Appendix A

# Harmonia$^{+PL}$ – procedure for negative impact risk assessment for invasive alien species and potentially invasive alien species in Poland

## QUESTIONNAIRE

## A0 | Context

Questions from this module identify the assessor and the biological, geographical & social context of the assessment.

**a01**. Name(s) of the assessor(s):

first name and family name

1. Dan Wołkowycki
2. Barbara Tokarska-Guzik
3. Bogdan Jackowiak

acomm01. Comments:

| | degree | affiliation | assessment date |
|---|---|---|---|
| (1) | dr inż. | Faculty of Forestry, Bialystok Univeristy of Technology | 07-07-2018 |
| (2) | prof. dr hab. | Faculty of Biology and Environmental Protection, University of Silesia in Katowice | 01-07-2018 |
| (3) | prof. dr hab. | Department of Plant Taxonomy, Institute of Environmental Biology, Faculty of Biology, Adam Mickiewicz University in Poznań | 01-07-2018 |

**a02**. Name(s) of ***the species*** under assessment:

Polish name: Łubin trwały

Latin name: ***Lupinus polyphyllus*** Lindl.

English name: Garden lupin

Współfinansowano w ramach projektu nr POIS.02.04.00-00-0100/16 pn. *Opracowanie zasad kontroli i zwalczania inwazyjnych gatunków obcych wraz z przeprowadzeniem pilotażowych działań i edukacją społeczną* ze środków Unii Europejskiej w ramach Programu Infrastruktura i Środowisko 2014-2020

acomm02. Comments:

*Lupinus polyphyllus* is one of several hundred species of the genus naturally occurring in North and Central America (CABI 2018 – B). The preferred scientific and common names are listed as in 'The Plant List' (2013 – B), 'Flowering plants and pteridophyes of Poland a checklist (Mirek et al. 2002 – P) and other sources (Beuthin 2012 – I, CABI 2018 – B). Synonymous Latin names of the species include: *L. arcticus* S. Wats. var. *prunophilus* (M.E. Jones) C.P. Sm., *L. amplus* Greene, *L. biddlei* Henderson ex C. P. Smith, *L. burkei* S. Wats. ssp. *burkei*, *L. grandifolius* Lindl. ex J. Agardh, *L. garfieldensis* C.P. Sm., *L. magnus* Greene, *L. matanuskensis* C.P. Sm., *L. pallidipes* A. Heller, *L. polyphyllus* Lindl. ssp. *bernardinus* (Abrams ex C. P. Sm.) Munz, *L. p.* Lindl. ssp. *polyphyllus*, *L. p.* Lindl. ssp. *superbus* (A. Heller) Munz, *L. p.* Lindl. var. *albiflorus* Lindl., *L. p*. Lindl. var. *burkei* (S. Watson) C. L. Hitchc., *L. p*. Lindl. var. *humicola* (A. Nelson) Barneby, *L. p*. Lindl. var. *grandifolius* (Lindl. ex J. Agardh) Torr. & A. Gray, *L. p.* Lindl. var. *pallidipes* (A. Heller) C. P. Sm., *L. p.* Lindl. var. *polyphyllus*, *L. procerus* Greene ex A. Heller, *L. subsericeus* B.L. Rob. ex Piper, *L. superbus* A. Heller (Beuthin 2012 – I, The Plant List 2013, CABI 2018, USDA NRCS 2018 – B). The differentiated taxonomic approach (distinguishing subspecies and varieties) is linked to the wide geographical spread and ease of hybridisation (Beuthin 2012 – I). There are many varieties of the species in cultivation. There are also many synonyms of the English name (apart from the ones given below): altramuz perenne, big-leaved lupine, blue-pod lupine, marsh legume, perennial lupin, Washington lupine (Kurlovich 2002 – P, Beuthin 2012 – I, CABI 2018, USDA NRCS 2018 – B).

| Polish name (synonym I) | Polish name (synonym II) |
|---|---|
| – | – |
| Latin name (synonym I) | Latin name (synonym II) |
| *Lupinus elongatus* Greene ex A. Heller | *Lupinus tooelensis* C. P. Sm. |
| English name (synonym I) | English name (synonym II) |
| Bigleaf lupine | Large leaf lupine |

**a03**. **Area** under assessment:

**Poland**

acomm03. Comments:

–

**a04**. **Status** of *the species* in Poland. *The species* is:

| | |
|---|---|
| | native to Poland |
| | alien, absent from Poland |
| | alien, present in Poland only in cultivation or captivity |
| | alien, present in Poland in the environment, not established |
| **X** | alien, present in Poland in the environment, established |

aconf01. Answer provided with a

| low | medium | high | level of confidence |
|---|---|---|---|
| | | **X** | |

acomm04. Comments:

Garden lupin originating from North America (Beuthin 2012 – I, CABI 2018 – B), has been observed in the present area of Poland since the second half of the 19th century (Tokarska-Guzik 2005 – P). The species has the status of a established neophyte (kenophyte) in Poland (Tokarska-Guzik 2005 – P) and an invasive species on a national scale (Tokarska-Guzik et al. 2012 – P). The species is widespread across the country and is found in large numbers of sites (Zając and Zając 2001, 2015 – P, Tokarska-Guzik 2016-2017 – N). It is also cultivated, especially as an ornamental garden plant.

**a05**. The impact of *the species* on major domains. *The species* may have an impact on:

| | |
|---|---|
| **X** | the environmental domain |
| **X** | the cultivated plants domain |
| **X** | the domesticated animals domain |
| **X** | the human domain |
| | the other domains |

acomm05. Comments:

Garden lupin, originating from the western and eastern regions of North America, was introduced to Europe, Australia and New Zealand as an ornamental plant (park and flowerbed perennial), also as a fodder plant (cultivated as a green manure and grown for animal feed in hunting areas) and for soil stabilization and reclamation purposes (Szweykowska and Szweykowski 1993 – P, CABI 2018, USDA-NRCS 2018 – B). The first data documenting the escape of garden lupins from cultivation in Europe come from the turn of the 19th century (Fremstad 2010 – B). It is now widespread across the continent and in many regions is considered an invasive species posing a risk to native species and ecosystems (Tokarska-Guzik et al. 2012 – P, Pergl 2015 – I, CABI 2018 – B). Due to the massive occurrence of lupin, it endangers native biodiversity by penetrating natural and semi-natural habitats (CABI 2018 – B).

The species is highly competitive with native plant species. In the wild, it is able to create extensive clusters, ousting other species of herbaceous plants and radically changing the species composition and structure of vegetation, in particular in various types of forest margins, as well as in meadows and grasslands (Falencka-Jabłońska 2007 – P, Wołkowycki 2005-2018 – A, Tokarska-Guzik 2016-2017 – N). Plant communities with a high proportion of garden lupins are characterised by a reduced species diversity (Valtonen et al. 2006, Ramula and Pihlaja 2012 – P, Tokarska-Guzik 2016-2017 – N). The species influences the abundance and diversity of insect species in various ways, and indirectly affects the pollination potential and reproductive success of other plants. In places where garden lupin is abundant, the total number of arthropods may decrease, even by as much as approx. 45%. This is particularly the case for beetles, flies, butterflies and ants. However, the number of bumblebees, which are among the main pollinators of the species, may even double in communities in which lupin is present. As a result, pollination of other plant species by bumblebees, as well as by other *Apidae* (Valtonen et al. 2006, Jakobsson et al. 2015, Ramula and Sorvari 2017 – P), is facilitated in the vicinity of garden lupins. Garden lupin, like other members of thebean family (Fabaceae) plants, contributes to habitat fertility because of its coexistence with bacteria that can bind nitrogen from the air in the soil. The species is invasive and threatens some of the natural habitats of Natura 2000, i.e. lowland hay meadows used extensively (code 6510), mountain hay meadows used extensively (code 6520) as well as xeric sand calcareous grasslands (6120) and hydrophilous tall herb fringe communities of plains and of montane to alpine zones (6430) (Tokarska-Guzik et al. 2012 – P, Tokarska-Guzik 2016-2017 – N). It is grown as a fodder and an ornamental plant and as a green manure. It is eaten by animals, including deer. The seeds were sometimes used as food for humans, although many varieties (especially ornamental ones) have a high alkaloid content and toxic properties (CABI 2018 – B).

## A1 | Introduction

Questions from this module assess the risk for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation. This leads to *introduction*, defined as the entry of *the organism* to within the limits of *the area* and subsequently into the wild.

**a06**. The probability for ***the species*** to expand into Poland's natural environments, **as a result of self-propelled expansion** after its earlier introduction outside of the Polish territory is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf02. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm06. Comments:

So far, the species has been reordered in 23 European countries (including all countries neighbouring Poland) both in cultivation and in the wild (e.g. Parfenov 1999 – P, Pergl 2015 – I, CABI 2018, EPPO 2018 – B). Garden lupin reproduces by seeds, which fall down near the parental plants, as well as by vegetative growth. The plant produces large quantities of seeds, which are relatively heavy and do not have any structures facilitating dispersion. The seeds are spread gravitationally (barochorically) or ballistically thanks to tensions in drying pods catapulting seeds over short distances from the parental plant (Timmins and Mackenzie 1995 – P). Therefore, the appearance of new sites on the territory of Poland as a result of long-distance spontaneous dispersion is unlikely. However, it cannot be excluded since the seeds can be transported with the current of river waters (CABI 2018 – B) and the species is able to spread effectively and relatively quickly along roads and railways (e.g. Faliński 1968, Falencka-Jabłońska 2007 – P). Garden lupin is widespread across Poland and therefore colonization from neighbouring areas is not relevant for population and range growth within the country. Nevertheless, because the species is already established in Poland, the criteria adopted in the procedure for assessing the risk of the negative impact of invasive and potentially invasive alien species in Poland – *Harmonia*$^{+PL}$ indicate the choice of the following response: high probability with a high degree of certainty.

**a07**. The probability for *the species* to be introduced into Poland's natural environments by **unintentional human actions** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf03. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm07. Comments:

Seeds and rooted parts of the plant may be transported as a result of unintended human actions during agricultural, forestry, construction and road works, along with soil, organic material, agricultural and construction machinery, etc. The species is a component of meadows and pastures and is occasionally cultivated as a green manure. It is therefore likely that its seeds or (less frequently) its vegetative parts can be relocated with the transported agricultural products or animals. However, there is no evidence to support this. As the species is already widespread in Poland, the likelihood of emergence of new sites as a result of unintended human actions is high.

**a08**. The probability for *the species* to be introduced into Poland's natural environments by **intentional human actions** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf04. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm08. Comments:

*Lupinus polyphyllus* is available in horticultural offers, both in Poland and in other European countries, due to its ornamental qualities (Fremstad 2010, CABI 2018 – B). It is cultivated as a fodder plant and green manure (Szweykowska and Szweykowski 1993 – P, Fremstad 2010 – B). It is also used for the stabilisation and rehabilitation of post-industrial areas and for soil enrichment (CABI 2018 – B). The seeds of the plant produced in cultivated areas can easily trigger spontaneous populations, especially in human affected habitats (such as fallow lands,

roadsides and ruderal areas) and from there the plant can enter semi-natural habitats such as various grassland communities and forest margins. In the past, garden lupin was used as a food plant for wild animals. That initiated the expansion of the species, e.g. in the Białowieża Forest (Faliński 1968, 1986 – P). The high genetic diversity of wild populations may indicate human-initiated expansion through repeated introductions at many sites (Vyšniauskienė et al. 2011 – P, Li et al. 2016 – P). Both the scale of the species spread across Poland and many European countries, as well as its use as an ornamental and useful plant, indicate a high probability of its introduction into the natural environment of Poland as a result of intended human actions.

## A2 | Establishment

Questions from this module assess the likelihood for *the species* to overcome survival and reproduction barriers. This leads to *establishment*, defined as the growth of a population to sufficient levels such that natural extinction within *the area* becomes highly unlikely.

**a09**. Poland provides **climate** that is:

| | |
|---|---|
| | non-optimal |
| | sub-optimal |
| **X** | optimal for establishment of *the species* |

aconf05. Answer provided with a

| low | medium | high | level of confidence |
|---|---|---|---|
| | | **X** | |

acomm09. Comments:

Garden lupin originates from western and eastern North America, where it grows from California to Alaska (Fremstad 2010, USDA-NRCS 2018 – B). It prefers a temperate, continental climate with dry summers, where the average temperature of the warmest month is >10°C and the average temperature of the coldest month is >0°C (CABI 2018 – B). In Poland, the species is widespread across the country and is also present in most of Europe's biogeographical regions (DAISIE, CABI 2018 – B). It can withstand severe climate conditions and is also found in the northern regions of the continent (Fremstad 2010 – B), e.g. in Scandinavia and northern Russia. Outside Europe, it grows in New Zealand, Australia and South America (Chile) (CABI 2018 – B). In Poland, favourable climatic conditions for the growth of this species are present in almost the whole country, which is confirmed by its current distribution (Zając and Zając 2001, Tokarska-Guzik 2005 – P). Below ground parts of the plant are characterised by high resistance to frost, and winter conditions in Poland are well-withstood by seeds (CABI 2018 – P). For most lupin species, the minimum germination temperature is low (1-2°C) and a temperature between 4-6°C is optimal. Low air temperature at the beginning of the growth period accelerates the flowering of plants. During the development phase of the vegetative shoots, lupin prefers a moderately warm temperature. Flowering is most intense at temperatures in the range of 15-25°C. The period of seed ripening is significantly reduced at higher temperatures and extended at high air humidity (Kurlovich 2002 – P). The similarity between the Polish climate and the climate of some parts of the native range of the species (as well as in other parts of its secondary range) is very high (with the exception of the average temperature in January, which is between 0 and -5°C in Poland) and ranges between 94 and 100% similarity with the native range of lupin, which means that the climatic conditions in Poland are optimal for this species.

**a10**. Poland provides **habitat** that is

| | |
|---|---|
| | non-optimal |
| | sub-optimal |
| **X** | optimal for establishment of *the species* |

| | | | | | |
|---|---|---|---|---|---|
| aconf06. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm10. Comments:

Within its natural range, the species grows in meadows, coastal habitats and roadsides (Fremstad 2010, USDA-NRCS 2018 – B). In the secondary range, which includes Poland, it colonizes many habitat types: from open, ruderal (roadsides, wastelands) situations to semi-natural ones, e.g. meadows, forest margins (Vyšniauskiene et al. 2011, Ramula 2014 – P, Tokarska-Guzik 2016-2017 – N), as well as river banks and wetlands (Timmins and Mackenzie 1995, Meier et al. 2013 – P). Due to its preferences and the availability of suitable habitats, garden lupin has optimal conditions for establishment across the entire Polish lowlands.

The species has minimal soil and habitat requirements. As a plant that coexists with bacteria that bind nitrogen (*Bradyrhizobium* sp.) in the soil air, it is able to occupy uncommon habitats with low fertility. It is found on a variety of soils, including sandy soils which are acidic and inert (Fremstad 2010 – B). Lupin withstands moisture deficiencies quite well due to its well-developed root system. This tolerance does not apply only to the germination period (Kurlovich 2002 – P).

## A3 | Spread

Questions from this module assess the risk of *the species* to overcoming dispersal barriers and (new) environmental barriers within Poland. This would lead to spread, in which vacant patches of suitable habitat become increasingly occupied from (an) already-established population(s) within Poland.

Note that spread is considered to be different from range expansions that stem from new introductions (covered by the Introduction module).

**a11**. The capacity of *the species* to disperse within Poland by natural means, **with no human assistance**, is:

| | |
|---|---|
| | very low |
| | low |
| **X** | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf07. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm11. Comments:

Approximation (type of data C).
Garden lupin is a perennial plant with an estimated life span of approx. 20 years (Ramula 2014 – P). The species spreads through seeds and vegetative growth (CABI 2018 – B). In addition, the plant has a high regeneration capacity after the destruction (cutting) of the above-ground parts (Timmins and Mackenzie 1995 – P, Tokarska-Guzik 2016-2017 – N). A single plant usually forms several clusters of inflorescences reaching 50-150 cm in height (Fremstad 2010 – B). The fruits (pods) which are approx. 5 cm long, contain 10 to 12 seeds (Fremstad 2010 – B). The seeds are not adapted for long-distance dispersion and fall in the vicinity of the parental plants. They are released due to the stress created in the walls of the pods as they dry (ballochorically) and spread over a distance of several metres (Podbielkowski 1995 – P, CABI 2018 – B). They weigh between 20 and 70 mg. A single plant produces from several hundred to over two and a half thousand seeds (Aniszewski et al. 2001 – P). The seeds in the pods mature a few weeks after fertilisation. They germinate after a resting period, at the beginning of the next growing season. They can last for a few years in a soil seed bank, but their life span decreases very rapidly and viability falls to approx. 1% after two years (CABI 2018 – B). The species spreads very effectively in disturbed habitats, in particular on roadsides and forest margins (Faliński 1968, Falencka-Jabłońska 2007 – P). Expansion also progresses relatively quickly on uncultivated areas in river valleys where

seeds can be carried by water (CABI 2018 – B). Usually the average rate of spontaneous spread of the species is not greater than 100–1000 m/year.

Population expansion (type of data B). Data collected in Finland (Lahti et al. 1995 – P) suggested a more rapid spread of garden lupin, since the species expanded its range by nearly 400 km over two decades. However, this was possible probably mainly due to significant human interference: the development of spontaneous populations from seeds of plants introduced in many places for cultivation, as well as the transfer of seeds during mowing of roadsides.

**a12**. The frequency of the dispersal of *the species* within Poland by **human actions** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf08. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm12. Comments:

The species is often cultivated as an ornamental plant (it is still available in horticultural offers both as seeds and as seedlings), as fodder, as green manure, and it is also used in the rehabilitation of degraded areas (Kurlovich 2002 – P, CABI 2018, EPPO 2018 – B). In the past, it was planted in the forests as a food plant for animals, e.g. in the Białowieża Forest (Faliński 1968, 1986 – P). The high genetic diversity of wild populations may suggest human-initiated expansion through multiple introductions to different sites rather than through progressive expansion from one or more colonisation sites (Vyšniauskienė et al. 2011, Li et al. 2016 – P).

## A4a | Impact on the environmental domain

Questions from this module qualify the consequences of *the species* on wild animals and plants, habitats and ecosystems.

Impacts are linked to the conservation concern of targets. Native species that are of conservation concern refer to keystone species, protected and/or threatened species. See, for example, Red Lists, protected species lists, or Annex II of the 92/43/EWG Directive. Ecosystems that are of conservation concern refer to natural systems that are the habitat of many threatened species. These include natural forests, dry grasslands, natural rock outcrops, sand dunes, heathlands, peat bogs, marshes, rivers & ponds that have natural banks, and estuaries (Annex I of the 92/43/EWG Directive).

Native species population declines are considered at a local scale: limited decline is considered as a (mere) drop in numbers; severe decline is considered as (near) extinction. Similarly, limited ecosystem change is considered as transient and easily reversible; severe change is considered as persistent and hardly reversible.

**a13**. The effect of *the species* on native species, through **predation, parasitism or herbivory is**:

| | |
|---|---|
| **X** | inapplicable |
| | low |
| | medium |
| | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf09. | Answer provided with a | low | medium | high | level of confidence |

acomm13. Comments:

The species is a non-parasitic plant.

**a14**. The effect of *the species* on native species, through **competition** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf10. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm14. Comments:

Garden lupin is able to form compact, dense clusters which strongly shade less tall herbaceous plants. It is a species that successfully competes for space and habitat resources with native plants. The development of lupin clusters may cause decrease in population size of other species, decrease in species diversity and, consequently, change in the structure of native plant communities (Valtonen et al. 2006, Ramula and Pihlaja 2012 – P, CABI 2018 – B), although there are also studies that show only a small impact of garden lupin on the diversity of local species (Hejda 2013 – P). The species may have a negative impact in particular on sun-loving and thermophilic plants of grassland communities and mixed forest margins. In Poland, this could potentially affect critically endangered species – for example *Thesium ebracteatum*, and *Agrimonia pilosa* – listed in Annex 2 of the Habitats Directive (Wołkowycki 2005-2018 – A). The species is invasive and threatens some of the natural habitats of Natura 2000, i.e. lowland hay meadows used extensively (code 6510), mountain hay meadows used extensively (code 6520) as well as xeric sand calcareous grasslands (6120) and hydrophilous tall herb fringe communities of the plains and of montane to alpine levels (6430) (Tokarska-Guzik et al. 2012 – P, Tokarska-Guzik 2016-2017 – N). High content of alkaloids in some varieties of *Lupinus polyphyllus* may limit the germination of other plants through chemical (allelopatic) interactions (Loydi et al. 2015 – P). The presence of larger patches of garden lupin affects the fauna of insects in various ways, causing a decrease in the number of butterflies, beetles etc., but also an increase in the number of bumblebees and other bee species.The inflorescences, abundant in flowers which are able to produce pollen twice (Vinogradova et al. 2012 – P) are very attractive for insects, thanks to which garden lupin can effectively compete for pollinators. The impact of the species on the pollination efficiency of other plants is therefore rather ambiguous; it may lead to reduced reproductive success of some plants (mainly those pollinated by butterflies), but increased reproductive success in other plants pollinated by bumblebees (Valtonen et al. 2006, Ramula and Pihlaja 2012, Jakobsson et al. 2015, Ramula and Sorvari 2017 – P).

**a15**. The effect of *the species* on native species, through **interbreeding** is:

| | |
|---|---|
| **X** | no / very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf11. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm15. Comments:

The species is characterized by a broad diversity of genotypes and varieties (Pergl 2015 – I, CABI 2018 – B), it crossbreeds easily and forms hybrids with other representatives of its genus (Kurlovich 2002 – P), but none of them belong to the native flora of Poland.

**a16**. The effect of *the species* on native species by **hosting pathogens or parasites** that are harmful to them is:

| | |
|---|---|
| | very low |
| | low |
| **X** | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf12. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm16. Comments:

Lupin is a host of pathogens (bacteria, viruses, fungi, insects) affecting various plant species, in particular other members of the *Fabaceae* family. Lupins are attacked by various fungi, which can also be found on other bean plants, both native and cultivated, i.e. *Phycomycetes* (*Peromospora*, *Phytophthora* and *Pythium*), *Ascomycetes* (*Erysiphe*, *Mycosphaerella* and *Dydimella*), *Basidiomycetes* (*Uromyces*) and *Deuteromycetes* (*Ascochyta*, *Septoria*, *Phyllosticta*, *Colletotrichum*, *Cercospora*, *Fusarium* and *Botrytis* fungi) (Kurlovich 2002 – P). One of the potentially most dangerous pathogens is Tobacco ringspot virus (TRSV), which affects not only different plant species but also bees (Li et al. 2014 – P, EPPO 2018 – B).

**a17**. The effect of *the species* on ecosystem integrity, by **affecting its abiotic properties** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf13. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm17. Comments:

Garden lupin is able to change the physical and chemical properties of the habitats it occupies. As a species that coexists with root bacteria that bind nitrogen from the air, garden lupin contributes to an increase in the nitrogen content of the soil, which in time may lead to generally deleterious changes in the composition of plant communities (Davis 1991, Valtonen et al. 2006, Święczkowska and Hołdyński 2017 – P, CABI 2018 – B). However, the results of the research on this subject are not conclusive (Meier et al. 2013 – P). The extensive root system prevents soil erosion. In flood-liable river valleys where garden lupin was present, a thicker layer of fine sediments, a higher carbon/nitrogen ratio and a higher soil carbon content were recorded (Meier et al. 2013 – P).

**a18**. The effect of *the species* on ecosystem integrity, by **affecting its biotic properties** is:

| | |
|---|---|
| | low |
| | medium |
| **X** | high |

| | | | | | |
|---|---|---|---|---|---|
| aconf14. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm18. Comments:

The development of lupin clusters may cause decrease in population size of other species, decrease in species diversity and, consequently, change in the structure of native plant communities (Valtonen et al. 2006, Ramula and Pihlaja 2012 – P, CABI 2018 – B), although there are also studies showing only a small impact of garden lupin on the diversity of local species (Leiden 2013 – P). The species influences the abundance and species richness of insects in various ways. Abundant flowers which are able to produce pollen twice (Vinogradova et al. 2012 – P) are very attractive for insects, thanks to which garden lupin can effectively compete for pollinators. In places where garden lupin is abundant, the total number of arthropods may decrease, even by as much as approx. 45%. This is particularly the case for beetles, flies, butterflies and ants. However, the number of bumblebees, which are among the main pollinators of the species, may even double in communities in which lupin is present. As a result, pollination of other plant species by bumblebees, as well as by other *Apidae* (Valtonen et al. 2006, Jakobsson et al. 2015, Ramula and Sorvari 2017 – P), is facilitated in the vicinity of garden lupins. The impact of the species on the pollination efficiency of other plants is therefore rather ambiguous; it may lead to reduced reproductive

| | |
|---|---|
| | success of some plants (mainly those pollinated by butterflies), but increased in other plants pollinated by bumblebees (Valtonen et al. 2006, Ramula and Pihlaja 2012, Jakobsson et al. 2015, Ramula and Sorvari 2017 – P). |

## A4b | Impact on the cultivated plants domain

Questions from this module qualify the consequences of *the species* for cultivated plants (e.g. crops, pastures, horticultural stock).

For the questions from this module, consequence is considered 'low' when presence of *the species* in (or on) a population of target plants is sporadic and/or causes little damage. Harm is considered 'medium' when *the organism's* development causes local yield (or plant) losses below 20%, and 'high' when losses range >20%.

**a19**. The effect of *the species* on cultivated plant targets through **herbivory or parasitism** is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf15. | Answer provided with a | low | medium | high **X** | level of confidence |

| | |
|---|---|
| acomm19. | Comments:<br>The species is a non-parasitic plant. |

**a20**. The effect of *the species* on cultivated plant targets through **competition** is:

| | |
|---|---|
| | inapplicable |
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf16. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm20. | Comments:<br>Lupin is grown as a fodder plant and as a green manure. It does not compete with other plants in field and garden cultivations. |

**a21**. The effect of *the species* on cultivated plant targets through **interbreeding** with related species, including the plants themselves is:

| | |
|---|---|
| | inapplicable |
| | no / very low |
| | low |
| **X** | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf17. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm21. | Comments: |

The species can easily be crossbred and hybridised with other lupin species grown in Poland as ornamental, fodder and fertiliser plants (Kurlovich 2002 – P, CABI 2018 – B). It is predicted that in the worst case the condition of plants or the yield of the cultivated population are reduced from c 5% to c 20% (consequence medium), with a medium likelihood.

**a22**. The effect of *the species* on cultivated plant targets by **affecting the cultivation system's integrity** is:

| | |
|---|---|
| | very low |
| **X** | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf18. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm22. | Comments: |

Lupin does not grow as a weed in crops and does not interfere with the integrity of field or garden cultivations. It is grown as a fodder plant and as a green manure. Exceptionally, an excessive increase in the population of varieties with a high content of poisonous alkaloids, when they occur in pastures and meadows can result in a reduction of the utility of grasslands (CABI 2018 – B). It has been predicted that in the worst case the condition of plants or yield of cultivated populations can be reduced by less than about c 5% (consequence low), and the influence will affect from 1/3 to 2/3 of plant target populations (medium likelihood).

**a23**. The effect of *the species* on cultivated plant targets by hosting **pathogens or parasites** that are harmful to them is:

| | |
|---|---|
| | very low |
| | low |
| **X** | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf19. | Answer provided with a | low | medium **X** | high | level of confidence |

| | |
|---|---|
| acomm23. | Comments: |

Lupin is a host of pathogens (bacteria, viruses, fungi, insects) affecting various plant species, in particular other members of the *Fabaceae* family. Lupins are attacked by various fungi, which can also be found on other bean plants, both native and cultivated, i.e. *Phycomycetes* (*Peromospora*, *Phytophthora* and *Pythium*), *Ascomycetes* (*Erysiphe*, *Mycosphaerella* and *Dydimella*), *Basidiomycetes* (*Uromyces*) and *Deuteromycetes* (*Ascochyta*, *Septoria*, *Phyllosticta*, *Colletotrichum*, *Cercospora*, *Fusarium* and *Botrytis* fungi) (Kurlovich 2002 – P) as well as the bacterium *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (listed on the A2 list, EPPO 2018 – B). Tobacco ringspot virus (TRSV, listed on the A2 list) is one of the potentially most dangerous pathogens – it affects not only different plant species but also bees (Li et al. 2014 – P, EPPO 2018 – B).

## A4c | Impact on the domesticated animals domain

Questions from this module qualify the consequences of *the organism* on domesticated animals (e.g. production animals, companion animals). It deals with both the well-being of individual animals and the productivity of animal populations.

**a24**. The effect of *the species* on individual animal health or animal production, through **predation or parasitism** is:

| | |
|---|---|
| **X** | inapplicable |
| | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf20. | Answer provided with a | low | medium | high | level of confidence |

acomm24. Comments:

The species is a non-parasitic plant

**a25**. The effect of *the species* on individual animal health or animal production, by having properties that are hazardous upon **contact**, is:

| | |
|---|---|
| | very low |
| **X** | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf21. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm25. Comments:

Some varieties of garden lupin have alkaloid toxicity and may be harmful to farmed animals if consumed in higher quantities (CABI 2018 – B), but other varieties are cultivated as fodder for animals.

**a26**. The effect of *the species* on individual animal health or animal production, by hosting **pathogens or parasites** that are harmful to them, is:

| | |
|---|---|
| | inapplicable |
| | very low |
| | low |
| **X** | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf22. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm26. Comments:

Garden lupin is a host of Tobacco ringspot virus (TRSV), which infects not only various plant species but also contributes to the dieback of bee colonies (Li et al. 2014 – P, EPPO 2018 – B).

## A4d | Impact on the human domain

Questions from this module qualify the consequences of *the organism* on humans. It deals with human health, being defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (definition adopted from the World Health Organization).

**a27**. The effect of *the species* on human health through **parasitism** is:

| | |
|---|---|
| **X** | inapplicable |
| | very low |

| | |
|---|---|
| | low |
| | medium |
| | high |
| | vert high |

| | | | | | |
|---|---|---|---|---|---|
| aconf23. | Answer provided with a | low | medium | high | level of confidence |

| | |
|---|---|
| acomm27. | Comments:<br>The species is a non-parasitic plant |

**a28**. The effect of *the species* on human health, by having properties that are hazardous upon **contact**, is:

| | |
|---|---|
| | very low |
| **X** | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf24. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm28. | Comments:<br>Some varieties of lupin contain alkaloids and are toxic, but other have been used as food (additives to flour). Consumption of limited amounts of plant does not cause severe poisoning in humans, although it may cause allergic reactions in a small number of people (CABI 2018 – B). |

**a29**. The effect of *the species* on human health, by hosting **pathogens or parasites** that are harmful to humans, is:

| | |
|---|---|
| **X** | inapplicable |
| | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf25. | Answer provided with a | low | medium | high | level of confidence |

| | |
|---|---|
| acomm29. | Comments:<br>The species does not transmit pathogens or parasites that are harmful to humans. |

## A4e | Impact on other domains

Questions from this module qualify the consequences of *the species* on targets not considered in modules A4a-d.

**a30**. The effect of *the species* on causing damage to **infrastructure** is:

| | |
|---|---|
| **X** | very low |
| | low |
| | medium |
| | high |
| | very high |

| | | | | | |
|---|---|---|---|---|---|
| aconf26. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm30. | Comments:<br>There are no known impacts of the species on the infrastructure. |

## A5a | Impact on ecosystem services

Questions from this module qualify the consequences of *the organism* on ecosystem services. Ecosystem services are classified according to the Common International Classification of Ecosystem Services, which also includes many examples (CICES Version 4.3). Note that the answers to these questions are not used in the calculation of the overall risk score (which deals with ecosystems in a different way), but can be considered when decisions are made about management of *the species*.

**a31**. The effect of *the species* on **provisioning services** is:

| | |
|---|---|
| | significantly negative |
| | moderately negative |
| | neutral |
| **X** | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf27. | Answer provided with a | low | medium<br>**X** | high | level of confidence |

| | |
|---|---|
| acomm31. | Comments:<br>Garden lupin has a positive effect on provisioning services as a plant grown for fodder, as well as (indirectly) for green manure. |

**a32**. The effect of *the species* on **regulation and maintenance services** is:

| | |
|---|---|
| | significantly negative |
| | moderately negative |
| **X** | neutral |
| | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf28. | Answer provided with a | low | medium<br>**X** | high | level of confidence |

| | |
|---|---|
| acomm32. | Comments:<br>Garden lupin is able to change the physical and chemical properties of the habitats it occupies. It is cultivated as a green manure, and used in the rehabilitation of degraded areas. As a species that coexists with root bacteria that bind nitrogen from the air, garden lupin contributes to an increase in the nitrogen content of the soil, which in time may lead to deleterious changes in the composition of plant communities (Valtonen et al. 2006 – P, Pergl 2015 – I, CABI 2018 – B). However, the results of the research on this subject are not conclusive (Meier et al. 2013 – P). The extensive root system prevents soil erosion. In river valleys subject to flooding, where lupins were present, a thicker layer of fine sediments, a higher carbon/ nitrogen ratio and a higher soil carbon content were recorded (Meier et al. 2013 – P). Garden lupin, by changing biotic and abiotic factors, may limit the development of plant species associated with semi-natural grassland communities, forest margins etc. The species has a negative impact on many butterflies, beetles and other groups of insects, but has a positive impact on bumblebees and other *Apidae*, which are very important pollinators of various plants. By influencing insect populations, the presence of lupin clusters can affect the pollination efficiency of various plants, both cultivated and wild (Valtonen et al. 2006, Jakobsson et al. 2015, Ramula and Sorvari 2017 – P). |

**a33**. The effect of *the species* on **cultural services** is:

| | |
|---|---|
| | significantly negative |
| | moderately negative |
| | neutral |
| **X** | moderately positive |
| | significantly positive |

| | | | | | |
|---|---|---|---|---|---|
| aconf29. | Answer provided with a | low | medium **X** | high | level of confidence |

acomm33. Comments:

Garden lupin is cultivated, i.a. because of its ornamental qualities. The presence of small patches of the species in the wild may increase the aesthetic value of the landscape and have a positive impact on its recreational features (especially when its flowers are blooming).

## A5b | Effect of climate change on the risk assessment of the negative impact of *the species*

Below, each of the *Harmonia*$^{+PL}$ modules is revisited under the premise of the future climate. The proposed time horizon is the mid-21st century. We suggest taking into account the reports of the Intergovernmental Panel on Climate Change. Specifically, the expected changes in atmospheric variables listed in its 2013 report on the physical science basis may be used for this purpose. The global temperature is expected to rise by 1 to 2°C by 2046-2065.

Note that the answers to these questions are not used in the calculation of the overall risk score, but can be but can be considered when decisions are made about management of *the species*.

**a34**. INTRODUCTION – Due to climate change, the probability for *the species* to overcome geographical barriers and – if applicable – subsequent barriers of captivity or cultivation in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf30. | Answer provided with a | low | medium | high **X** | level of confidence |

acomm34. Comments:

The species is currently cultivated and established in Poland (Tokarska-Guzik et al. 2012 – P). It belongs to the group of plants which are frost resistant and not susceptible to water shortages, and which have already found optimal conditions for development in the Polish climate. The species grows in most of the countries neighbouring with Poland, both in cultivation and in the wild. Geographical barriers were overcome by the deliberate introduction and adaptation of the species. Climate change will not have any impact on plant introduction and on their persistence in cultivation and wildlife.

**a35**. ESTABLISHMENT – Due to climate change, the probability for *the species* to overcome barriers that have prevented its survival and reproduction in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf31. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm35. Comments:

The species is already established (Tokarska-Guzik et al. 2012 – P). Poland has optimal climatic and habitat conditions for the development of the species. Forecasted climate changes will not affect the survival and reproduction of garden lupin in Poland.

**a36**. SPREAD – Due to climate change, the probability for *the species* to overcome barriers that have prevented its spread in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf32. | Answer provided with a | low | medium<br>**X** | high | level of confidence |

acomm36. Comments:

The species is able to spread effectively in the current conditions. It is not limited by climatic conditions, although some studies suggest that the growth rate of the population of garden lupin may increase with a more humid climate and a prolongation of the vegetative season (Ramula 2014 – P). An increase of temperature may accelerate the natural nitrogen cycle and nitrification processes (Magnusson et al. 2014, Schaeffer et al. 2013 – P) and thus affect the distribution of garden lupin, which lives in symbiosis with nitric bacteria. However, due to the wide spread of garden lupin in Europe, it is currently not possible to assess the impact of climate change on its range (Pergl 2015 – I).

**a37**. IMPACT ON THE ENVIRONMENTAL DOMAIN – Due to climate change, the consequences of *the species* on wild animals and plants, habitats and ecosystems in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf33. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

acomm37. Comments:

The species is able to compete effectively with native plants in the present climate. Forecasted climate change will not increase its reproductive success, competitiveness or impact on abiotic, biotic factors and ecosystem structure.

**a38**. IMPACT ON THE CULTIVATED PLANTS DOMAIN – Due to climate change, the consequences of *the species* on cultivated plants and plant domain in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf34. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm38. | Comments:<br>The species has no direct impact on cultivated plants and plant production in Poland, but may have an indirect impact on pollinator numbers (beneficial for bumblebees and other bees, negative for butterflies and other insects). Climate change will not change this. |

**a39**. IMPACT ON THE DOMESTICATED ANIMALS DOMAIN – Due to climate change, the consequences of *the species* on domesticated animals and animal production in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf35. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm39. | Comments:<br>High alkaloid content in some garden lupin varieties can be harmful to livestock (when consumed in larger quantities), but other varieties are used as fodder. The species may potentially affect bee colonies through the transmission of TRSV. Climate change will not change this. |

**a40**. IMPACT ON THE HUMAN DOMAIN – Due to climate change, the consequences of *the species* on human in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf36. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm40. | Comments:<br>Some varieties of garden lupin are moderately toxic to humans. Climate change will not change this. |

**a41**. IMPACT ON OTHER DOMAINS – Due to climate change, the consequences of *the species* on other domains in Poland will:

| | |
|---|---|
| | decrease significantly |
| | decrease moderately |
| **X** | not change |
| | increase moderately |
| | increase significantly |

| | | | | | |
|---|---|---|---|---|---|
| aconf37. | Answer provided with a | low | medium | high<br>**X** | level of confidence |

| | |
|---|---|
| acomm41. | Comments:<br>The species has no impact on the infrastructure facilities. Climate change will not change this. |

## Summary

| Module | Score | Confidence |
|---|---|---|
| Introduction (questions: a06-a08) | 1.00 | 1.00 |
| Establishment (questions: a09-a10) | 1.00 | 1.00 |
| Spread (questions: a11-a12) | 0.75 | 1.00 |
| Environmental impact (questions: a13-a18) | 0.70 | 0.90 |
| Cultivated plants impact (questions: a19-a23) | 0.25 | 0.60 |
| Domesticated animals impact (questions: a24-a26) | 0.38 | 0.50 |
| Human impact (questions: a27-a29) | 0.25 | 1.00 |
| Other impact (questions: a30) | 0.00 | 1.00 |
| Invasion (questions: a06-a12) | 0.92 | 1.00 |
| Impact (questions: a13-a30) | 0.70 | 0.80 |
| Overall risk score | 0.64 | |
| Category of invasiveness | moderately invasive alien species | |

## A6 | Comments

This assessment is based on information available at the time of its completion. It has to be taken into account, however, that biological invasions are, by definition, very dynamic and unpredictable. This unpredictability includes assessing the consequences of introductions of new alien species and detecting their negative impact. As a result, the assessment of the species may change in time. For this reason it is recommended that it regularly repeated.

acomm42. Comments:

–

## Data sources

**1. Published results of scientific research (P)**


Aniszewski T, Kupari MH, Leinonen AJ. 2001. Seed Number, Seed Size and Seed Diversity in Washington Lupin (*Lupinus polyphyllus* Lindl.). Annals of Botany 87: 77-82

Davis MR. 1991. The comparative phosphorus requirements of some temperate perennial legumes. Plant and Soil 133(1): 17-30

Falencka-Jabłońska M. 2007. Gatunki roślin synantropijnych jako wskaźniki stopnia przekształcenia biocenoz leśnych. Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej 9(2/3): 279-287

Faliński JB. 1986. Vegetation Dynamics in Temperate Lowland Primeval Forests. pp. 537. Springer Netherlands.

Faliński JB. (ed.) 1968. Park Narodowy w Puszczy Białowieskiej. s. 503. PWRiL, Warszawa

Hejda M. 2013. Do species differ in their ability to coexist with the dominant alien *Lupinus polyphyllus*? A comparison between two distinct invaded ranges and a native range. NeoBiota 17: 39-55

Jakobsson A, Padrón B, Agren J. 2015. Distance-dependent effects of invasive *Lupinus polyphyllus* on pollination and reproductive success of two native herbs. Basic and Applied Ecology 16: 120-127

Kurlovich BS. (ed.) 2002. *Lupins*. Geography, classification, genetic resources and breeding. s. 468. OY International North Express, St. Petersburg, Pellosniemi

Lahti T, Lampinen R, Kurtto A. 1995. Suomen putkilokasvien levinneisyyskartasto. Version 2.0. University of Helsinki, Finnish Museum of Natural History, Botanical Museum, Helsinki.

Li JL, Cornman RS, Evans JD, Pettis JS, Zhao Y, Murphy C, Peng WJ, Wu J, Hamilton M, Boncristiani HF, Jr., Zhou L, Hammond J, Chen YP. 2014. Systemic Spread and Propagation of a Plant-Pathogenic Virus in European Honeybees, *Apis mellifera*. mBio 5(1): e00898-13 (doi:10.1128/mBio.00898-13)

Li S-L, Vasemägi A, Ramula S. 2016. Genetic variation and population structure of the garden escaper *Lupinus polyphyllus* in Finland. Plant. Syst. Evol. 302: 399-407

Loydi A, Donath TW, Eckstein RL, Otte A. 2015. Non-native species litter reduces germination and growth of resident forbs and grasses: allelopathic, osmotic or mechanical effects? Biological Invasions 17(2): 581-595

Magnusson B, Myrold DD, Reed SC, Sigurdsson BD, Körner C. 2014. Ecological consequences of the expansion of N2‐fixing plants in cold biomes. Oecologia 176: 11–24

Meier CI, Reid BL, Sandoval O. 2013. Effects of the invasive plant *Lupinus polyphyllus* on vertical accretion of fine sediment and nutrient availability in bars of the gravel-bed Paloma river. Limnologica 43(5): 381-387

Mirek Z, Piękoś-Mirkowa H, Zając A, Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. p. 422. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Parfenov VI. 1999. Opredelitel' vysšich rastenij Belarusi. Izdatel'stvo "Dizajn PRO", Minsk

Podbielkowski Z. 1995. Wędrówki roślin. p. 238. Wyd. Szkolne i Pedagogiczne, Warszawa

Ramula S. 2014. Linking vital rates to invasiveness of a perennial herb. Oecologia 174: 1255-1264

Ramula S, Pihlaja K. 2012. Plant communities and the reproductive success of native plants after the invasion of an ornamental herb. Biological Invasions 14(10): 2079-2090

Ramula S, Sorvari J. 2017. The invasive herb *Lupinus polyphyllus* attracts bumblebees but reduces total arthropod abundance. Arthropod-Plant Interactions 11(6): 911-918

Schaeffer SM, Sharp E, Schimel SP, Welker JM. 2013. Soil-plant N processes in a High Arctic ecosystem, NW Greenland are altered by long-term experimental warming and higher rainfall. Glob Change Biol 19: 3529–3539

Szweykowska A, Szweykowski J. (eds.) 1993. Słownik botaniczny. Wiedza Powszechna, Warszawa

Święczkowska J, Hołdyński Cz. 2017. Flora il zróżnicowanie zbiorowisk nieleśnych Puszczy Boreckiej. sp. 233. Wydawnictwo Uniwersytetu Warmińsko-Mazurskieo w Olsztynie, Olsztyn

Timmins SM, MacKenzie IW, 1995. Weeds in New Zealand Protected Natural Areas Database. Department of Conservation Technical Series, 8. Wellington, New Zealand: Department of Conservation, ss. 291 (http://www.doc.govt.nz/Documents/science-and-technical/docts08.pdf)

Tokarska-Guzik B. 2005. The establishment and spread of alien plant species (kenophytes) in the flora of Poland. Wydawnictwo Uniwersytetu Śląskiego, Katowice.

Tokarska-Guzik B, Dajdok Z, Zając M, Zając A, Urbisz A, Danielewicz W, Hołdyński Cz. 2012. Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych. [Alien plants in Poland with particular reference to invasive species]. Generalna Dyrekcja Ochrona Środowiska, Warszawa

Valtonen A, Jantunen J, Saarinen K. 2006. Flora and lepidoptera fauna adversely affected by invasive *Lupinus polyphyllus* along road verges. Biological Conservation 133(3): 389-396

Vinogradova Yu, Tkacheva EV, Mayorov SR. 2012. About Flowering Biology of Alien Species: 1. *Lupinus polyphyllus* Lindl. Russian Journal of Biological Invasions 3(3): 163-171

Vyšniauskienė R, Rancelienė V, Žvingila D, Patamsytė J. 2011. Genetic diversity of invasive alien species *Lupinus polyphyllus* population in Lithuania. Agriculture 98: 383-390

Zając A, Zając M. (eds.) 2001. Atlas rozmieszczenia roślin naczyniowych w Polsce. p. xii + 714. Nakładem Pracowni Chorologii Komputerowej Instytutu Botaniki Uniwersytetu Jagiellońskiego, Kraków.

Zając A, Zając M. (eds.) 2015. Distribution of kenophytes in the Polish Carpathians and their foreland. Nakładem Instytutu Botaniki Uniwersytetu Jagiellońskiego, Kraków

**2. Databases (B)**

CABI 2018. *Lupinus polyphyllus* [original text by Ramula S.]. In: Invasive Species Compendium. (www.cabi.org/isc)

EPPO 2018. *Lupinus polyphyllus* (LUPPO) (https://gd.eppo.int/taxon/LUPPO)

Fremstad E. 2010. NOBANIS – Invasive Alien Species Fact Sheet – *Lupinus polyphyllus*. – From: Online Database of the European Network on Invasive Alien Species – NOBANIS (https://www.nobanis.org/globalassets/speciesinfo/l/lupinus-polyphyllus/lupinus-polyphyllus.pdf)

The Plant List 2013. *Lupinus polyphyllus* Version 1.1. Published on the Internet (http://www.theplantlist.org/tpl1.1/record/ild-8908)

USDA NRCS 2018. Plants Database. Data Source and Documentation for *Lupinus polyphyllus* Lindl. (https://plants.usda.gov/core/profile?symbol=lupo2)

**3. Unpublished data (N)**

Tokarska-Guzik B. 2016-2017. Conditions of *Lupinus polyphyllus* occuring in the Kamienne Mountains and Rudawy Janowickie Mountains. Data collected as part of the project *The innovate approach supporting monitoring of non-forest Natura 2000 habitats, using remote sensing methods* – HabitARS; NCBiR No BIOSTRATEG2/297915/3/NCBR/2016 (http://habitars.pl/)

**4. Other (I)**

Beuthin M. 2012. Plant guide for bigleaf lupine (*Lupinus polyphyllus*). USDA-Natural Resources Conservation Service, Plant Materials Center, Corvallis, OR. (https://plants.usda.gov/plantguide/pdf/pg_lupo2.pdf)

Pergl J. 2015. EU Non-native Organism Risk Assessment Scheme: *Lupinus polyphyllus* (draft). GB Non-native Species Secretariat.

**5. Author's own data (A)**

Wołkowycki D. 2005-2018. Data on occurrence conditions of *Lupinus polyphyllus* in the Podlasie Province (unpbl.).