Occurrence of invasive neophytes in managed biotopes in the former open-cast mining areas of Luxembourg

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Abstract. This paper presents the results of an overview survey of the following invasive alien plant species carried out in managed biotopes across the former open-cast mining districts in the Luxembourgish Minette region: *Ailanthus altissima* (tree of heaven), *Buddleja davidii* (summer lilac), *Bunias orientalis* (Turkish wartycabbage), *Fallopia japonica* (Japanese knotweed), *Heracleum mantegazzianum* (giant hogweed), *Lupinus polyphyllus* (big-leaved lupine), *Mahonia aquifolium* (Oregon grape), *Pinus nigra* (black pine), *Prunus laurocerasus* (cherry laurel), *Rhus typhina* (staghorn sumac), *Robinia pseudoacacia* (black locust), *Senecio inaequidens* (narrow-leaved ragwort), *Solidago canadensis* (Canada goldenrod), *Solidago gigantea* (tall goldenrod) and *Syringa vulgaris* (common lilac). The results indicate that some of the surveyed species are widely spread across the former mining districts, whereas others were only sporadically recorded or not found at all. The recorded data provide a basis for further control efforts and suggestions for suitable eradication measures are given.

Keywords. Biological invasions, invasive alien species, neophytes, plant invasions, vascular plants, open-cast mining, semi-natural biotopes, Terres Rouges, Minette, Gutland, Luxembourg.

1. Introduction

With the end of open-cast ore mining in the Luxembourgish Minette region in the late 1970s, large excavation and backfill areas fell into disuse (Leytem & Muschang 2017). Since then, most of these abandoned surfaces were reclaimed by nature. In many places, nutrient-poor substrates and dry site conditions led to the development of small-scale mosaics of biotopes with high ecological value (e.g. scree, rocky slopes, dry grasslands). Besides natural succession and urban development, the spread of invasive alien plant species with the ability to grow under dry site conditions are a potential threat to these biotopes.

In order to gain insight into what extent the Luxembourgish post-mining areas are already populated by potentially problematic neophytes, we conducted a systematic survey in 2018 and 2019. During this survey, transect inspections were carried out on sites with high ecological value and occurrences of the following plant species were recorded: *Ailanthus altissima* (Mill.) (tree of heaven), *Buddleja davidii* Franch. (summer lilac), *Bunias orientalis* L. (Turkish wartycabbage), *Fallopia japonica* (Houtt.) (Japanese knotweed), *Heracleum mantegazzianum* Somm. & Lev. (giant hogweed), *Lupinus polyphyllus* Lindl. (big-leaved lupine), *Mahonia aquifolium* (Pursh) (Oregon grape), *Pinus nigra* Arnold (black pine), *Prunus laurocerasus* L. (cherry laurel), *Rhus typhina* L. (staghorn sumac), *Robinia pseudoacacia* L. (black locust), *Senecio inaequidens* DC. (narrow-leaved ragwort), *Solidago canadensis* L. (Canada goldenrod), *Solidago gigantea* Ait. (tall goldenrod) and *Syringa vulgaris* L. (common lilac).

These species can establish themselves on dry and rocky sites, in natural grasslands or at forest edges (Nehring et al. 2013) and therefore pose a potential risk to the biotopes present in the study area. Ries et al. (2013) rated six of these species as being of high ecological impact and thus assigned them to the national black list of invasive species (*Fallopia japonica*, *Heracleum mantegazzianum*, *Pinus nigra*, *Robinia pseudoacacia*, *Solidago canadensis* and *Solidago gigantea*). Three other species were assigned to the national watch list (medium ecological impact): *Mahonia aquifolium*, *Rhus typhina* and *Senecio inaequidens*.

The present article gives an overview of the study results. The nomenclature of the vascular plants follows Lambinon & Verloove (2015).

2. Material and methods

2.1. Study area

The study area is situated in the former open-cast mining area in southern Luxembourg (Minette region). It covers a total surface of 347 hectares and consists of 296 individual plots. Plot borders were adopted from the data set for biotope management of the national Administration for Nature and Forestry (ANF). The individual plots are situated in the former mining districts: Brucherbierg, Carrière Cloos, Dëmptgesgrond, Ellergronn, Giele Botter, Haard, Heedefeldchen, Hérenterbierg, Hesselbierg, Hiel-Eisekaul, Kallek, Kiemerchen, Kleesgrënnchen, Kolscheed, Lalléngerbierg, Lannebierg, Léiffrächen, Nossbierg, Perchesbierg, Quäschebierg, Ronnebierg, Scheierbierg, Um Suebel, Weimeschkëppchen, and Weissewee (Fig. 1). The size of the surveyed plots ranges from 144 square meters to 10 hectares.

Due to time constraints, some smaller open-cast mining districts could not be included in the survey. However, considering the total surface and number of the surveyed plots as well as their distribution across the former mining area, the study results provide a representative overview of the distribution of the surveyed species in ecologically sensitive areas of the Luxembourg post-mining landscapes.

2.2. Survey

In 2018, a preliminary study was launched in the former mining districts of Giele Botter and Kiemerchen. In this study, occurrences of the surveyed species were precisely recorded via handheld GPS units (Garmin GPSMap 64s) and reported as point data without connection to survey plots. The aim of the pilot study was to test the recording method and to estimate the effort required for a larger study.

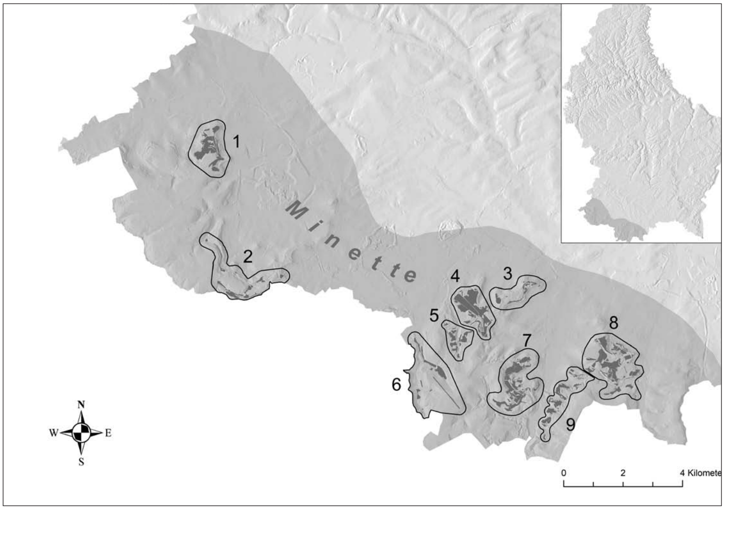

Fig. 1. Overview map of the Luxembourgish Minette region (light grey) with indication of survey plots (dark grey) and former mining districts (1: Giele Botter; 2: Kallek, Kiemerchen, Ronnebierg, Scheierbierg, Um Suebel; 3: Brucherbierg, Weimeschkëppchen, Weissewee; 4: Léiffrächen; 5: Heedefeldchen, Kleesgrënnchen; 6: Ellergronn, Hiel-Eisekaul; 7: Léiffrächen; 8: Haard, Carrière Cloos; 9: Dëmptgesgrond, Hérenterbierg, Hesselbierg, Kolscheed, Lannebierg, Perchesbierg, Quäschebierg).

In the 2019 follow-up study, the study area was extended to the above-mentioned areas (section 2.1). The first surveys of the follow-up study were carried out in the Lalléngerbierg district using the method tested in 2018 (collection of point data). However, since some of the surveyed plots contained large scale plantations of black pine trees, the measurement of individual plants with GPS proved to be too time-consuming, detailed and ineffective. In view of the broad aim of the study to provide a general overview, the survey method was thus changed to the recording of cover-abundance classes according to Braun-Blanquet (cf. Glavac 1996). Previously recorded point data were converted accordingly.

3. Results

Some of the considered species were frequently found on the surveyed plots; in some places in large numbers or with high coverages. These include *Pinus nigra* (black pine), *Robinia pseudoacacia* (black locust) and *Solidago canadensis* (Canada goldenrod). Moreover, *Cotoneaster horizontalis* (wall cotoneaster) was frequently recorded on the survey plots and is therefore discussed below, although this species was not considered in the original study design. On the other hand, *Fallopia japonica* (Japanese knotweed), *Senecio inaequidens* (narrow-leaved ragwort), *Rhus typhina* (staghorn sumac), *Prunus laurocerasus* (cherry laurel), *Buddleja davidii* (summer lilac), *Syringa vulgaris* (common lilac) and *Mahonia aquifolium* (Oregon grape) were found only sporadically and with low numbers of individuals.

The following species were not recorded at all in the present survey: *Ailanthus altissima* (tree of heaven), *Bunias orientalis* (Turkish wartycabbage), *Heracleum mantegazzianum* (giant hogweed), *Lupinus polyphyllus* (big-leaved lupine) and *Solidago gigantea* (tall goldenrod).

Individual results for the recorded species are described in the following subsections. On map figures, spatial distribution and cover-abundance of the different species were converted to a 1 × 1 km raster for display reasons. In terms of cover-abundance, the highest degree of coverage found in the respective 1 × 1 km square is delineated.

3.1. *Pinus nigra*

Among the studied species, *Pinus nigra* (black pine) was most frequently recorded with occurrences in 94 out of 296 plots (31.8 percent). The species is widely spread over the Minette region and occurs in nearly every larger mining district (Fig. 2). In the districts of Lalléngerbierg and Brucherbierg, cover-abundance rates of the species were particularly high (Braun-Blanquet scale 2 and 3).

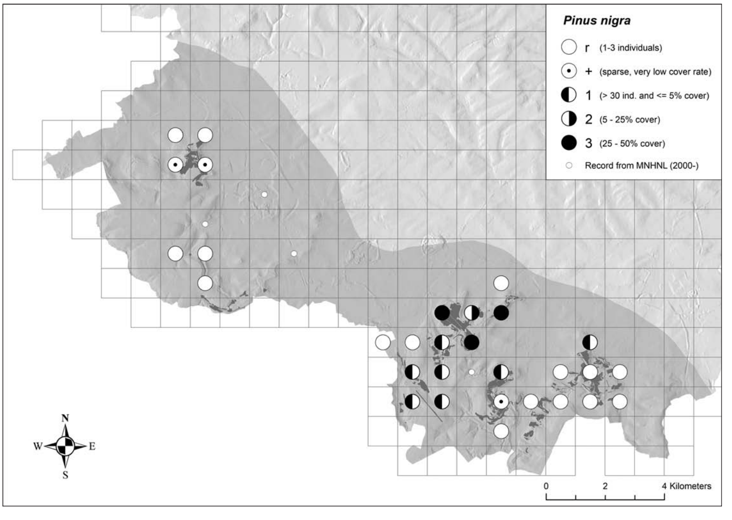

Fig. 2. Distribution and cover-abundances of *Pinus nigra* (black pine) across the study area.

3.2. *Robinia pseudoacacia*

Robinia pseudoacacia (black locust) was found second most frequently, in 59 out of 296 plots (19.9 percent). It is also widely spread over the former mining districts. Sporadically, the species reaches high cover-abundance rates in the districts of Kiemerchen, Hiel-Eisekaul, Kleesgrënnchen, Lalléngerbierg, Léiffrächen (Braun-Blanquet scale 2 and 3) and especially in the Haard area, where the species reaches coverage rates of more than five percent in six different plots (Fig. 3).

3.3. *Solidago canadensis*

Solidago canadensis (Canada goldenrod) was found in 30 out of 296 plots (10.1 percent). The species forms larger populations, especially in the districts of Hiel-Eisekaul and Carrière Cloos, as well as on two individual plots in the districts of Scheierbierg and Lalléngerbierg. On the other surveyed plots, the species currently only reaches coverage rates of less than five percent (Fig. 4).

3.4. *Cotoneaster horizontalis*

Though not part of the original list of surveyed species, *Cotoneaster horizontalis* (wall

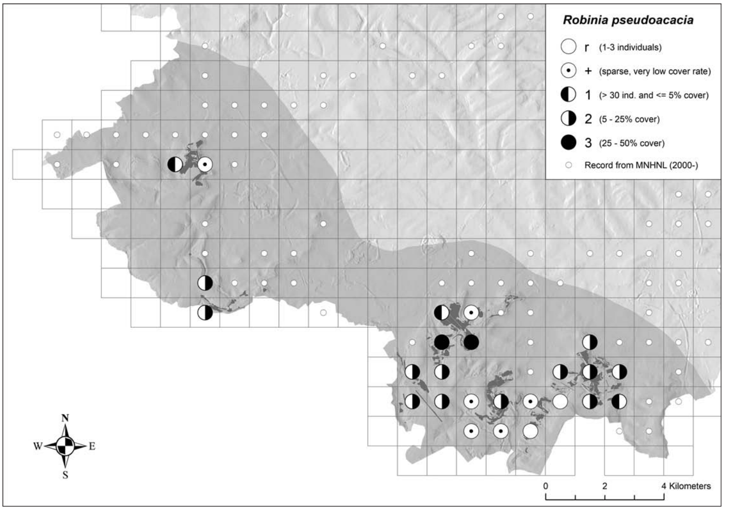

Fig. 3. Distribution and cover-abundances of *Robinia pseudoacacia* (black locust) across the study area.

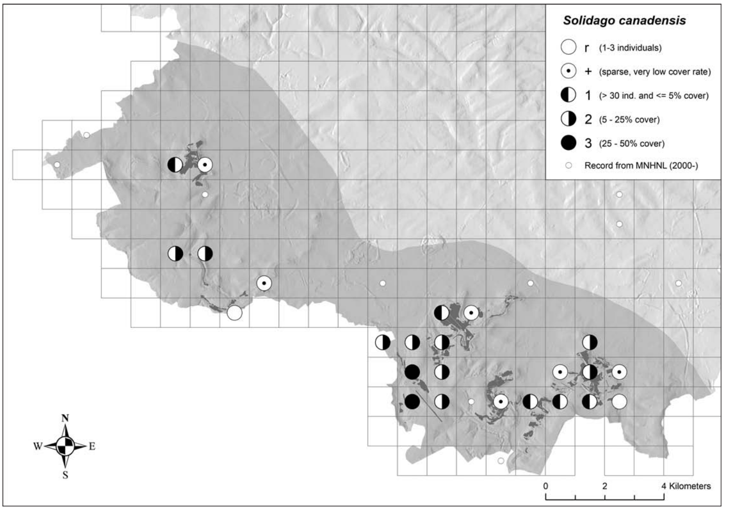

Fig. 4. Distribution and cover-abundances of *Solidago canadensis* (Canada goldenrod) across the study area.

cotoneaster) was found relatively frequently on 15 out of 296 plots (5.1 percent). However, throughout the various survey plots, the species was recorded with very low cover-abundance rates (single plants to sparse occurrence) (Fig. 5).

3.5. *Fallopia japonica*

Fallopia japonica (Japanese knotweed) was recorded in 7 out of 296 plots (2.4 percent). On one plot in the Haard district, the species formed a dominance stand with a cover density of more than five percent of the plot area. On another plot in the Kolscheed district, it was found with a larger number of individuals. The other recorded occurrences of the species consisted of very small stands (Fig. 6). Japanese knotweed was found exclusively in marginal areas of the study plots, or in areas with more profound soils and higher soil moisture. By contrast, the species was not found on scree slopes and in semi-natural dry grasslands.

3.6. *Buddleja davidii*

Buddleja davidii (summer lilac) was only found in 3 out of 296 survey plots (1 percent). Two of these plots are adjacent and

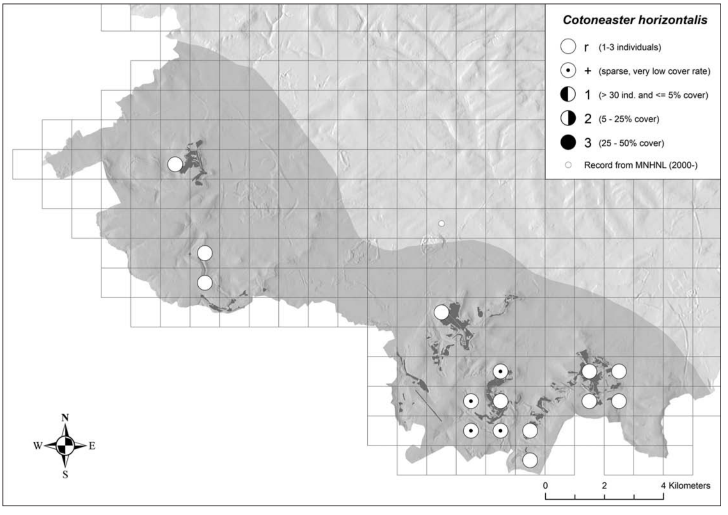

Fig. 5. Distribution and cover-abundances of *Cotoneaster horizontalis* (wall cotoneaster) across the study area.

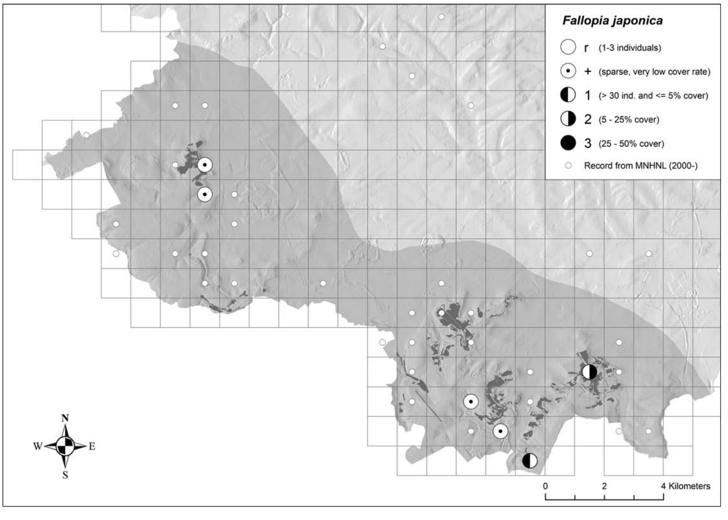

Fig. 6. Distribution and cover-abundances of *Fallopia japonica* (Japanese knotweed) across the study area.

located in the Lannebierg district, where the species forms a larger, coherent stand on the slopes of a small valley. The third occurrence of the species consists of a single plant recorded at the edge of the Haard area close to the southern entry gate (Fig. 7).

3.7. Other recorded species

Prunus laurocerasus (cherry laurel), *Syringa vulgaris* (common lilac), *Senecio inaequidens* (narrow-leaved ragwort), *Mahonia aquifolium* (Oregon grape) and *Rhus typhina* (staghorn sumac) were only found in one or two plots and in very small numbers.

4. Discussion

4.1. *Pinus nigra*

The largest stands of black pine exist in the area of the former open-cast mining districts of Lalléngerbierg, Nossbierg and Brucherbierg. The probable reason for its high abundance in these areas is cultivation of black pine in the course of reforestation, which was originally planned as subsequent use for the former open-cast mining areas (Frankenberg & Colling 2019). This is particularly evident at the southern cuesta in the Brucherbierg area, where black pine is the dominant forest tree in the wooded hillside areas. Other areas with larger occurrences of black pine exist in the district Hiel-Eisekaul, on the northern edge of Léiffrächen and on a single plot in the Haard district. In these areas, plantation of the species as a forest tree is also the most probable cause for its occurrence.

Due to its resistance to drought, black pine can grow on scree, rocky slopes and within dry semi-natural grasslands (Kowarik 2003). A few years after older black pine trees have started seed production, ring-shaped zones with sometimes several hundred shoots form around these trees. As the shoots grow larger, shading leads to a change of site conditions underneath the canopies which, in turn, enables other fringe and woodland species to colonize these areas. As a result, these areas are subject to succession towards forest. In addition, the seeds of black pine trees on wind-exposed growing sites can be dispersed over long distances (Buckley et al. 2005). This allows the species to colonize also more distant areas.

Apart from black pines, the spread of the native *Pinus sylvestris* (Scots pine) has a similar impact on dry semi-natural grasslands in the former open-cast mining areas. Thus, both pine species present in sensitive areas should be assessed similarly in terms of their risk potential to grassland biotopes of high ecological value.

In terms of control measures, removal of pine species from colonized sites before they

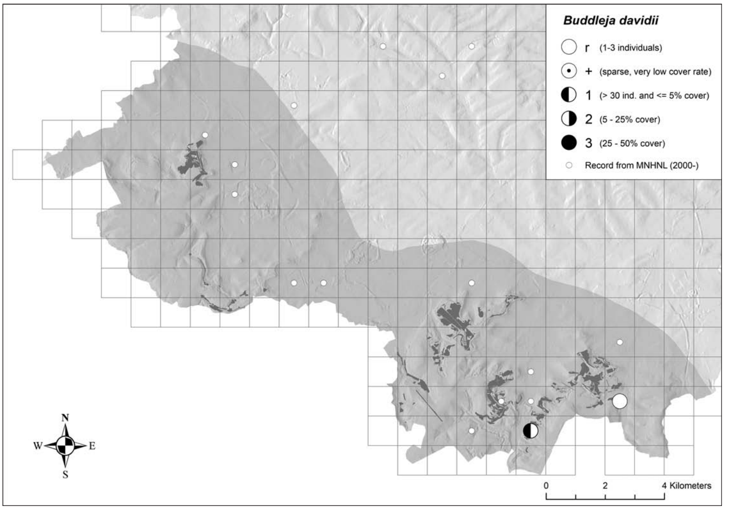

Fig. 7. Distribution and cover-abundances of *Buddleja davidii* (summer lilac) across the study area.

reach the age of seed production is essential for successful eradication. Once seed production takes place, simply removing trees and shoots from a site is no longer enough, because the stands can regenerate from their seed bank. Although black pine seeds have a short life span in soil (Kaliniewicz & Tylek 2019), all upcoming shoots in these areas should be uprooted or cut annually over a period of several years until no more germination of pine seeds occurs (Schmiedel et al. 2015).

4.2. *Robinia pseudoacacia*

Black locust was most frequently found in the districts Haard and Hiel-Eisekaul. Dominance stands of this species also exist in the districts of Kiemerchen, Lalléngerbierg, Kleesgrënnchen and on a single plot in the district of Léiffrächen. Within the other plots, black locust was found frequently, but mostly in low numbers and densities.

The spread of black locust in Kleesgrënnchen was apparently caused by garden escapes from neighbouring private gardens. Most other dominance stands can be assumed to originate from plantations in the context of the originally planned, subsequent forestry use of former open-cast mining areas (Cierjacks et al. 2013, Frankenberg & Colling 2019). In some places, specifically on backfill sites, black locust was apparently planted on upper slope edges as an erosion control plant.

Two ecological characteristics make black locust a potentially dangerous invader for nutrient-poor, semi-natural grasslands: Firstly, the species belongs to the pea family (*Fabaceae*) and can fix atmospheric nitrogen within nodules in their root system (in symbiosis with nitrogen-fixing bacteria). This ability leads to an accumulation of nitrogen in the soil and, in the long term, to a shift towards eutrophic site conditions (DAISIE 2009). Secondly, the species can reproduce very efficiently via suckers and thus colonize grassland areas quickly starting from single trees at the edges (Kowarik 2003, Pyšek et al. 2012).

Control of black locust is difficult, as simple felling of older trees leads to strongly increased root breeding with a multitude of suckers emerging from the roots around the felled tree (Kowarik 2003). Black locust trees should therefore be "incompletely girdled" (cutting most of the phloem around the stem, but leaving a small bark bridge), to weaken the plant over several years and eventually cause it to dry out (Böcker & Dirk 2008). Schiffleithner & Essl (2016) describe this method as most effective for black locust control, and when carried out correctly, black locust stands can thus be completely eradicated. However, even when older trees are girdled and suckers are regularly cut, complete eradication of the species on a site can easily take more than a decade (Schiffleithner & Essl 2016). Along motorways and railways, as well as in the Haard district, this method is already used to eradicate the largest stands of black locust.

4.3. *Solidago canadensis*

The largest populations of Canada goldenrod were found in the districts of Hiel-Eisekaul and Carrière Cloos, where the species is forming large dominance stands in nutrient-poor grassland communities. Two further dominance stands of the species were recorded on single plots in the districts of Scheierbierg and Lalléngerbierg. Within the other surveyed plots, Canada goldenrod was sporadically found, but always in lower numbers or small patches.

In Central Europe, Canadian goldenrod usually settles on urban and industrial wastelands. However, the species can also spread into nutrient-poor (fallow or neglected) grasslands, where it can accelerate the succession process and thus lead to a decline of typical nutrient-poor grassland species (Kowarik 2003). This effect is especially apparent in some plots at Hiel-Eisekaul.

Eradication of Canadian goldenrod in sensitive biotopes is difficult when the species is already widespread. Suitable control methods with little impact on the surrounding vegetation are manual uprooting shortly before flowering and regular, extensive grazing of goldenrod stands (Schmiedel et al. 2015). However, since these methods are expensive and time-consuming, they should only be employed on biotope complexes with high ecological value.

4.4. *Cotoneaster horizontalis*

Originating from China and introduced as an ornamental plant, wall cotoneaster is now also found in natural habitats, like rock formations, dry bushland, forest edges and dry grassland (Nehring et al. 2013).

Existing data from the database of the National Museum of Natural History (MNHNL 2000-) do not provide any indication of a wide distribution of the species in the former open-cast mining areas. By contrast, within the course of the present study, the species was found to be present in nine different former open-cast mining districts on a total of 15 different plots. However, the recorded stands consisted either of single plants or of very small stands of few individuals.

Uprooting of single plants with removal of the complete rootstock or cutting the above-ground plant in autumn with subsequent covering of the rootstock with black foil are possible control measures for wall cotoneaster eradication (Schmiedel et al. 2015). Since wall cotoneaster appears to be widespread over the former open-cast mining areas, but so far only seems to form small populations, its complete elimination from managed biotope plots areas should be relatively easy if carried out promptly and consistently.

4.5. *Fallopia japonica*

Japanese knotweed was most frequently found in the Haard district, but is also present in Giele Botter, Um Suebel, Lalléngerbierg, Léiffrächen, Dëmptgesgrond, Lannebierg and Kolscheed. Though widely spread over the former open-cast mining areas, the species was not seen to invade nutrient-poor dry habitats. Instead, the species grows on backfill sites with allochthonous, more profound soil material (i.e. in the Haard district) and in places with better water and nutrient supply (usually in depressions and valleys). For this reason, Japanese knotweed, which is highly invasive in other habitats (Pfeiffenschneider 2007, Glesener et al. 2009, Pfeiffenschneider et al. 2014a, b), is only considered a minor threat to the dry and nutrient-poor scree, rock and grassland biotopes of the former open-cast mining areas.

On a backfill site in the Haard district, a smaller stand of Japanese knotweed was successfully eliminated by cutting and subsequent covering with black foil (Jacques Mersch - Biomonitor, pers. comm.). In the context of the present study, the elimination of this stand could be confirmed.

4.6. *Buddleja davidii*

The only larger stand of summer lilac found in the present study is located in the Lannebierg district, where the species grows on the slopes of a small valley between two adjacent plots. Another occurrence of an individual plant was recorded in the Haard district, which was apparently established by a garden escape.

Since the distribution of summer lilac across the surveyed plots is limited to a few individual stands, elimination would be possible with manageable effort. Suitable measures are the excavation of plants with the whole rootstock or manual uprooting of seedlings and smaller plants (Schmiedel et al. 2015).

4.7. Other recorded species

Within the surveyed plots, *Prunus laurocerasus* (cherry laurel), *Syringa vulgaris* (common lilac), *Senecio inaequidens* (narrow-leaved ragwort), *Mahonia aquifolium* (Oregon grape) and *Rhus typhina* (staghorn sumac) only occurred in one or two single plots and with low numbers of individual plants. Thus, eradication of these species across the surveyed plots would be feasible with little effort in terms of time and money. However, two of these finds should be closely monitored, as they concern potentially problematic species on disturbed sites where suitable conditions for quick further dispersal exist: 1. Staghorn sumac was found next to the former Nardecchia landfill site in the district of Ronnebierg. Since the landfill is currently being removed within the course of site decontamination, staghorn sumac could easily spread across the newly created raw soil areas. 2. Narrow-leaved ragwort was found in the district of Lalléngerbierg (vis-à-vis the Nossbierg district) on the edge of a driveway and a nearby cul-de-sac. The ruderal embankments along the driveway and a neighbouring scree slope offer potentially suitable habitats for a quick dispersal of the species.

Conclusions

In the authors' opinion, further control measures should initially focus on small and isolated stands of problematic species in otherwise unpopulated areas. Thus, further spread of these species could be efficiently prevented with little effort. In addition, regular survey visits to particularly valuable biotope complexes would be an effective method to detect new stands of problematic species at an early stage.

In a next step, larger occurrences of problematic species in sensitive areas or adjacent to particularly valuable biotopes should be eliminated. In this context, we emphasise the necessity of a sound follow-up monitoring over several years to prevent stand regeneration from the seed bank or root parts left in the soil.

By contrast, with regard to larger stands of problematic species without any biotopes or sensitive areas in their immediate vicinity, the cost of eradication measures is likely to exceed the expected benefit. For the time being, these stands should be left in place but nevertheless be monitored regularly to limit further expansion if necessary.

A minor drawback of the current study was the strong focus on predefined survey plots. Thus, in some places, large stands of potentially invasive species found in areas directly adjacent to the surveyed plots were not systematically documented, although they can act as sources for dispersal and further colonization. Additional investigations should therefore not only focus on the actual survey plots, but also include the surroundings.

Data collected in the present study will be integrated into the database on the natural heritage of the Grand Duchy of Luxembourg (MNHNL 2000-) and will also be shared with the ANF to serve as a basis for further control measures.

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References

Böcker, R. & M. Dirk, 2008. Development of an effective girdling method to control *Robinia pseudoacacia* L. - First results and outlook. In: Rabitsch W., F. Essl & F. Klingenstein (Eds.): Biological Invasions – Ecology to Conservation. *NeoBiota* 7: 63-75.

Buckley, Y., E. Brockerhoff, L. Langer, N. Ledgard, H. North & M. Rees, 2005. Slowing down pine invasion despite uncertainty in demography and dispersal. *Journal of Applied Ecology* 42: 1020-1030.

Cierjacks, A., I. Kowarik, J. Joshi, S. Hempel, M. Ristow, M. von der Lippe & E. Weber, 2013. Biological Flora of the British Isles: *Robinia pseudoacacia*. *Journal of Ecology* 101: 1623-1640.

DAISIE, 2009. Handbook of Alien Species in Europe. Invading Nature – Springer Series in Invasion Ecology, Volume 3. Springer Science+Business Media B.V., 399 pp.

Frankenberg, T. & G. Colling, 2019. Flora und Vegetation der ehemaligen Erzabbaugebiete im Süden Luxemburgs und der Baggerweiherlandschaft an der Obermosel. *Tuexenia* Beiheft 12: 43-83.

Glavac, V., 1996. Vegetationsökologie. Gustav Fischer Verlag, Jena, 358 pp.

Glesener, B., M. Pfeiffenschneider & C. Ries, 2009. Die Verbreitung von *Impatiens glandulifera*, *Fallopia japonica*, *F. sachalinensis*, *F. ×bohemica* und *Heracleum mantegazzianum* entlang der Hauptfließgewässer Luxemburgs. *Bulletin de la Société des naturalistes luxembourgeois* 110 : 69-73.

Kaliniewicz, Z. & P. Tylek, 2019. Aspects of the Process of Sorting European Black Pine Seeds. *Forests* 10 (11): 966, 11 pp.

Kowarik, I., 2003. Biologische Invasionen. Neophyten und Neozoen in Mitteleuropa. Ulmer, Stuttgart, 380 pp.

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, Meise, CXXXIX + 1195 pp.

Leytem, M. & M. Muschang, 2017. Eine Landschaft in Wandel. Entdeckungspfad „Prënzebierg – Giele Botter“ Lehrpfad Geologie „Giele Botter“. Überarbeitete Auflage. Unter Mitarbeit von: A. Scheer, Y. Kayl, N. Scheuer, G. Schmidt, P. Thonon, C. Storoni, L. Frank, A. Faber & J. Cungs. Ministère du Développement durable et de Infrastructures – Administration de la nature et des forêts – Arrondissement Sud, Leudelange, 93pp.

MNHNL, 2000-. Recorder-Lux, database on the natural heritage of the Grand Duchy of Luxembourg. National Museum of Natural History, Luxembourg. URL: https://mdata.mnhn.lu [Accessed 2020-01-08]

Nehring, S., I. Kowarik, W. Rabitsch & F. Essl (Hrsg.), 2013. Naturschutzfachliche Invasivitätsbewertungen für in Deutschland wild lebende gebietsfremde Gefäßpflanzen. *BfN-Skripten* 352, Bundesamt für Naturschutz, Bonn, 202 pp.

Pfeiffenschneider, M., 2007. Über die Verbreitung von *Heracleum mantegazzianum*, *Impatiens glandulifera*, *Fallopia japonica* und *F. sachalinensis* entlang der Gewässer Obersauer, Woltz, Clerve, Wiltz und ihrer Nebengewässer (Luxemburg). *Bulletin de la Société des naturalistes luxembourgeois* 108 : 7-10.

Pfeiffenschneider, M., P. Gräser & C. Ries, 2014a. Distribution of selected neophytes along the main rivers of Luxembourg. *Bulletin de la Société des naturalistes luxembourgeois* 115 : 101-108.

Pfeiffenschneider, M., P. Gräser & C. Ries, 2014b. Distribution of selected neophytes along the national railway network of Luxembourg. *Bulletin de la Société des naturalistes luxembourgeois* 115 : 95-100.

Pyšek, P., M. Chytrý, J. Pergl, J. Sádlo & J. Wild, 2012. Plant invasions in the Czech Republic: current state, introduction dynamics, invasive species and invaded habitats. *Preslia* 84: 575-629.

Ries, C., Y. Krippel, M. Pfeiffenschneider & S. Schneider, 2013. Environmental impact assessment and black, watch and alert list classification after the ISEIA Protocol of non-native vascular plant species in Luxembourg. *Bulletin de la Société des naturalistes luxembourgeois* : 114: 15-21.

Schiffleithner, V. & F. Essl, 2016. Is it worth the effort? Spread and management success of invasive alien plant species in a Central European National Park. *NeoBiota* 31: 43-61.

Schmiedel, D., E.-G. Wilhelm, S. Nehring, C. Scheibner, M. Roth & S. Winter, 2015. Management-Handbuch zum Umgang mit gebietsfremden Arten in Deutschland, Band 1: Pilze, Niedere Pflanzen und Gefäßpflanzen. Ergebnisse des F+E-Vorhabens (FKZ 3513 86 0200). *Naturschutz und Biologische Vielfalt*, Heft 141 (1), Bundesamt für Naturschutz, Bonn - Bad Godesberg, 709 pp.