	+	+	4	8
0		*Portulaca oleracea*	+	+	4	8
0		*Prunella vulgaris*	+	+	4	8
0		*Clinopodium vulgare*	I	+	4	8
0		*Veronica arvensis*	+	+	3	6
0		*Conyza canadensis*	I	r	3	6
0		*Galinsoga parviflora*	I	r	3	6
0		*Erodium cicutarium*	+	r	2	4
4		***Lepidium latifolium***	+	r	2	4
0		***Senecio inaequidens***	**V**	r	14	27
0		*Rumex crispus*	**IV**	r	11	21
0		*Erophila verna*	**II**		4	8
1		*Epilobium hirsutum*	**II**		4	8
0		*Galium aparine*	**II**		4	8
0		*Vicia sativa* subsp. *nigra*	I		3	6
0		*Rumex acetosa*	I		3	6
0		*Dipsacus fullonum*	I		2	4
0		*Galinsoga quadriradiata*	I		2	4
0		*Geranium molle*	I		2	4
0		*Geranium pratense*	I		2	4
0		*Mercurialis annua*	I		2	4
4	X	***Plantago coronopus***	I		2	4
0		*Senecio ovatus*	I		2	4
1		*Taraxacum* sp.	II	**V**	38	73
0		*Plantago lanceolata*	II	**V**	36	69
0		*Medicago lupulina*	I	**V**	34	65
0		*Sonchus oleraceus*	+	**V**	32	62
0		*Trifolium pratense*	+	**IV**	24	46
1		*Trifolium repens*		**V**	31	60
0		*Leontodon autumnalis*		**IV**	28	54

0		*Matricaria discoidea*		**III**	20	38
0		*Geranium pusillum*		**III**	15	29
0	X	*Capsella bursa-pastoris*		**II**	14	27
0		*Medicago sativa*		**II**	10	19
0		*Crepis capillaris*		**II**	9	17
1		*Vicia cracca*		**II**	9	17
1		*Ranunculus repens*		**II**	8	15
0		*Matricaria recutita*		I	7	13
1		*Senecio vernalis*		I	6	12
0		*Veronica chamaedrys*		I	6	12
0		*Geranium robertianum*		I	4	8
0		*Glechoma hederacea*		I	4	8
0		*Veronica persica*		I	4	8
		Woody species				
		Rubus sp.	I	+	4	8
0		*Rubus idaeus*	+	r	2	4
0		*Fraxinus excelsior*	II		6	12
0		*Rosa canina*	II		6	12
0		*Acer campestre*	II		4	8
0		*Crataegus* sp.	II		4	8
0		*Clematis vitalba*	II		4	8
		Rosa rugosa	I		3	6
0		*Prunus spinosa*	I		3	6
0		*Cornus sanguinea*	I		2	4
0		*Cotoneaster* sp.	I		2	4
		Ligustrum sp.	I		2	4
		Symphoricarpos albus	I		2	4



Fig. 5. Sparse vegetation along roadside of the N14 near a storage area (Medernach). Photo: 03.08. 2017, S. Ehl.

(Fig. 8a), as they were present in almost 80% of the relevés, while *Polygonum aviculare* and *Poa annua* were found on all roadsides of national and B roads (Fig. 8b).

Only a small number of species with a higher constancy could be found along the investigated motorways (Fig. 8a). In our relevés recorded along motorways so far, only 14 species were found with a constancy of more than 40 % (constancy classes III to V). In contrast, a broader basic spectrum of 28 plant species in the corresponding con-

Table 2. Salt tolerant vascular plant species present in Luxembourg, Belgium and/or Germany, but not observed in this study. L = occurrence in Luxembourg. B = occurence in Arlon, Belgium (Remacle 2015). D1 = occurrence near Trier, Germany; D2 = halotolerant species, both according to Hand et al. 2016; ? = halotolerance uncertain. S = Ellenberg's salinity indicator values, cf. Table 1 (Ellenberg et al. 2001), n/s = not specified. BR = halotolerant species sensu Brandes (2009a, 2009b).

Vascular plant species	L	B	D1	D2	S	BR
Ambrosia artemisiifolia	X		X	X	0	X
Artemisia tournefortiana					n/s	X
Atriplex oblongifolia	X		X		1	X
Atriplex sagittata (syn. *A. nitens*)	X		X	?	0	X
Atriplex tatarica					0	X
Chenopodium glaucum	X		X	?	3	
Cochlearia danica	X	X	X	X	4	X
Diplotaxis tenuifolia	X		X	?	0	X
Dittrichia graveolens	X	X	X	X	n/s	X
Hordeum jubatum	X		X	X	2	X
Poa subcaerulea	X		X	?	n/s	X
Pulicaria dysenterica	X	X	X		0	X
Spergularia marina (syn. *S. salina*)	X	X	X	X	9	X

stancy classes was documented along the other road types (Fig. 8b).

In comparison to other road types, motorways showed higher population rates of halophytes. This applies especially to the invasive alien halophyte species narrow-leaved ragwort (*Senecio inaequidens*, Fig. 9) and twoscale saltbush (*Atriplex micrantha*, Fig. 10), which were recorded with a higher presence on the median strip of motorways. However, both could not or hardly ever be found along national and B roads. Apart from rare exceptions, their occurrence seems to be confined to the heavily polluted roadsides of motorways. At present, the national and B roads are still dominated by dense covers of ruderal herbs. An exception is the weeping alkali grass (*Puccinellia distans*, Fig. 11), which was observed with a similar constancy on motorways and national / B roads (Table 1). This may be a consequence of *Puccinellia distans* being deliberately sown to



Fig. 6. Vegetation under a guardrail along the N7 (Hoscheid-Dickt). Photo: 09.08.2017, S. Ehl.



Fig. 7. Roadside vegetation at the motorway slip road from the A6 to the A3 (Croix de Gasperich). Photo: 01.09.2018, T. Frankenberg.

cover bare soil on salt-exposed road shoulders, a former common practice in Germany (Meierott et al. 2008, cited in Brandes 2009a). In contrast to *Senecio inaequidens* and *Atriplex micrantha,* which appear to be confined to the motorway network in the southern areas of the country (Fig. 12 and 13), *Puccinellia distans* was detected all over Luxembourg (Fig. 14).

Grass species with a high presence on verges of national and B roads (i.e. occurrence on > 50 % of sampling sites) are annual meadow grass (*Poa annua*), common meadow-grass (*Poa pratensis*), perennial ryegrass (*Lolium*

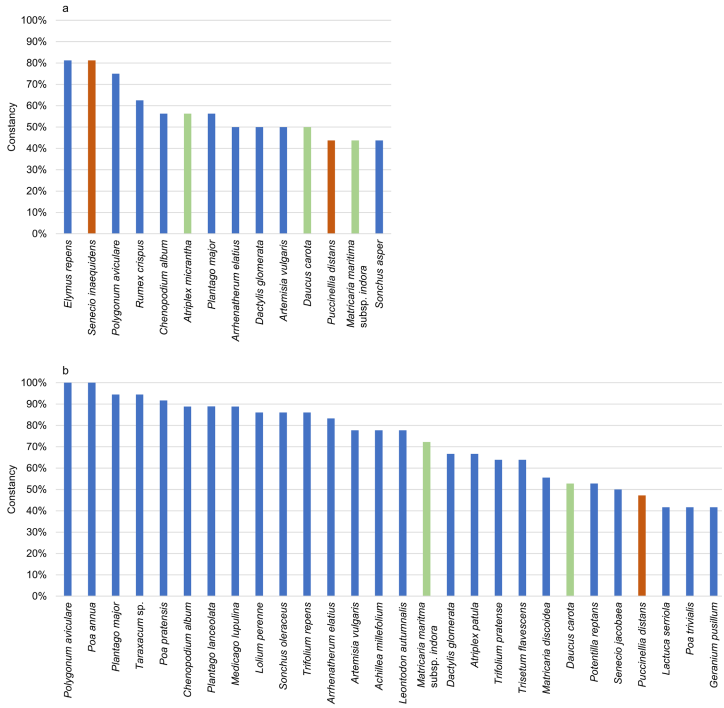


Fig. 8. Relative constancy of the most frequently observed plant species (constancy >40%) on (a) motorways and (b) national / B roads in Luxembourg. Orange: plants with a high salt tolerance; green: plants with a moderate salt tolerance; blue: plants lacking salt tolerance sensu Ellenberg 2001 (indicator value 0).



Fig. 9. *Senecio inaequidens* at the median stripe along the A1 (Potaschbierg). Photo: 04.08.2017, T. Frankenberg.



Fig. 10. Continuous plant stock of *Atriplex micrantha* at the median stripe of the A1 (Potaschbierg). Photo: 04.08.2017, T. Frankenberg.



Fig. 11. *Puccinellia distans* at a small unsealed stripe along the A13 (Mondorf-les-Bains). Photo: 16.07.2018, T. Frankenberg.

perenne), false oat-grass (*Arrhenatherum elatius*), cock's-foot (*Dactylis glomerata*) and yellow oatgrass (*Trisetum flavescens*). Herbaceous plants with a high presence along national and B roads are common knotgrass (*Polygonum aviculare*), broadleaf plantain (*Plantago major*), common dandelion (*Taraxacum* sp.), white goosefoot (*Chenopodium album*), ribwort plantain (*Plantago lanceolata*), black medick (*Medicago lupulina*), common sowthistle (*Sonchus oleraceus*), white and red clover (*Trifolium repens*, *T. pratense*), common mugwort (*Artemisia vulgaris*), common yarrow (*Achillea millefolium*), spear saltbush (*Atriplex patula*), autumn hawkbit (*Leontodon autumnalis*),

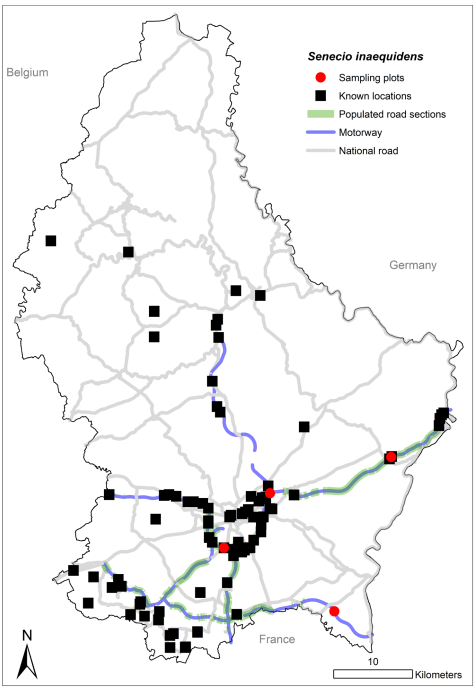


Fig. 12. Observations of *Senecio inaequidens* in Luxembourg. Known locations in the Recorder-LUX database (MNHNL 2000-); populated road sections from Frankenberg & Gräser (2014).

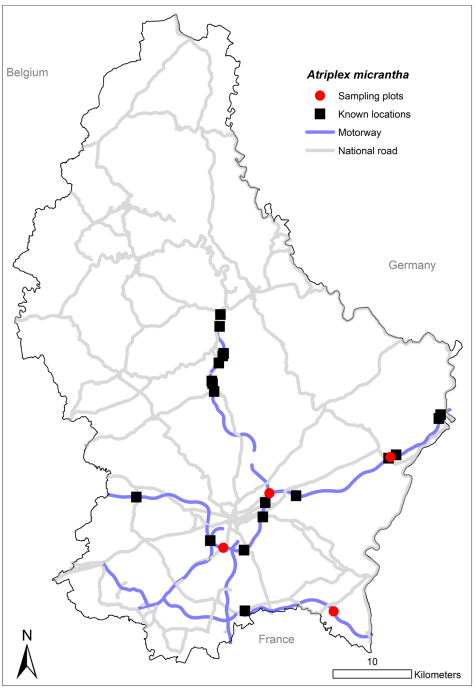


Fig. 13. Observations of *Atriplex micrantha* in Luxembourg. Known locations in the Recorder-LUX database (MNHNL 2000-).

sea mayweed and disc mayweed (*Matricaria maritima* subsp. *inodora*, *M. discoidea*).

According to these records, the majority of national and B roads in Luxembourg is flanked by tall oatgrass meadows with a high percentage of ruderal herbs. Relatively few halotolerant species (sensu Brandes 2009a and Ellenberg et al. 2001) have been detected. Among the recorded halophytes were weeping alkali grass (*Puccinellia distans*) – which occurred on 46 % of the sampling plots (Table 1) –, roadside pepperwort (*Lepidium ruderale*) and cockspur (*Echinochloa crus-galli*). Particularly noteworthy is the occurrence of the broadleaved pepperwort (*Lepidium latifolium*) next to the national road (N10) in the commune of Ehnen in 2017 (Fig. 15) and at the motorway (A13) near Mondorf-les-Bains in 2018. The species is listed as vulnerable in the Red List of the Vascular Plants of Luxembourg, which also serves as a national checklist (Colling 2005). In the Recorder-Lux database of the National Museum of Natural History (MNHNL 2000-), the most recent observation was made in 2015 - when the broadleaved pepperwort was observed along the N7 (B7) (Krippel & Colling 2016) -, all other entries date back to 1999 and before.

4. Discussion

There were notable differences in the species composition along motorways and national / B roads. Some halophytes like narrow-leaved ragwort (*Senecio inaequidens*) - first recorded in Luxembourg in 1988 (Reichling 1990) - and twoscale saltbush (*Atriplex micrantha*) - first observed in Luxembourg in 2007 (Weicherding 2007) but disregarded until 2015 (Krippel & Colling 2016) - are mainly restricted to the heavily polluted and salt-affected verges and median strips of motorways, which are of limited suitability for many native plant species. *Senecio inaequidens* though begins to spread

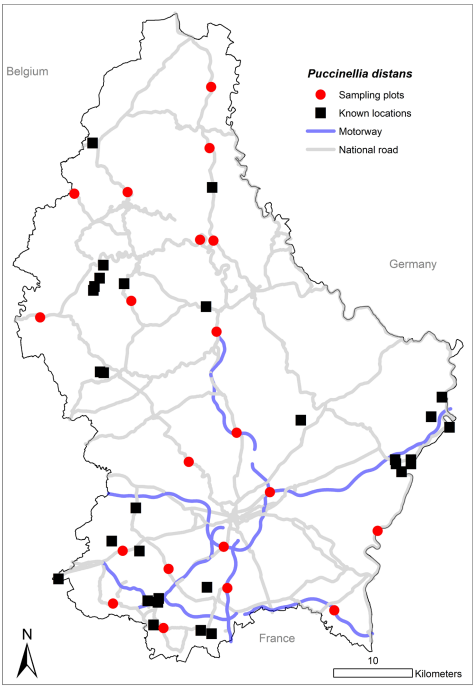


Fig. 14. Observations of *Puccinellia distans* in Luxembourg. Known locations in the Recorder-LUX database (MNHNL 2000-).

more frequently apart from motorways (Krippel & Colling 2016, Krippel et al. 2018) - occasional spread was already previously known (Krippel & Colling 2010). It can be found with increasing frequency at a distance from major roads e.g. during field surveys of agricultural land (Krippel at al. 2018). This thesis has been affirmed by former surveys (Frankenberg & Gräser 2014). Another invasive alien plant species that was only observed along motorways in our study was *Rosa rugosa*. For this plant - not listed in Ellenberg et al. (2001) - several studies confirm a certain halotolerance (Bruun 2005, Föller et al. 2012), which enables this species to grow along salt-treated motorways. Only weeping alkali grass (*Puccinellia distans*) has been found with a relative constancy on verges of national roads for decades (Steichen 1995).

Buck's-horn plantain (*Plantago coronopus*) is currently spreading along the road network of Central Europe (Gerstberger 2001). In Germany, the species has been recorded twice recently, both sites being located in Rhineland-Palatinate south of Mainz (Hanselmann 2017). The first occurrence of the taxon in Luxembourg (Kirchberg) was recorded by Thierry Helminger and dates back to 2014 (Krippel et al. 2018). In the survey for the present study, the presence of *Plantago coronopus* was documented for the first time along national roads. A relatively high number of individuals was found on the verges of two motorways: A1 (2017, Potaschbierg) and A6 (2018, Croix de Gasperich) (Fig.16). Further findings are located near Wasserbillig (2018, Park and Ride parking "Mesenich", Fig. 17) and Diekirch (2018, parking rue de l'industrie). Both observations were made by coincidence during field work for other studies. Presumably dormant in the soil seed bank, the halophyte was able to grow with a high abundance on raw soil habitats that featured limited suitability for non-halophyte plants. According to Hand et al. (2016), *Plantago coronopus* is about to find its niche along motorways and other roads exposed to de-icing salt. The taxon seems to have established in Luxembourg and often occurs with relatively high cover-abundances.



Fig. 15. *Lepidium latifolium* on a roadside of the N10 near Ehnen. Photo: 04.08.2017, K. Mildenberger.



Fig. 16. Larger stock of *Plantago coronopus* along the slip road of the A6 to the A3 (Croix de Gasperich). Photo: 01.09.2018, T. Frankenberg.

Another typical roadside halophyte, the Danish scurvygrass (*Cochlearia danica*), was not present in our relevés, even though we were expecting to find it, as it was recently recorded in Trier in Germany (Hand et al. 2016), Arlon in Belgium (Remacle 2015) as well as in Luxembourg (2011 in Kirchberg, 2016 in Capellen, Krippel et al. 2018). The general spread of *Cochlearia danica* has been following the pattern of roads leading from the coast to the hinterland (Brandes 2009a).



Fig. 17. Random observation of *Plantago coronopus* along the roadside at the Park & Ride parking "Mesenich" near Wasserbillig. Photo: 27.09.2018, S. Ehl.

Expected plant species that have not been recorded recently in Luxembourg but are present in neighbouring areas in Belgium and Germany are *Atriplex oblongifolia*, *Atriplex sagittata* (Syn. *Atriplex nitens*), *Dittrichia graveolens* and *Poa humilis* (Table 2) (Remacle 2015, Hand et al. 2016). Another example is the salt tolerant species *Spergularia marina* (Cheeseman et al. 1985), which is spreading from the Hessian-Thuringian potash mining area (Brandes 2009a) and has apparently been recorded at roadsides near Luxembourg (Schnedler & Bönsel 1987, Remacle 2015, Hanselmann 2017). None of the taxa mentioned above were found on the sampled plots though.

On the other hand, several plant species present in Luxembourg were not found within the scope of the present study, e.g. *Ambrosia artemisiifolia*, *Diplotaxis tenuifolia*, *Hordeum jubatum* and *Pulicaria dysenterica*.

In addition to the roadside relevés, we searched halophytes in the surroundings of a road salt deposit (Potaschbierg). Cockspur (*Echinochloa crus-galli*), green foxtail (*Setaria viridis*) and small lovegrass (*Eragrostis minor*) have been detected on the front yard lawn of the facility.

5. Conclusions

As the survey has only covered a proportionally small share of the road network of Luxembourg and other sites of interest (ports, airports, salt deposits) the Luxembourgish roadside flora could not be systematically examined yet. Although further observations of single plant species relevant to our study are available (e.g. the Recorder-Lux database of the National Museum of Natural History or the "Notes floristiques" in the Bulletin of the "Société des naturalistes luxembourgeois"), the recorded data remain mostly fragmentary (Fig. 11-13). More investigation is needed for a comprehensive assessment of the flora and vegetation of roadside habitats and to provide new insights into the dispersal of neophytes / halophytes in Luxembourg.

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Literature

Brandes, D. & F. Oppermann, 1995. Straßen, Kanäle und Bahnanlagen als lineare Strukturen in der Landschaft sowie deren Bedeutung für die Vegetation. *Ber. Reinh.-Tuexen Ges.* 7: 89-110.

Brandes, D., 2009a. Autobahnen als Wuchsorte und Ausbreitungswege von Ruderal- und Adventivpflanzen. *Braunschweiger Naturkundliche Schriften* 8(2): 373-394.

Brandes, D., 2009b. Virtuelle Exkursion: Autobahnen als neuartige Ruderalstandorte. Digital presentation. URL: https://www.zobodat.at/pdf/Brandes-Dietmar_93_2009_0001-0053.pdf [Accessed 16.07.2019].

Brandes, D., 2016. Die spontane Flora der Straßen von Braunschweig - Hohe Artenzahl und unerwartete Florendynamik im lokalen Maßstab; The spontaneous flora of urban streets of Braunschweig - High phytodiversity and unexpected dynamics of flora in a local scale. *Braunschweiger Naturkundliche Schriften* 14: 57-89.

Braun-Blanquet, J., 1964. Pflanzensoziologie - Grundzüge der Vegetationskunde. Springer-Verlag, Wien, 866 pp.

Bruun, H. H., 2005. *Rosa rugosa* Thunb. ex Murray. *J Ecology* 93: 441-470.

Colling, G., 2005. Red List of the Vascular Plants of Luxembourg. *Ferrantia* 42: 77 pp.

Cheeseman, J. M., P. Bloebaum, C. Enkoji & L. K. Wickens, 1985. Salinity tolerance in *Spergularia marina*. *Canadian Journal of Botany* 63(10): 1762-1768.

Čuda, J., Z. Rumlerová, J. Bruna, H. Skálová & P. Pysek, 2017. Floods affect the abundance of invasive *Impatiens glandulifera* and its spread from river corridors. *Diversity and Distributions* 23: 342-354.

Dierschke, H., 1994. Pflanzensoziologie - Grundlagen und Methoden. Verlag Eugen Ulmer, Stuttgart, 683 pp.

Ellenberg, H., H. E. Weber, R. DÜll, V. Wirth & W. Werner, 2001. Zeigerwerte von Pflanzen in Mitteleuropa – *Scripta Geobotanica* XVIII. Goltze-Verlag, Göttingen, 262 pp.

Föller, J., A. Kellner & V. Wissemann, 2012. Die Schöne und das Biest – Differentielle Salztoleranz als eine mögliche Ursache evolutionären Erfolgs der sympatrischen *Rosa rugosa* Thunb. und *Rosa mollis* Sm. *Kiel. Not. Pflanzenkd.* 38: 68-77.

Frankenberg, T. & P. Gräser, 2014. Vorkommen des Schmalblättrigen Greiskrauts (*Senecio inaequidens* DC.) in Luxemburg, Erfassung der aktuellen Verbreitung der Art entlang der Autobahnen und Autobahnzubringer. – Studie erstellt im Auftrag des Naturhistorischen Museums Luxembourg. https://neobiota.lu/wp/wp-content/uploads/2011/12/2014_BIOINV_INV_Senecio_inaequidens.pdf [Accessed 19.07.2019].

Gerstberger, P., 2001. *Plantago coronopus* subsp. *commutata* als Straßenrandhalophyt eingebürgert in Mitteleuropa. *Tuexenia* 21: 249-256.

Hand, R., H. Reichert, W. Bujnoch, U. Kottke & S. Caspari, 2016. Flora der Region Trier (1. & 2. Band). Verlag Michael Weyand GmbH, Trier, 1637 pp.

Hanselmann, D., 2017. Neue Zierde für den Straßensaum – Erstnachweis von *Limonium gmelini* (Willd.) Kuntze in Deutschland (und weitere Anmerkungen zu aktuellen Entwicklungen der Straßenbegleitflora in Rheinland-Pfalz). *Mainzer naturwiss. Archiv* 54: 155-167.

Krippel, Y. & G. Colling, 2010. Notes floristiques. Observations faites au Luxembourg (2008-2009). Bull. Soc. Nat. luxemb. 111 : 11-32.

Krippel, Y. & G. Colling, 2016. Notes floristiques. Observations faites au Luxembourg (2014-2015). *Bull. Soc. Nat. luxemb*. 118: 27-51.

Krippel, Y., T. Helminger & G. Colling, 2018. Notes floristiques. Observations faites au Luxembourg (2016-2017). *Bull. Soc. Nat. luxemb*. 120: 57-76.

Lambinon, J. & F. Verloove (collab. L. Delvosalle, B. Toussaint, D. Geerinck, I. Hoste, F. Van Rossum, B. Cornier, R. Schumacker, A. Vanderpoorten & H. Vannerom), 2015. Nouvelle Flore de la Belgique, du Grand-Duché de Luxembourg, du Nord de la France et des Régions voisines (Ptéridophytes et Spermatophytes), 6e éd., 2e tirage, avec corrections. Jardin botanique, Meise, CXXXIX + 1195 pp.

Meierott, L., O. Elsner, R. Otto, H. Scheller & C. Weingart, 2008. Flora der Haßberge und des Grabfelds - 2. Bde. IHW-Verlag, Eching, 1448 pp.

MNHNL, 2000-. Recorder-Lux, database on the natural heritage of the Grand Duchy of Luxembourg. Musée national d'histoire naturelle, Luxembourg. URL: https://map.mnhn.lu [Accessed 16.07.2019].

Petrischak, H., 2014.Neophyten in Mitteleuropa. *Biologie in unserer Zeit* 44(6): 410-419.

Reichelt, G. & O. Willmanns, 1973. Vegetationsgeographie - Das Geographische Seminar: Praktische Arbeitsweisen. Westermann Verlag, Braunschweig, 212 pp.

Reichling, L., 1990. Observations floristiques au Luxembourg 1980-1989. *Bull. Soc. Nat. luxemb.* 90: 55-70.

Remacle, A., 2015. L'intérêt botanique des espaces verts autoroutiers : le cas de l'autoroute E411 près d'Arlon (province de Luxembourg, Belgique). *Dumortiera* 107: 3-21.

Schnedler, W. & D. Bönsel, 1987. Über einige halophile Pflanzenarten an hessischen Straßen und Autobahnen – insbesondere über die Salz-Schuppenmiere (*Spergularia salina* J. et K. Presl). *Hessische Floristische Briefe*. 36 (3): 34-45.

Steichen, J., 1995. Zur Ausbreitung von *Puccinellia distans* (L.) Parl. an Straßenrändern in Luxemburg. *Bull. Soc. Nat. luxemb*. 96: 3-8.

Von der Lippe, M. & I. Kowarik, 2007. Long-distance dispersal of plants by vehicles as a driver of plant invasions. *Conservation Biology* 21(4): 986-996.

Weicherding, F.-J., 2007. Zur Verbreitung und Soziologie der adventiven Melden *Atriplex micrantha* Ledeb. (Verschiedensamige Melde), *Atriplex sagittata* Borkh. (Glanz-Melde) und *Atriplex oblongifolia* Waldst. et Kit. (Langblättrige Melde) (Chenopodiaceae) im Saarland und in angrenzenden Gebieten. *Abh. Delattinia* 33: 117-139.