Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2017/763379/ETU/ENV.D.2[1]

Name of organism: *Koenigia polystachya* (Wall. ex Meisn.) T.M.Schust. & Reveal

Figure 1 ***Koenigia polystachya*** **in Ireland (Image: Richard Shaw CABI)**

[1] This template is based on the Great Britain non-native species risk assessment scheme (GBNNRA).

Author(s) of the assessment:
including the following elements:

- Rob Tanner, European and Mediterranean Plant Protection Organisation, Paris, France
- Etienne Branquart, Invasive Species Unit, Service Public de Wallonie, Gembloux, Belgium

Risk Assessment Area: The risk assessment area is the territory of the European Union, excluding the outermost regions.

Peer review 1: Oliver Pescott, NERC Centre for Ecology and Hydrology, Wallingford, UK
Peer review 2: Johan van Valkenburg, National Plant Protection Organization, Wageningen, Netherlands

This risk assessment has been peer-reviewed by two independent experts and discussed during a joint expert workshop. Details on the review and how comments were addressed are available in the final report of the study.

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Contents

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**[2]	**COMMENT**
Summarise Entry[3]	**moderately likely**	**medium**	The entry pathway horticulture and transport (contaminant of soil) are the only relevant pathways for the entry of the species into the EU. However, a medium confidence has to be given as there is little evidence that the species is imported into the EU from outside of the risk assessment area.
Summarise Establishment[4]	**very likely**	**high**	The species is established within the risk assessment area in the following member states: Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Poland, United Kingdom. Further establishment is very likely.
Summarise Spread[5]	**moderately**	**medium**	In some Member States (UK for example), the species has shown rapid spread over a very short period of time (e.g. 2 years). Further spread is likely within the risk assessment area but a moderate rating of confidence is given as a rapid spread has not been realised in every member state where the species is established.
Summarise Impact[6]	**moderate**	**low**	Perennial knotweed species (*Fallopia*) in general are known to cause high impacts on the habitats they invade and include impacts on native biodiversity (plants and invertebrate populations). *K. polystachya* may have moderate impacts on biodiversity especially as it grows

2 In a scale of low / medium / high, see Annex III

3 In a scale of very unlikely / unlikely / moderately likely / likely / very likely, see Annex I

4 In a scale of very unlikely / unlikely / moderately likely / likely / very likely, see Annex I

5 In a scale of very slowly / slowly / moderately / rapidly / very rapidly

6 In a scale of minimal / minor / moderate / major / massive, see Annex II

			in more man-made habitats. In addition, the species may negatively impact on ecosystem services and have minimal socio-economic impact. However, there have been no specific scientific studies evaluating the impacts of *K. polystachya* and as a result a low level of confidence is given.
Conclusion of the risk assessment[7]	**moderate**	**medium**	An overall moderate score has been given for the risk assessment which accounts for the likeness of entry, the fact the species is established and the moderate spread potential of the plant. Impacts, although not scientifically evaluated, are likely to be moderate as the species can form dense monocultures which can outcompete native plant species in man-made habitats. However, with the lack of scientific studies a medium level of confidence is given.

[7] In a scale of low / moderate / high

Distribution Summary:

The columns refer to the answers to Questions A6 to A12 under Section A.
The answers in the tables below indicate the following:

Yes recorded, established or invasive
– not recorded, established or invasive
? Unknown; data deficient

Member States

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	YES	YES	YES	
Belgium	YES	YES	YES	YES
Bulgaria	-	-	-	-
Croatia	-	-	-	-
Cyprus	-	-	-	-
Czech Republic	YES	YES	YES*	-
Denmark	YES	YES	YES	-
Estonia	-	-	YES*	-
Finland	-	-	YES	-
France	YES	YES	YES*	YES
Germany	YES	YES	YES*	-
Greece	-	-	-	-
Hungary	-	-	-	-
Ireland	YES	YES	YES	YES
Italy	YES	YES	YES*	-
Latvia	-	-	YES*	-
Lithuania	-	-	YES*	-
Luxembourg	-	-	YES	-
Malta	-	-	-	-
Netherlands	YES	YES	YES	-
Poland	YES	YES	YES*	-
Portugal	-	-	-	-
Romania	-	-	YES*	-

Slovakia	-	-	YES*	-
Slovenia	-	-	YES*	-
Spain		-	YES	-
Sweden	YES	-	YES	-
United Kingdom	YES	YES	YES	YES

* But to a much lower extent

Biogeographical regions of the risk assessment area

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Alpine	YES	YES	YES	-
Atlantic	YES	YES	YES*	YES
Black Sea	-	-	-	-
Boreal	YES	YES	YES	-
Continental	YES	YES	YES*	-
Mediterranean	-	-	YES	-
Pannonian	-	-	-	-
Steppic	-	-	-	-

* But to a much lower extent

SECTION A – Organism Information and Screening	
Organism Information	**RESPONSE**
A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	**Taxonomy:** Scientific name: *Koenigia polystachya* (Wall. ex Meisn.) T.M.Schust. & Reveal Kingdom: Plantae; Phylum: Magnoliophyta; Class: Angiospermae; Order: Caryophyllales; Family: Polygonaceae; Genus: *Koenigia* Note: The most recent taxonomic treatment places Himalayan knotweed in *Koenigia* (Schuster *et al*.., 2015). Many databases and publications use other synonyms. Note that *Persicaria wallichii* Greuter & Burdet is not mentioned as a synonym in Schuster *et al*.. (2015) but is given as the preferred name for *Polygonum polystachyum* Wall. ex Meisn. in The Plant List (2013). **Synonyms:** *Aconogonon polystachyum* (Wall. ex Meisn.) M. Král *Peutalis polystachya* (Wall. ex Meisn.) Raf. *Persicaria polystachya* (Wall. ex Meisn.) H. Gross 1913 *Persicaria wallichii* Greuter & Burdet *Polygonum polystachyum* Wall. ex Meisn. *Reynoutria polystachya* (Wall. ex Meisn.) Moldenke *Rubrivena polystachya* (Wall. ex Meisn.) M. Král **Common name:** English: Himalayan knotweed, bell-shaped knotweed, cultivated knotweed; garden smartweed; Kashmir plume; Danish: syren-pileurt; Finish: seljatatar;

	French: renouée à nombreux épis; German: vielähriger-Knöterich, Himalaya-Knöterich; Italian: poligono a spighe numerose; Dutch: Afghaanse duizendknoop; Norway: syrinslirekne; Russian: горец многоколосый **Description of the species:** *Koenigia polystachya* is a perennial herb growing up to 40-120 cm, rarely up to 180 cm. The stem is unarmed, ascending to erect and branched, usually reddish-brown, often flexuous above, smooth to densely pubescent. Leaves are lanceolate to elliptic-lanceolate, (7.5-) 9-22 (-27) × 2.8-7.8 cm, smooth to densely pubescent above, sparsely to densely below. The inflorescence a wide and spreading panicles are, 4-11 x 1-5.5 cm. Individual flowers are 3-5 mm long, usually creamy-white or sometimes pinkish in colour. Seeds are brown and small (2.1-2.5 mm long, and 1.3-1.8 mm wide). The flowers of *K. polystachya* are heterostylous (~~distyly~~distylous), usually with scattered, numerous reddish glands, slightly fragrant.
A2. Provide information on the existence of other species that look very similar [that may be detected in the risk assessment area, either in the wild, in confinement or associated with a pathway of introduction]	In the horticultural trade within the risk assessment area plants traded as *Persicaria polymorpha* or *Polygonum polymorhum* are morphologically very similar. Another species that recently gained popularity is *Koenigia weyrichii*, and this can be likewise confused. Currently, there is no evidence that *P. polymorpha* nor *Koenigia weyrichii* are invasive within the risk assessment area. *K. polystachya* can also be confused with Alaska wild-rhubarb (*Koenigia alaskana* (Small) T.M.Schust. & Reveal), which is native to Alaska. *K. alaskana* has petioles that are 0.8-3.5 mm long, inflorescences that are 0-4 cm long, and green-white to white flowers (Flora of North America Editorial Committee, 2015).
A3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the risk assessment area)	A rapid risk assessment has been produced by the GB Non-native Species Secretariat. Great Britain Non-Native Species Secretariat (NNSS, 2015): http://www.nonnativespecies.org/index.cfm?pageid=143 The summary of this GB risk assessment is as follows: Entry risk: very likely, confidence: very high Establishment risk: very likely, confidence: very high Spread risk: intermediate, confidence high Impacts risk: major, confidence medium Conclusion risk: medium, confidence medium

	Other assessments include: • National Biodiversity Ireland (2013): medium risk of impact as an invasive weed (score 16) http://www.biodiversityireland.ie/wordpress/wp-content/uploads/Invasives_taggedMediumImpact_2013RA3.pdf • Alaska Natural Heritage Program (ANHP, 2011): Invasiveness Rank 80/100 http://accs.uaa.alaska.edu/files/invasive-species/Persicaria_wallichii_RANK_POPO5.pdf • Belgium Biodiversity Platform (2018): Prioritization leading to regulation: score 10/12 (List B). http://ias.biodiversity.be/species/show/85 • Switzerland: info flora (2012): The species is included on the Black List of plants in Switzerland https://www.infoflora.ch/fr/assets/content/documents/neophytes/inva_poly_pol_f.pdf • Brittany (France): (Quere and Geslin, 2016) Listed as a IA1 plant: (plants presently present in the territory considered to be invasively invasive within natural or semi-natural plant communities, and competing with native species or producing significant changes in composition, structure and / or ecosystem functioning • Czech Republic: Pergl *et al*.., (2016): Listed on the Grey List: Species with lower impact, but for which some level of management and regulation is desirable In California *K. polystachya* is classified as an noxious weed (B List), Massachusetts, Montana, Oregon it is classified as a B designated weed, and Washington it is classified as a Class B noxious weed) (USDA 2011). The authors are not aware of any other risk assessments for this species.
A4. Where is the organism native?	*Koenigia polystachya* is native to central and eastern Asia (DiTomaso and Healy 2007, eFloras 2008). The species is native to China (Sichuan, Xizang and Yunnan Province), Afghanistan, Bhutan, India, Kashmir, Myanmar, Nepal, Pakistan and southern Tibet) (CABI, 2018; Flora of China, 2018). As the common name suggests, *K. polystachya* is native to high altitude regions occurring in forests and valleys between 2200 and 4500 m above sea level. The species is also recorded in Korea (Hong and Mun, 2003).
A5. What is the global non-native distribution of the organism outside the risk assessment area?	*Koenigia polystachya* has been introduced to North America, Europe, and New Zealand (Hinds and Freeman 2005, Bartoszek *et al*.. 2006, Landcare Research 2011). This species is recorded in the following US States: Alaska, California, Massachusetts, Montana, Oregon, and Washington (USDA 2011). *Koenigia polystachya* has been reported as uncommon in California, except perhaps in North and Central coastline. In Washington, this species has been reported as spreading vigorously (Whatcom County, 2016).

	In Canada in the following Provinces: British Columbia and Nova Scotia,. *K. polystachya* has been documented from Ketchikan and Metlakatla in the Pacific Maritime ecogeographic region of Alaska (AKEPIC 2011). *Koenigia polystachya* is considered an emerging invasive species in the Vancouver region (British Colombia) by the Greater Vancouver Invasive Plant Council (2009). An emerging invasive is defined by them as: currently found in isolated, sparse populations but are rapidly expanding their range within the region.
A6. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species been recorded and where is it established?	Recorded: Terrestrial biogeographic regions: • Alpine, Atlantic, Boreal, Continental Established: Terrestrial biogeographic regions: • Alpine, Atlantic, Boreal, Continental
A7. In which biogeographic region(s) or marine subregion(s) in the risk assessment area could the species establish in the future under current climate and under foreseeable climate change?	Current climate: Atlantic, Alpine, Boreal, Continental and Mediterranean. Future climate: Atlantic, Alpine, Boreal, Continental and Mediterranean. Increased and prolonged temperatures as a result of climate change (extending the growing season) will increase the growth of *K. polystachya* and increase the growth of the rhizome structures below ground increasing the potential invasiveness of the species. *K. polystachya* prefers average temperatures greater than 10 °C). Increased drought periods however, as a result of climate change will potentially limit the invasiveness of the species (*K. polystachya* prefers annual precipitation > 430 mm < 860 mm annually). For details on the assumptions made in relation to climate change see annex VI: projection of climatic suitability.
A8. In which EU member states has the species been recorded and in which EU member states has it established? List them with an indication of the timeline of observations.	Recorded in the following Member States: Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Poland, Sweden, United Kingdom

	Established in the following Member States: Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Poland, United Kingdom Webb & Chater (1964) regard *K. polystachya* as established in central and north-western Europe (e.g. Great Britain, Denmark, The Netherlands, Germany, France and Austria). Originally introduced to Britain as an ornamental garden plant. First recorded in cultivation in Britain in 1900 and by 1917 had spread to the wild in North Devon. Usually found in abandoned gardens and areas where garden waste has been dumped, e.g. roadsides. By 1986 it had been recorded in 205 10km squares across The United Kingdom, increasing to 374 by 1999 and 608 by 2010 (NNSS, 2015). In Ireland the species is described by the national Biodiversity Data Centre (2013) being established and as having a scattered distribution but locally abundant in many places. Pergl *et al.* (2016) record the species as established in the Czech Republic. In Poland the species was first reported by Schube (1927) from Gluchelaz in the Silesian Region (Bartoszek *et al.*, 2006). In Belgium first record was in 1898 (Verloove, 2006) as a rather rare, locally naturalized garden escape (Conolly, 1977). In addition, it was first recorded in 1898 in Oostende. Subsequently, the species was collected in numerous locations throughout Belgium and is well-established in several places: locally abundantly naturalized in the Kempen (Mol, at least since 1974 and Rijkevorsel, since 1995). Sometimes very persistent and probably naturalized elsewhere (Mirwart, Wijnegem, Petite-Chapelle). Usually found on canal- or river banks, road verges, sometimes in wasteland or as a relic of cultivation near houses (Verloove, 2017). In Italy is considered a naturalized alien and invasive; However, still no particular threats to biodiversity have been shown (Galasso *et al.*, 2006) *Koenigia polystachya* is resident in Sweden (GBIF, 2015). **Non-EU States (outside of the risk assessment area) but worth mentioning** *Koenigia polystachya* is distributed throughout Switzerland (Info Flora. 2012). *Koenigia polystachya* is established in Norway at four known localities (Lid & Lid 2005).

A9. In which EU member states could the species establish in the future under current climate and under foreseeable climate change?	The information is given separately for current climate and under foreseeable climate change conditions: Current climate: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom Future climate: Austria, Belgium, Czech Republic*, Denmark, Estonia*, Finland, France*, Germany*, Ireland, Italy*, Latvia*, Lithuania*, Luxembourg, Netherlands, Poland*, Romania*, Slovakia*, Slovenia*, Spain*, Sweden, United Kingdom * Risk reduced in future compared to current conditions. Increased and prolonged temperatures as a result of climate change (extending the growing season) will increase the growth of *K. polystachya* and increase the growth of the rhizome structures below ground increasing the potential invasiveness of the species. *K. polystachya* prefers average temperatures greater than 10 oC). Increased drought periods however, as a result of climate change will potentially limit the invasiveness of the species (*K. polystachya* prefers annual precipitation > 430 mm < 860 mm annually). For details on the assumptions made in relation to climate change see annex VI: projection of climatic suitability.
A10. Is the organism known to be invasive (i.e. to threaten or adversely impact upon biodiversity and related ecosystem services) anywhere outside the risk assessment area?	Yes. In its native range, in India in the Valley of the Flowers National Park, dense monocultures are found in habitats affected by past anthropogenic pressures or natural disturbances such as eroded, avalanche-prone, rocky areas with a fragmented treeline. Most recently dense populations were also observed in various natural nutrient poor alpine and sub-alpine ecosystems (Kala and Shrivastava, 2004: Negi *et al* 2017). In Asia, it is considered an alien invasive plant in Sri Lanka, where it is reported to colonise riparian, wetlands, water streams and canals in Nuwara Eliya (central Sri Lanka) and surrounding areas (Gunasekera, 2016). *Koenigia polystachya* is invasive in North America. *Koenigia polystachya* is considered an emerging

	invasive species in the Vancouver region (Canada) by Greater Vancouver (Greater Vancouver Invasive Plant Council, 2009). In the United States, *Koenigia polystachya* has been documented from Ketchikan and Metlakatla in the Pacific Maritime ecogeographic region of Alaska (AKEPIC 2011). In Alaska the species can negatively impact native plant species (the edible species salmonberry *Rubus spectabilis* and thimbleberry *Rubus parviflorus*). CABI (2018) list the species as invasive in California, Montana, Oregon, and Washington (citing USDA-NRCS, 2015). In Washington, this species has been reported as spreading vigorously (NatureServe, 2015).
A11. In which biogeographic region(s) or marine subregion(s) in the risk assessment area has the species shown signs of invasiveness?	Terrestrial biogeographic regions: • Alpine, Atlantic, Continental, (InfoFlora 2012, NNSS 2015, Pergl *et al* 2016; Quere and Geslin, 2016)
A12. In which EU member states has the species shown signs of invasiveness?	Belgium, France, Ireland, United Kingdom (including Scotland) The Belgium Biodiversity Platform (2018) state '*P. wallichii* [*K. polystachya*] grows vigorously and creates large, dense and persistent colonies that exclude native vegetation and prevents the establishment of tree seedlings. It also favours erosion of river banks and greatly alter natural ecosystems'. In Ireland, *K. polystachya* can form monocultures along road sides (Follak *et al*.., 2018) which can over shadow and outcompete native plant species (Personal observation, Tanner, 2009). According to Hill *et al*.. (2009), the adverse impacts of *P. wallichii* [*K. polystachya*] on native British species in terms of competition carries a 'high risk'. It can cause (> 80%) population declines of valued or rare species, and may reduce local species richness irreversibly. At a regional scale, it may cause species decline. However, Hill et al. (2009) also highlights that in the UK poses a 'medium risk' to natural and semi-natural habitats, and may occasionally colonize these areas. In France the species has shown invasive behaviour (Quere and Geslin, 2016). As such the species is listed as a IA1 plant: (plants presently present in the territory considered to be invasive within natural or semi-natural plant communities, and competing with native species or producing significant changes in composition, structure and / or ecosystem functioning).
A13. Describe any known socio-economic benefits	Apart from the value of the species as an ornamental plant sold by the horticulture trade,

of the organism.	*Koenigia polystachya* has little socio-economic benefits to the risk assessment area. The species is available in the horticultural trade as an ornamental garden plant and is often regarded as easy to grow with fragrant flowers. The species is available for sale from 7 suppliers recommended by the RHS plant finder (https://www.rhs.org.uk/Plants/Search-Results?formmode=true&context=l%3Den%26q%3DPersicaria%2Bwallichii%26sl%3DplantForm&query=Persicaria%20wa llichii). Outside of the risk assessment area, the plant is utilised as a vegetable in India (CABI, 2018) and Tibet (Boesi, 2014) but there is no evidence that the species is utilised for this purpose in the risk assessment area.

SECTION B – Detailed assessment

Important instructions:

- In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found."
- The classification of pathways developed by the Convention of Biological Diversity shall be used For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document[8] and the provided key to pathways[9].
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annexes I and II.
- With regard to the confidence levels, see Annex III.

PROBABILITY OF INTRODUCTION and ENTRY

Important instructions:

- Introduction is the movement of the species into the risk assessment area.
- Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within the risk assessment area.
- For organisms which are already present in the risk assessment area, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.1. How many active pathways are relevant to the potential introduction of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	few	high	The only pathways relevant for the entry of the species into the risk assessment area is via the horticulture trade - horticulture (escape from confinement) and transport – Contaminant (transport of habitat material (soil, vegetation).

[8] https://circabc.europa.eu/sd/a/738e82a8-f0a6-47c6-8f3b-aeddb535b83b/TSSR-2016-010%20CBD%20categories%20on%20pathways%20Final.pdf

[9] https://circabc.europa.eu/sd/a/0aeba7f1-c8c2-45a1-9ba3-bcb91a9f039d/TSSR-2016-010%20CBD%20pathways%20key%20full%20only.pdf

1.2. List relevant pathways through which the organism could be introduced. Where possible give detail about the specific origins and end points of the pathways as well as a description of any associated commodities. For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway.	**(1) Horticulture (escape from confinement).** **(2) transport – Contaminant (transport of habitat material (soil, vegetation)**		The main pathway for this species is introduction via the horticulture trade as plants for planting. Historically this is how the species entered the risk assessment area (see Belgium Biodiversity Forum, 2007 and Ison 2011).
Pathway name:	**(1) Horticulture (escape from confinement).**		
1.3. Is introduction along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)? (if intentional, only answer questions 1.4, 1.9, 1.10, 1.11 – delete other rows)	intentional	high	Entry via horticulture is an intentional pathway.
1.4. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.	**moderately likely**	**medium**	Although this pathway has been detailed as a historic pathway for the entry of the species into the risk assessment area (see Branquart *et al.*., 2007 and Ison 2011), there is no evidence that large volumes of the species are imported into the risk assessment area, probably due to the species not being imported from outside of the EU and it appears to have been replaced in trade by *P. polymorpha* and *K. weyrichii*. To highlight this point, an internet search for suppliers from ebay and amazon produced no results. Plantlife (2010) also note that the species is less popular as an ornamental species in recent years. Therefore, it is only moderately likely that large numbers of the organism will travel along this pathway. Information on volumes is not available.

			As entry via this pathway is deliberate, and planting of the species would be the end result of the movement of the species low numbers of propagules could result in the entry of the species.
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	The pathway 'Horticulture (escape from confinement)' is the deliberate movement of plant material into the risk assessment area and as such plant material would be maintained and moved to ensure survival. It is unlikely that *K. polystachya* will multiply along the pathway - Horticulture (escape from confinement) during transport and storage. Rhizomes would be the most likely plant parts for transport, rather than whole plant parts or seeds. Rhizome structures are robust and when packed appropriately could survive prolonged transport. However, cuttings and bare rooted plants or potted plants may also be used.
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	**very likely**	**high**	The pathway 'Horticulture (escape from confinement)' is the deliberate movement of plant material into the risk assessment area and as such plant material would be maintained and moved to ensure survival. No management practices would be carried out along this pathway.
1.7. How likely is the organism to enter the risk assessment area undetected?	**unlikely**	**medium**	It is unlikely that the organism will enter the risk assessment area undetected as the pathway 'Horticulture (escape from confinement)' is the deliberate movement of plant material into the risk assessment area.
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**very likely**	**high**	It is very likely that the organism will arrive during the months of the year most appropriate for establishment as the pathway 'Horticulture (escape from

			confinement)' is the deliberate movement of plant material into the risk assessment area. This can occur all year round.
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**very likely**	**high**	As the pathway is horticulture, which would result in the deliberate planting of the species in an outdoors situation, it is very likely that the species can transfer from this pathway to a suitable habitat.
1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	**moderately likely**	**medium**	A likely score has been given for the overall entry into the risk assessment area as the species has been recorded as entry via this pathway historically. However, the likely score as opposed to very likely coupled with the medium uncertainty is given as there is no evidence that the species enters the risk assessment area via this pathway in current times.
Pathway name:	**(2) Transport – Contaminant (transport of habitat material (soil, vegetation)**		
1.3. Is introduction along this pathway intentional (e.g. the organism is imported for trade) or unintentional (e.g. the organism is a contaminant of imported goods)? (if intentional, only answer questions 1.4, 1.9, 1.10, 1.11 – delete other rows)	unintentional	high	Entry via movement of soil or vegetation (Soll, 2004).
1.4. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Also comment on the volume of movement along this pathway.	**moderately likely**	**medium**	The transport of top soil and or other contaminated material with rhizomes of the species can facilitate entry into the RA area. There is the potential for numerous rhizomes to be transported along this pathway and only a small amount of rhizome is needed to produce a viable plant.
1.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)?	**very likely**	**high**	The pathway Transport – Contaminant (transport of habitat material (soil, vegetation) is the unintentional movement of plant material into the risk assessment

Subnote: In your comment consider whether the organism could multiply along the pathway.			area. As the rhizomes would be moved with soil it is likely that they would survive during passage. It is unlikely that *K. polystachya* will multiply along the pathway Rhizomes would be the most likely plant parts for transport, rather than whole plant parts or seeds. Rhizome structures are robust and when packed appropriately could survive prolonged transport.
1.6. How likely is the organism to survive existing management practices during passage along the pathway?	**likely**	**high**	Soil is unlikely to be treated as it is moved through the pathway and as such plant material would survive.
1.7. How likely is the organism to enter the risk assessment area undetected?	**likely**	**high**	It is likely that the organism will enter the risk assessment area undetected as rhizome material will be hidden in soil and only a small rhizome is needed to produce a viable plant.
1.8. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**very likely**	**high**	It is very likely that the organism will arrive during the months of the year most appropriate for establishment as movement on this pathway can occur all year round.
1.9. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**very likely**	**high**	As the pathway involves the movement of soil this may result in the deliberate positioning of soil (which could be contaminated with rhizome material) in an outdoors situation, it is very likely that the species can transfer from this pathway to a suitable habitat.
1.10. Estimate the overall likelihood of entry into the risk assessment area based on this pathway?	**moderately likely**	**medium**	A moderately likely score has been given for the overall entry into the risk assessment area. However, the likely score as oppose to very likely coupled with the medium uncertainty is given as there is no evidence that the species enters the risk assessment area via this pathway in current times.

PROBABILITY OF ESTABLISHMENT			
Important instructions: • For organisms which are already established in parts of the risk assessment area, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16.			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENT**
1.13. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between climatic conditions within it and the organism's current distribution?	**very likely**	**high**	It is very likely that *Koenigia polystachya* will be able to establish in the risk assessment area with a high level of confidence. The species is already established within the risk assessment area (Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Poland, United Kingdom). Climatic conditions in the EU, particularly in the Atlantic and Continental regions, are similar to those found in the aforementioned countries where the species has formed established populations. In addition, the species could become established in the Alpine and Boreal biogeographical regions.
1.14. How likely is it that the organism will be able to establish in the risk assessment area based on the similarity between other abiotic conditions within it and the organism's current distribution?	**very likely**	**high**	*K. polystachya* has a wide tolerance to soil conditions begin able to grow in soils seasonally waterlogged to free draining soils. *K. polystachya* grows best in nutrient-rich soils (FOEN, 2006; Alaska Natural Heritage Program, 2011). The species is already established within the risk assessment area (Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland,

			Italy, Netherlands, Poland, United Kingdom) further establishment is very likely.
1.15. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in the risk assessment area?	**widespread**	**high**	The habitats necessary for the survival of the species are widespread within the RA area. *K. polystachya* grows best in unshaded areas (WSDA 2008) and seedlings may not survive in shaded areas. This species grows in moist, disturbed sites, roadsides, fields, and waste areas (Hinds and Freeman 2005, DiTomaso and Healy 2010, Klinkenberg 2012). In Poland, it has established only in anthropogenically disturbed areas (Bartoszek 2006). However, it can also establish in areas disturbed by river action or flooding (Washington State Noxious Weed Control Board, 2004). The species grows along riverbanks in the risk assessment area. In Ireland, linear monocultures occur alongside roadsides (personal observation, Tanner).
1.16. If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area ?	**NA**	**high**	*K. polystachya* does not require another species for any part of its lifecycle.
1.17. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	**very likely**	**high**	It is very likely that *K. polystachya* will establishment despite competition from existing species. *K. polystachya* is highly competitive species which grows from an underground rhizome network established in previous seasons. The species emerges early in the growing season (before many native species) and can grow up to 2 metres in height which act to outshade native vegetation (DiTomaso and Healy 2007, Wilson, 2007). The species can form dense monocultures

			which exclude native plants species.
1.18. How likely is it that establishment will occur despite predators, parasites or pathogens already present in the risk assessment area?	**very likely**	**high**	There are no host specific natural enemies within the risk assessment area. Any generalist organisms which feed on or infect *K. polystachya* will not prevent its establishment.
1.19. How likely is the organism to establish despite existing management practices in the risk assessment area?	**moderately likely**	**high**	There are a number of management practices applied to ‘knotweed’ species within the risk assessment area and those management practices for *Fallopia japonica* can be applied for *K. polystachya.* However, these management practices are mainly applied to established populations and not to prevent establishment.
1.20. How likely are existing management practices in the risk assessment area to facilitate establishment?	**likely**	**high**	The establishment of *K. polystachya* is suited to disturbed habitats especially along roadsides and disused waste ground. It is therefore likely that the current urbanization trend occurring in Europe may favor the establishment of the species.
1.21. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in the risk assessment area?	**likely**	**high**	The extensive creeping rhizome underground network produced by the species makes eradication problematic as all underground plant material will need to be eradicated. Root and stem fragments as small as 1cm in length can form new plants colonies (Soll, 2004; NNSS, 2015).
1.22. How likely are the biological characteristics of the organism to facilitate its establishment in the risk assessment area?	**very likely**	**high**	*K. polystachya* is a perennial that reproduces sexually by seed and vegetatively by rhizomes and stem fragments (Soll, 2004; NNSS, 2015). The requirements for seed germination are not documented within the risk assessment area and it is unclear if the seeds are a major component of establishment of the species. Ison (2011) report that seed production is rare in the UK. However, similar to other knotweed species, disturbance (and rhizomes within the soil) can promote the

			establishment of the species. A rhizome fragment as small as 1 cm in length can produce a viable plant.
1.23. How likely is the adaptability of the organism to facilitate its establishment?	**very likely**	**high**	The species is very adaptable, and this is shown with the wide range of habitats and abiotic conditions within which the species can grow. It should also be highlighted that in the plants native range the species grows at high altitude elevations whereas in the risk assessment area, the species can establish at significantly lower elevations.
1.24. How likely is it that the organism could establish despite low genetic diversity in the founder population?	**very likely**	**high**	As previously highlighted, seed production and seed germination are not considered a major reproductive component for the plant. Therefore, as the species multiplies by rhizomes – this will result in a lower genetic diversity. This is not likely to prevent the species from establishing.
1.25. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in the risk assessment area? (If possible, specify the instances in the comments box.)	**very likely**	**high**	*Koenigia polystachya* has been introduced to North America, Europe, and New Zealand (Hinds and Freeman 2005, Bartoszek *et al.*. 2006, Landcare Research 2011). This species is recorded in the following US States: Alaska, California (classified as an noxious weed B List), Massachusetts, Montana, Oregon (B designated weed), and Washington (classified as a Class B noxious weed) (USDA 2011) and in Canada in the following Provinces: British Columbia and Nova Scotia,. *K. polystachya* has been documented from Ketchikan and Metlakatla in the Pacific Maritime ecogeographic region of Alaska (AKEPIC 2011). *Koenigia polystachya* is considered an emerging invasive species in the Vancouver region (British

			Colombia) by the Greater Vancouver Invasive Plant Council (2009). An emerging invasive is defined by them as: currently found in isolated, sparse populations but are rapidly expanding their range within the region. The species is already established within the risk assessment area (Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Netherlands, Poland, United Kingdom) and further establishment is highly likely.
1.26. If the organism does not establish, then how likely is it that casual populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is present because of continual release, is an example of a transient species.	**very likely**	**high**	The species is already established within the risk assessment area.
1.27. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).	**very likely**	**high**	Atlantic, Alpine, Boreal and Continental
1.28. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions	**very likely**	**high**	Thorough assessment of the risk of establishment in relevant biogeographical regions in foreseeable climate change conditions: explaining how foreseeable climate change conditions will influence this risk. ~~With regard to climate change, provide information on~~ • ~~the applied timeframe (2070)~~ • ~~the applied scenario (eRCP 4.5)~~ Increased and prolonged temperatures as a result of climate change (extending the growing season)

			will increase the growth of *K. polystachya* and increase the growth of the rhizome structures below ground increasing the potential invasiveness of the species. *K. polystachya* prefers average temperatures greater than 10 °C). Increased drought periods however, as a result of climate change will potentially limit the invasiveness of the species (*K. polystachya* prefers annual precipitation > 430 mm < 860 mm annually). Modelling by the Centre of Ecology and Hydrology (annex VI) suggests there will be a significant decrease in suitability within Atlantic, Black Sea, Continental and Mediterranean regions. However, there will be an increase in the alpine and boreal Arctic biogeographical region.

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within the risk assessment area.
- Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section. In other words, intentional anthropogenic "spread" via release or escape should be dealt within the introduction and entry section.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How important is the expected spread of this organism within the risk assessment area by natural means? (Please list and comment on each of the mechanisms for natural spread.)	**moderate**	**high**	In general, knotweed rhizomes and stem pieces are transported along waterways and by flooding (DiTomaso and Healy, 2007). Knotweeds can also be dispersed short distances in sea water (Wilson, 2007). Knotweeds can regenerate from <2 cm rhizome (Wilson, 2007). NNSS (2015) notes that seed production is rare and some populations appear to be sterile in the PRA area. Requirements for seed germination/viability are unknown (CABI, 2017). However, others note that *K. polystachya* flowers are perfect (bisexual) and plants regularly produce seed (Wilson, 2007). The small seeds are dispersed by wind/water. Seed production has been reported to be low in California, British Columbia (Alaska Natural Heritage Program (2011). A moderate rating has been given for spread as in some countries where the species is present (e.g. AT, BE and CZ) distribution trends do not show a rapid spread.
2.2. How important is the expected spread of this organism within the risk assessment area by human assistance?	**major**	**medium**	*K. polystachya* is planted as an ornamental in gardens in the EPPO region. In the UK, there are 7 suppliers

(Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities.			in the RHS Plant Finder (https://www.rhs.org.uk/). This species has been promoted by the Daily Telegraph in the UK: http://www.telegraph.co.uk/gardening/plants/10634486/Top-10-plants-for-a-rainy-day.html?frame=2820359 *K. polystachya* has escaped cultivation (CABI, 2017). Dumped garden waste may contain rhizomes and stem fragments (NNSS, 2015). The species can be spread by soil (as a contaminant) especially as only small amounts of rhizomes can form viable plants (Soll, 2004). The one country with a long history of cultivation of *K. polystachya* (UK) has recorded high rates of spread (NNSS, 2015).
2.2a. List and describe relevant pathways of spread. Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 2.3a, 2.4a, etc. and then 2.3b, 2.4b etc. for the next pathway.	UNAIDED (natural dispersal) Transport – Contaminant (transport of habitat material (soil, vegetation)		
Pathway name:	**UNAIDED (natural dispersal)**		
2.3. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**high**	
2.4. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?	**moderately likely**	**high**	One root fragment as small as 1 cm in length can form new plant colonies (CABI, 2018).

2.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	Although there is no research conducted on specific aspects of regeneration in rhizomes for *K. polystachya*, there has been research conducted on other knotweed species. A high rhizome regeneration for *Fallopia japonica* var. *japonica* has been recorded for both terrestrial and aquatic environments highlighting that knotweeds can persist in water bodies for prolonged periods of time and be carried through waterbodies.
2.6. How likely is the organism to survive existing management practices during spread?	**very likely**	**medium**	As 1 cm of rhizome in length can form new plant colonies management practices would need to exhaust all underground plant material which is often impractical along waterbodies.
2.7. How likely is the organism to spread in the risk assessment area undetected?	**very likely**	**high**	As 1 cm of rhizome in length can form new plant colonies, small fragments can be incorporated into waterbodies and spread through the risk assessment area undetected.
2.8. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	If spreading through a riparian system the species is very likely to transfer to a suitable habitat.
2.9. Estimate the potential rate of spread within the Union based on this pathway (please provide quantitative data where possible)	**moderately**	**medium**	In the UK the species has been shown to spread rapidly (however, not due to natural dispersal) (NNSS, 2015), however, it is not clear and unlikely to be due to natural spread. A moderate score has been given as the species has not shown similar high spread in other EU Member States (Branquart pers comm., 2018).
End of pathway assessment, repeat as necessary.			
Pathway name:	**Transport – Contaminant (transport of habitat material (soil, vegetation)**		The transport of top soil and or other contaminated material with rhizomes of the species can facilitate spread within the RA area.
2.3. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional	**unintentional**	**high**	The species would be spread through the contaminant of top soil or other material and thus it is an

(the organism is a contaminant of imported goods)?			unintentional pathway of spread.
2.4. How likely is it that a number of individuals sufficient to originate a viable population will spread along this pathway from the point(s) of origin over the course of one year?	**very likely**	**high**	One root fragment as small as 1 cm in length can form new plant colonies (CABI, 2018).
2.5. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	Although there is no research conducted on specific aspects of regeneration in rhizomes for *K. polystachya*, there has been research conducted on other knotweed species. For *Fallopia japonica* var. *japonica*, as little as 0.7g of root material is sufficient to establish new plants (Brock and Wade, 1992).
2.6. How likely is the organism to survive existing management practices during spread?	**likely**	**medium**	Careful methodical management practices would be needed to ensure that the species did not spread with contaminated soil. This is often not feasible with such small rhizomes.
2.7. How likely is the organism to spread in the risk assessment area undetected?	**very likely**	**high**	Small amounts of rhizomes can regenerate into large plants and thus they can remain buried in top-soil undetected.
2.8. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	Top soil would be physically transferred to suitable habitats and thus it is very likely that the species will transfer to suitable habitats.
2.9. Estimate the overall potential for spread within the Union based on this pathway?	**moderately**	**high**	Although there is no evidence of the movement of the species along this spread pathway, it could be a rapid movement – a low confidence score highlights the lack of information.
2.10. Within the risk assessment area, how difficult would it be to contain the organism in relation to these pathways of spread?	**with some difficulty**	**medium**	The species can spread via natural dispersal which will, will some difficulty be able to be prevented due mainly to connecting water bodies. In addition, spread by contamination will be difficult to prevent as the rhizomes which can regenerate into a viable plant are small.
2.11. Estimate the overall potential rate of spread in relevant biogeographical regions under current conditions	**moderately**	**low**	Within the Atlantic, Black Sea, Continental and Mediterranean regions there is a moderate potential

for this organism in the risk assessment area (using the comment box to indicate any key issues and please provide quantitative data where possible).			for spread.
2.12. Estimate the overall potential rate of spread in relevant biogeographical regions in foreseeable climate change conditions (please provide quantitative data where possible)	**moderately**	**low**	Within the Atlantic, Black Sea, Continental and Mediterranean regions there is a moderate potential for spread.

MAGNITUDE OF IMPACT			
Important instructions: • Questions 2.13-2.17 relate to biodiversity and ecosystem impacts, 2.18-2.20 to impacts on ecosystem services, 2.21-2.25 to economic impact, 2.26-2.27 to social and human health impact, and 2.28-2.30 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed. • Each set of questions starts with the impact elsewhere in the world, then considers impacts in the risk assessment area (=EU excluding outermost regions) separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change). • Only negative impacts are considered in this section (socio-economic benefits are considered in Qu. A.7)			
QUESTION	**RESPONSE**	**CONFIDENCE**	**COMMENTS**
Biodiversity and ecosystem impacts			
2.13. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the risk assessment area?	**major**	**medium**	Dense foliage restricts light to other plants (Info Flora, 2013). *K. polystachya* pushes back [outcompetes] native bushes of edible salmonberry and thimbleberry (eaten fresh and preserved in Alaska) (see http://www.uaf.edu/files/ces/cnipm/annualinvasivespeciesconference/13thAnnualMeetingProceedings/Winter%20-%20Economic%20impacts%20CNIPM%20Presentation%202012%20.pdf) It also grows very quickly and outcompetes native plant species in Pacific Northwest, USA (Natureserve Explorer, 2015) [Himalayan knotweed impacts riparian areas (Skamania County, Washington, Noxious Weeds; WA State Noxious Weed Control Board 2003). It is known to exclude native species (Skamania County, Washington, Noxious Weeds).]

			Many relatives of *K. polystachya* are major invasive species for which more documentation on impacts exists e.g. *Fallopia japonica, F. sachalinensis and F. x bohemica* Lavoie 2017). The commonly cited WSDA (2008) actually addresses 4 knotweeds together and is not specific to Himalayan knotweed. A negative impact of knotweeds (generally) on invertebrates (i.e. reduced abundance and species richness) is mentioned in WSDA (2008) and demonstrated by a European study of *F. japonica*, *F. sacchalinensis* and *F. x bohemica* by Gerber *et al.*. (2008). There is no data specifically for the impact of *K. polystachya* on invertebrates and higher levels of the food chain. *K. polystachya* has large leaves and produces thick foliage, which outshades underlying vegetation (WSDA 2008) and displaces native species (DiTomaso and Healy 2007). This species can limit the establishment of trees (WSDA 2008). *K. polystachya* can reduce the quality of fish and wildlife habitat in riparian areas. Infestations may reduce insect populations that provide food sources to salmon (WSDA 2008).
2.14. How important is the current known impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) in the risk assessment area (include any past impact in your response)?	**moderate**	**low**	To-date there are no know studies that have scientifically evaluated the impact of *K. polystachya* in the risk assessment area. According to Hill *et al.*. (2009), the adverse impacts of *K. polystachya* on native British species in terms of competition carries a ‘high risk’. It can cause local severe (> 80%) population declines of valued or rare species, and may reduce local species richness irreversibly. At a regional scale, it may cause species

			decline. Impacts, although not scientifically evaluated, are likely to be moderate as the species can form dense monocultures which can outcompete native plant species but the current populations within the EU are mainly within man-made habitats (such as along roads) although some of them may be found also in riparian ecosystems (Hill *et al*., 2009; NNSS, 2015; Gunasekera, 2016; Floron 2018). However, with the lack of scientific studies a low level of confidence is given.
2.15. How important is the potential future impact of the organism on biodiversity at all levels of organisation likely to be in the risk assessment area?	**moderate**	**medium**	Impacts, although not currently scientifically evaluated, are likely to be moderate in the future as the species can form dense monocultures which can outcompete native plant species but this occurs mainly in man-made habitats.
2.16. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in the risk assessment area?	**moderate**	**low**	At present within the risk assessment area there have been no studies conducted on the impact of *K. polystachya* on native plant species. According to Hill *et al*.. (2009), *K. polystachya* in the UK poses a 'medium risk' to natural and semi-natural habitats, and may occasionally colonize these areas. However, populations of this species are usually confined to habitats with low or medium conservation value. *K. polystachya* also brings a 'medium risk' of altering ecosystem function, including nutrient cycling, physical alteration, successions and food webs.
2.17. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in the risk assessment area?	**moderate**	**medium**	As a species that has the tendencies to form monospecific stands, there is the potential of the species having a high impact on native biodiversity but as Hill *et al*.., 2009 details the species normally colonises habitats with a low or medium conservation value. In Poland the species 'occurs exclusively in habitats evidently suffering more or less from human impact,

			where it is accompanied by ubiquitous native and synanthropic species' (Bartoszek *et al.*., 2006).
Ecosystem Services impacts			
2.18 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the risk assessment area?	**moderate**	**medium**	No specific scientific studies have been conducted on the impacts of *K. polystachya* on ecosystem services and thus all information comes from observations. It is documented that in the USA, *K. polystachya* reduces the availability of nutrients in the soil. It competes with trees and can reduce shade along rivers and streams by displacing native, woody species (WSDA 2008). Infestations produce dense mats of leaf litter that prevent the germination of native species (Wilson 2007).
2.19. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in the risk assessment area (include any past impact in your response)?	**moderate**	**medium**	No specific scientific studies have been conducted on the impacts of *K. polystachya* on ecosystem services and thus all information comes from observations. As a species that can grow in riparian systems, *K. polystachya* has the potential of negatively impacting on cultural ecosystem services by reducing access to water bodies for recreational activities. The species can also invade urban areas of cultural importance thereby decreasing the appeal. Hill *et al.*., (2009) suggests the impact on ecosystem processes and structures is moderate and reversible.
2.20. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in the risk assessment area in the future?	**moderate**	**medium**	See above comments in question 2.19. With increased spread and established populations, *K. polystachya* will potentially have moderate impacts within Atlantic, Alpine, Boreal, Continental biogeographical regions in the future.
Economic impacts			
2.21. How great is the overall economic cost caused by the organism within its current area of distribution	**moderate**	**medium**	There are no known economic assessments of *K. polystachya* in the current area of distribution excluding

(excluding the risk assessment area), including both costs of / loss due to damage and the cost of current management			the risk assessment area. Control costs for knotweed species can be high and involve significant resources and labour-intensive methods including removal of contaminated soils, however there are no figures available for the species. Kala (2004) suggests that the species can reduce the value of pasture land in the plants native range though no monetary figures are given. Control costs for knotweed species can be high and involve significant resources and labour-intensive methods including removal of contaminated soils, however there are no figures available for the species. In Washington State, USA, when invasive knotweeds are taken together (*Fallopia sachalinense*, *K. polystachya*, *Fallopia japonica and Fallopia bohemica*) the annual direct economic impact per county is estimated at $48 000.
2.22. How great is the economic cost of / loss due to damage* of the organism currently in the risk assessment area (include any past costs in your response)? *i.e. excluding costs of management	**minor**	**medium**	The species can have negative implications for home sellers and buyers as the presence of the species can prevent banks from lending money http://www.telegraph.co.uk/finance/personalfinance/borrowing/mortgages/12012333/Now-its-not-only-knotweed-that-will-stop-you-getting-a-mortgage.html
2.23. How great is the economic cost of / loss due to damage* of the organism likely to be in the future in the risk assessment area? *i.e. excluding costs of management	**minor**	**medium**	See above.
2.24. How great are the economic costs / losses associated with managing this organism currently in the risk assessment area (include any past costs in your response)?	**minor**	**low**	No information has been found on the issue.

2.25. How great are the economic costs / losses associated with managing this organism likely to be in the future in the risk assessment area?	**minor**	**low**	See above.
Social and human health impacts			
2.26. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the risk assessment area and for third countries, if relevant (e.g. with similar eco-climatic conditions).	**minor**	**medium**	The species can have negative implications for home sellers and buyers as the presence of the species can prevent banks from lending money http://www.telegraph.co.uk/finance/personalfinance/borrowing/mortgages/12012333/Now-its-not-only-knotweed-that-will-stop-you-getting-a-mortgage.html. There are no known human health impacts known for this species.
2.27. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the risk assessment area.	**moderate**	**low**	No information has been found on the issue
Other impacts			
2.28. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	**minimal**	**high**	There are no host specific natural enemies within the risk assessment area feeding on the species.
2.29. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box)	**NA**	**medium**	
2.30. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in the risk assessment area?	**moderate**	**medium**	NA: there are no natural enemies within the risk assessment area.

ANNEXES

REFERENCES

AKEPIC database (2011) Alaska Exotic Plant Information Clearinghouse Database. 2011. Available: http://akweeds.uaa.alaska.edu

Alaska Natural Heritage Program (2011). http://accs.uaa.alaska.edu/files/invasive-species/Persicaria_wallichii_RANK_POPO5.pdf http://accs.uaa.alaska.edu/files/invasive-species/Persicaria_wallichii_BIO_POPO5.pdf

Bartoszek *et al*.., 2006. *Polygonum polystachyum* Wall. ex Meissner in Poland: status, distribution, habitats. Biodiv Res Conserv. 1-2, 86-88.

Belgium Biodiversity Plateform (2018) http://ias.biodiversity.be/species/show/85

Boesi, A (2014) Traditional knowledge of wild food plants in a few Tibetan communities. J. Ethnobiol. Ethnomed. 10:75. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4232625/

Biodiversity Ireland (2013): http://www.biodiversityireland.ie/wordpress/wp-content/uploads/Invasives_taggedMediumImpact_2013RA3.pdf

Brock J, Wade M (1992) Regeneration of Japanese knotweed (*Fallopia japonica*) from rhizomes and stems: Observations from greenhouse trials. Proceedings: IXth International Symposium on the Biology of Weeds, Association Nationale Pour La Protection Des PI antes, Dijon, France. pp. 85 - 94.

CABI (2018) *Persicaria wallichii*. http://www.cabi.org/isc/datasheet/120210.

Conolly AP (1977) The distribution and history in the British Isles of some alien species of *Polygonum* and *Reynoutria*. Watsonia 11: 291-311.

DiTomaso JM, Healy EA (2007) Weeds of California and other Western States. Vol 2. Weeds of California and other Western States. Vol 1. CA, USA: UC Davis. [University of California ANR Pub. 3488.]

Flora of North America Editorial Committee (2015) Flora of North America North of Mexico. St. Louis, Missouri and Cambridge, Massachusetts, USA: Missouri Botanical Garden and Harvard University Herbaria. http://www.efloras.org/flora_page.aspx?flora_id=1

Flora of China (2018) http://www.efloras.org/flora_page.aspx?flora_id=2

FOEN (2006) An inventory of alien species and their threat to biodiversity and economy in Switzerland. Federal Office for the Environment, Switzerland.

Follak S, Eberius M, Essl F, Furdos A, Sedlacek N, Trognitz (2018) Invasive alien plants along roadsides in Europe. EPPO Bulletin. DOI: https://doi.org/10.1111/epp.12465

GBIF (2015) Global Biodiversity Information Facility. http://www.gbif.org/species

Gerber E, Krebs C, Murrell C, Moretti M, Rocklin R, Schaffner U (2008) Exotic invasive knotweeds (Fallopia spp.) negatively affect native plant and invertebrate assemblages in European riparian habitats. Biological Conservation, 141(3):646-654.

Galasso G, Colatore A Kleih M (2006) Notula: 1246. In: Notulae alla checklist della fl ora vascolare italiana: 2 (1192-1266). Scoppola A. (ed.). Inform. Bot. Ital., Firenze, 38 (1): 206-207

Greater Vancouver Invasive Plant Council (2009) Invasive plants in Greater Vancouver. https://www.burnaby.ca/Assets/Invasive+Species+-+Invasive+Plants+in+Greater+Vancouver.pdf

Gunasekera L (2016) Himalayan plant invading beautiful Nuwaraeliya. Pahana. 16

Hinds H, Freeman C (2005) Persicaria wallichii Greuter & Burdet. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 12+ vols. New York and Oxford. Vol. 5, p. 581.

Hill MO, Beckmann BC, Bishop JDD, Fletcher MR, Lear DB, Marchant JH, Maskell LC, Noble DG, Rehfisch MM, Roy HE, Roy S, Sewell J (2009) Developing an indicator of the abundance, extent and impact of invasive non-native species (Final report). London, UK: DEFRA, 49 pp. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=16063

Hong SP, Mun HG (2003) Unrecorded and introduced taxon in Korea: *Persicaria wallichii* Greuter & Burdet (Persicaria, Polygonaceae). Korean Journal of Plant Taxonomy 33 (2): 7-219.

Info Flora (2012) *Polygonum polystachyum*. www.infoflora.ch

Ison J (2011) Himalayan knotweed, *Persicaria wallichii* (Factsheet). GB non-native species secretariat (NNSS). York, UK: NNSS, 3 pp. http://www.nonnativespecies.org//factsheet/downloadFactsheet.cfm?speciesId=2603

Kala CP (2004) Pastoralism, plant conservation, and conflicts on proliferation of Himalayan knotweed in high altitude protected areas of the Western Himalaya, India, Biodiversity and Conservation. 13(5), 985-995.

Kala CP, Shrivastava RJ (2004) Successional changes in Himalayan alpine vegetation: two decades after removal of livestock grazing. In: Weed Technology, 18(Suppl.). Lawrence, USA: Weed Science Society of America, 1210-1212.

Klinkenberg, B. (Editor) (2012) *Persicaria wallichii* Greuter & Burdet. In: E-Flora BC: Electronic Atlas of the Plants of British Columbia. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia. Vancouver, BC. [18 February 2011] Available: http://www.geog.ubc.ca/biodiversity/eflora/index.shtml

Landcare Research. 2011. *Persicaria wallichii* Greuter and Burdet (1989). New Zealand Plants. Landcare Research. Lincoln, New Zealand. [25 February 2011] http://nzflora.landcareresearch.co.nz/

Lavoie C (2017) The impact of invasive knotweed species (*Reynoutria* spp.) on the environment: review and research perspectives, Biological Invasions. 19, 2319-2337.

Lid J Lid DT (2005) Norsk flora. (7. ed. by R. Elven). Det norske samlaget, Oslo.

National Biodiversity Data Centre (2013) http://www.biodiversityireland.ie/wordpress/wp-content/uploads/Himalayan-knotweed.pdf

NatureServe (2015) NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: February 15, 2017). http://explorer.natureserve.org/servlet/NatureServe?searchName=Persicaria+wallichii

NNSS (2015) Himalayan knotweed (*Persicaria wallichii*). Rapid Risk Assessment. Non-Native Species Secretariat, UK. http://www.nonnativespecies.org/index.cfm?sectionid=51

Pergl J, Sádlo J, PetruseK A, Laštůvka Z, Musil J, Perglova I, Šanda R, Šefrova H, Šíma J, Vohralík V, Pyšek P (2016) Black, grey and watch lists of alien species in the Czech Republic based on environmental impacts and management stratergy. NeoBiota, 28, 1-37.

Plantlife (2010) Here today, here tomorrow? Horizon scanning for invasive non-native plants. Available at: https://plantnetwork.org/links/biodiversity-wildlife-links/here-today-here-tomorrow-horizon-scanning-for-invasive-non-native-plants/ [accessed 23rd May 2018].

Quere E Geslin J (2016) Liste des plantes vascularies invasives de Bretagne. DREAL Bretagne, Région Bretagne. Conservatoire botanique national de Brest, 27 p. + annexes. Available at: http://www.cbnbrest.fr/docnum.php?id=63312
Schube T. 1927. Ergebnisse der Durchforschung der schlesischen Gef‰sspflanzenwelt in Jahre 1929. Jahres-Bericht der Schlesischen Gesellschaft f¸r vaterlandische Cultur, Breslau 102: 76-82.

Schuster TM. *et al.*. (2015) An updated molecular phylogeny of Polygonoideae (Polygonaceae): relationships of *Oxygonum*, *Pteroxygonum*, and *Rumex*, and a new circumscription of *Koenigia* (Taxon) 64:1188-1208.

Soll J (2004) Controlling knotweed (*Polygonum cuspidatum*, *P. sachalinense*, *P. polystachyum* and hybrids) in the Pacific Northwest. Portland, Oregon, USA: Nature Conservancy, Oregon Field Office. http://www.invasive.org/gist/moredocs/polspp01.pdf

The Plant List, 2013. http://www.theplantlist.org/. Accessed 15/02/17

USDA (2010) Germplasm Resources Information Network (GRIN). Online Database. Beltsville, Maryland, USA: National Germplasm Resources Laboratory. https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx

Washington State Noxious Weed Control Board (2004) Written findings of the Washington State Noxious Weed Control Board. Proposed Listing for 2003. Available at: https://www.nwcb.wa.gov/images/weeds/Polygonum-polystachyum-ca-2004.pdf

Webb DA, Charter (1964) Polygonum, In. T.G. Tutin VH Heywood, NA Burges, DH Valentine, SM Walters and DA Wedd, eds. Flora Europaea, Vol. 1, University Press, Cambridge. Pp. 76-90.

Whatcom County (2016) Noxious Weed List. http://www.whatcomcounty.us/DocumentCenter/View/16498/Whatcom-Co-Noxious-Weed-List-2016?bidId=

Wilson LM (2007) Key to identification of invasive knotweeds in British Columbia. B.C. Ministry of Forest and Range, Forest Practices Branch, Kamloops, B.C. https://www.for.gov.bc.ca/hra/Publications/invasive_plants/Knotweed_key_BC_2007.pdf

WSDA (2008) IPM Plant Profile: Japanese Knotweed, Giant Knotweed, Bohemian Knotweed, Himalayan Knotweed. Integrated Pest Management, Washington State Department of Agriculture. [19th March 2012] http://agr.wa.gov/PlantsInsects/Weeds/Knotweed/Knotweed.aspx

Verloove F (2008) Catalogue of neophytes in Belgium (1800-2005). Filip Verloove. – Meise, National Botanic Garden of Belgium, 2006. 89 p.; ill.; 21 cm. – (Scripta Botanica Belgica, vol. 39).

Verloove F (2017) On: Manual of the Alien Plants of Belgium. Botanic Garden of Meise, Belgium. At: alienplantsbelgium.be, accessed 16/02/2017. Manual of the Alien Plants of Belgium. http://alienplantsbelgium.be/content/rubrivena-polystachya
Informatore Botanica Italiana 38 (I) 191-214, 2006.

ANNEX I Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	Description	Frequency
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Biodiversity and ecosystem impact**	**Ecosystem Services impact**	**Economic impact (Monetary loss and response costs per year)**	**Social and human health impact**
	Question 2.18-22	*Question 2.23-25*	*Question 2.26-30*	*Question 2.31-32*
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected[10]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

[10] Not to be confused with „no impact“.

ANNEX III Scoring of Confidence Levels

(modified from Bacher *et al.*. 2017)

Confidence level	Description
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory.

ANNEX IV Ecosystem services classification (CICES V5.1, simplified) and examples

For the purposes of this risk assessment, please feel free to use what seems as the most appropriate category / level / combination of impact (Section – Division – Group), reflecting information available.

Section	Division	Group	Examples (i.e. relevant CICES "classes")
Provisioning	**Biomass**	**Cultivated *terrestrial* plants**	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes; Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials); Cultivated plants (including fungi, algae) grown as a source of energy *Example: negative impacts of non-native organisms to crops, orchards, timber etc.*
		Cultivated *aquatic* plants	Plants cultivated by in- situ aquaculture grown for nutritional purposes; Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials); Plants cultivated by in- situ aquaculture grown as an energy source. *Example: negative impacts of non-native organisms to aquatic plants cultivated for nutrition, gardening etc. purposes.*
		Reared animals	Animals reared for nutritional purposes; Fibres and other materials from reared animals for direct use or processing (excluding genetic materials); Animals reared to provide energy (including mechanical) *Example: negative impacts of non-native organisms to livestock*
		Reared *aquatic* animals	Animals reared by in-situ aquaculture for nutritional purposes; Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials); Animals reared by in-situ aquaculture as an energy source *Example: negative impacts of non-native organisms to fish farming*
		Wild plants (terrestrial and aquatic)	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition; Fibres and other materials from wild plants for direct use or processing (excluding genetic materials); Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy *Example: reduction in the availability of wild plants (e.g. wild berries, ornamentals) due to non-native organisms (competition, spread of disease etc.)*
		Wild animals (terrestrial and aquatic)	Wild animals (terrestrial and aquatic) used for nutritional purposes; Fibres and other materials from wild animals for direct use or processing (excluding genetic materials);

			Wild animals (terrestrial and aquatic) used as a source of energy *Example: reduction in the availability of wild animals (e.g. fish stocks, game) due to non-native organisms (competition, predations, spread of disease etc.)*
	Genetic material from all biota	**Genetic material** from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population; Higher and lower plants (whole organisms) used to breed new strains or varieties; Individual genes extracted from higher and lower plants for the design and construction of new biological entities *Example: negative impacts of non-native organisms due to interbreeding*
		Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population; Wild animals (whole organisms) used to breed new strains or varieties; Individual genes extracted from organisms for the design and construction of new biological entities *Example: negative impacts of non-native organisms due to interbreeding*
	Water[11]	**Surface water** used for nutrition, materials or energy	Surface water for drinking; Surface water used as a material (non-drinking purposes); Freshwater surface water, coastal and marine water used as an energy source *Example: loss of access to surface water due to spread of non-native organisms*
		Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking; Ground water (and subsurface) used as a material (non-drinking purposes); Ground water (and subsurface) used as an energy source *Example: reduced availability of ground water due to spread of non-native organisms and associated increase of ground water consumption by vegetation.*
Regulation & Maintenance	**Transformation** of biochemical or physical inputs to ecosystems	**Mediation of wastes or toxic substances** of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals; Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals *Example: changes caused by non-native organisms to ecosystem functioning and ability to filtrate etc. waste or toxics*
		Mediation of nuisances of anthropogenic origin	Smell reduction; noise attenuation; visual screening (e.g. by means of green infrastructure) *Example: changes caused by non-native organisms to ecosystem structure, leading to reduced ability to mediate nuisances.*

[11] Note: in the CICES classification provisioning of water is considered as an abiotic service whereas the rest of ecosystem services listed here are considered biotic.

	Regulation of physical, chemical, biological conditions	**Baseline flows and extreme event** regulation	Control of erosion rates; Buffering and attenuation of mass movement; Hydrological cycle and water flow regulation (Including flood control, and coastal protection); Wind protection; Fire protection *Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example, destabilisation of soil, increased risk or intensity of wild fires etc.*
		Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context); Seed dispersal; Maintaining nursery populations and habitats (Including gene pool protection) *Example: changes caused by non-native organisms to the abundance and/or distribution of wild pollinators; changes to the availability / quality of nursery habitats for fisheries*
		Pest and disease control	Pest control; Disease control *Example: changes caused by non-native organisms to the abundance and/or distribution of pests*
		Soil quality regulation	Weathering processes and their effect on soil quality; Decomposition and fixing processes and their effect on soil quality *Example: changes caused by non-native organisms to vegetation structure and/or soil fauna leading to reduced soil quality*
		Water conditions	Regulation of the chemical condition of freshwaters by living processes; Regulation of the chemical condition of salt waters by living processes *Example: changes caused by non-native organisms to buffer strips along water courses that remove nutrients in runoff and/or fish communities that regulate the resilience and resistance of water bodies to eutrophication*
		Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans; Regulation of temperature and humidity, including ventilation and transpiration *Example: changes caused by non-native organisms to ecosystems' ability to sequester carbon and/or evaporative cooling (e.g. by urban trees)*
Cultural	**Direct, in-situ and outdoor interactions** with living systems that depend on presence in the environmental setting	**Physical and experiential** interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions; Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions *Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species*

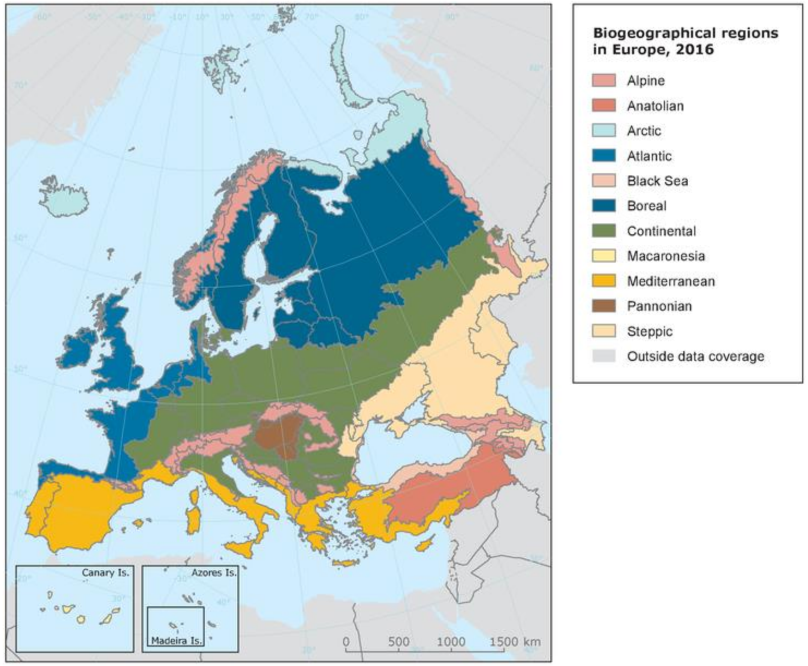
			composition etc.) that make it attractive for recreation, wild life watching etc.
		Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge; Characteristics of living systems that enable education and training; Characteristics of living systems that are resonant in terms of culture or heritage; Characteristics of living systems that enable aesthetic experiences *Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have cultural importance*
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	**Spiritual, symbolic** and other interactions with natural environment	Elements of living systems that have symbolic meaning; Elements of living systems that have sacred or religious meaning; Elements of living systems used for entertainment or representation *Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have sacred or religious meaning*
		Other biotic characteristics that have a **non-use value**	Characteristics or features of living systems that have an existence value; Characteristics or features of living systems that have an option or bequest value *Example: changes caused by non-native organisms to ecosystems designated as wilderness areas, habitats of endangered species etc.*

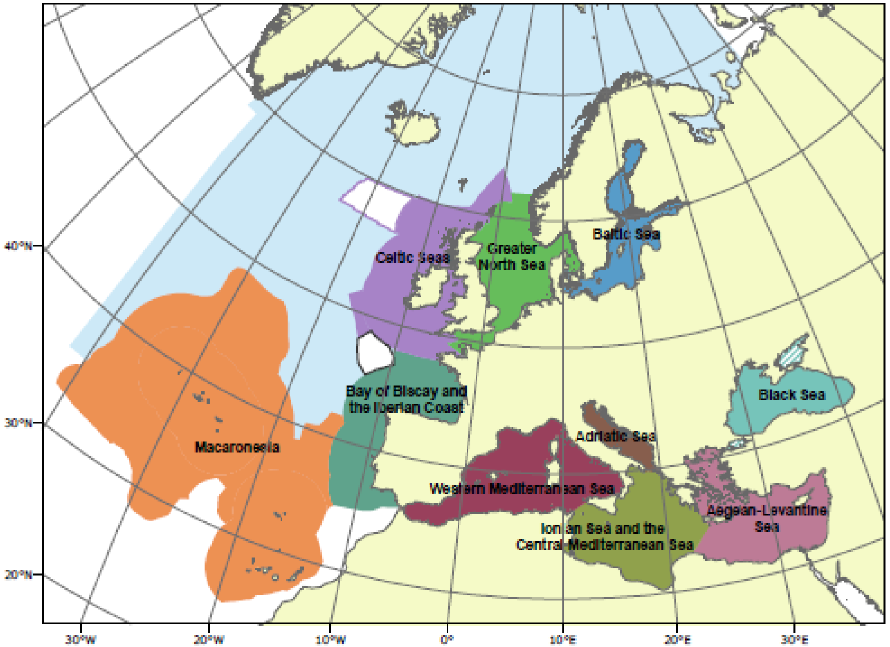
ANNEX V EU Biogeographic Regions and MSFD Subregions

See https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2 , http://ec.europa.eu/environment/nature/natura2000/biogeog_regions/

and

https://www.eea.europa.eu/data-and-maps/data/msfd-regions-and-subregions-1/technical-document/pdf





ANNEX VI: Projection of climatic suitability for *Koenigia polystachya* establishment

Daniel Chapman
20th July 2018

Aim

To project the climatic suitability for potential establishment of *Koenigia polystachya* in Europe, under current and predicted future climatic conditions.

Data for modelling

Species occurrence data were obtained by searching multiple large online databases for all synonyms of *Koenigia polystachya* listed by the Global Biodiversity Information Facility (GBIF). The data sources searched were GBIF, Early Detection and Tracking System (EDDMaps), Atlas of Living Australia (ALA), USGS Biodiversity Information Serving Our Nation (BISON), Berkeley Ecoinformatics Engine, Integrated Digitized Biocollections (iDigBio) and iNaturalist, as well as a personal database of native range records (Rob Tanner, *pers. comm.)*.

We scrutinised occurrence records from regions where the species is not known to be established and removed any that appeared to be dubious or where the georeferencing was too imprecise (e.g. records referenced to a country or island centroid) or outside of the coverage of the predictor layers (e.g. small island or coastal occurrences). The remaining records were gridded at a 0.25 x 0.25 degree resolution for modelling (Figure 1a). This resulted in a total of 533 grid cells containing records of *K. polystachya* for the modelling (Figure 1a), which is a reasonable number for distribution modelling.

Current day climate data representing 1960-1990 average conditions were taken from the bioclimatic variables contained within the WorldClim v1 database (Hijmans et al., 2005). These were originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) and were aggregated to a 0.25 x 0.25 degree grid for use in the model. Consideration of the likely limiting factors on establishment by *Koenigia polystachya* in Europe led to selection of the following climate variables were used in the modelling:

- Minimum temperature of the coldest month (Bio6 °C) reflecting winter cold stress.
- Mean temperature of the warmest quarter (Bio10 °C) reflecting the summer thermal regime.
- Climatic moisture index (CMI, ratio of mean annual precipitation, Bio12, to annual potential evapotranspiration, PET) reflecting plant moisture regimes. To calculate CMI, monthly PETs were estimated from the WorldClim monthly temperature data and solar radiation using the simple method of Zomer et al. (2008) which is based on the Hargreaves evapotranspiration equation (Hargreaves, 1994). *Koenigia polystachya* occurs in relatively humid environments and might be restricted by excessive drought stress. CMI was log+1 transformed for analysis.
- Precipitation seasonality (Bio15, the coefficient of variation among monthly precipitations), reflecting the likelihood of periodic drought or waterlogging stress.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 4.5 and 8.5 were also obtained. For both scenarios, the above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m).

RCP 4.5 is a moderate climate change scenario in which CO_2 concentrations increase to approximately 575 ppm by the 2070s and then stabilise, resulting in a modelled global temperature rise of 1.8 °C by 2100 (90^{th} percentile range 1.1-2.6 °C) (IPCC Working Group I, 2013). RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change. In RCP8.5 atmospheric CO_2 concentrations increase to approximately 850 ppm by the 2070s, resulting in a modelled global mean temperature rise of 3.7 °C by 2100 (90^{th} percentile range 2.6 to 4.8°C) (IPCC Working Group I, 2013).

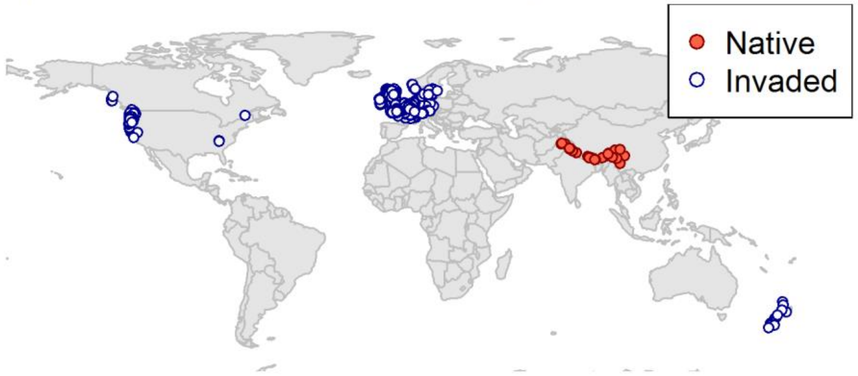
The model also included one non-climatic predictor to capture a possible association between human activities and invasive non-native species:

- <u>Human influence index</u> from the Global Human Influence Index Dataset of the Last of the Wild Project (WCS & CIESIN, 2005) which is developed from nine global data layers covering human population pressure (population density), human land use and infrastructure (built-up areas, night-time lights, land use/land cover) and human access (coastlines, roads, railroads, navigable rivers). The index ranges between 0 and 1 and was log+1 transformed for the modelling to improve normality.

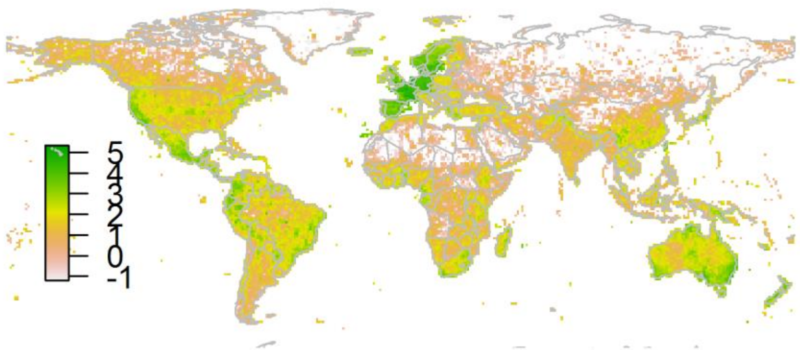
Finally, the recording density of vascular plants (phylum Tracheophyta) on GBIF was obtained as a proxy for spatial recording effort bias (Figure 1b).

Figure 1. (a) Occurrence records obtained for *Koenigia polystachya* and used in the modelling, showing the native range and (b) a proxy for recording effort – the number of vascular plant records (phylum Tracheophyta) held by the Global Biodiversity Information Facility, displayed on a $\log_{10}$ scale.

(a) Species distribution used in modelling



(b) Estimated recording effort (log10-scaled)



Species distribution model

A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale (Elith et al., 2010), we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore background samples (pseudo-absences) were sampled from two distinct regions:

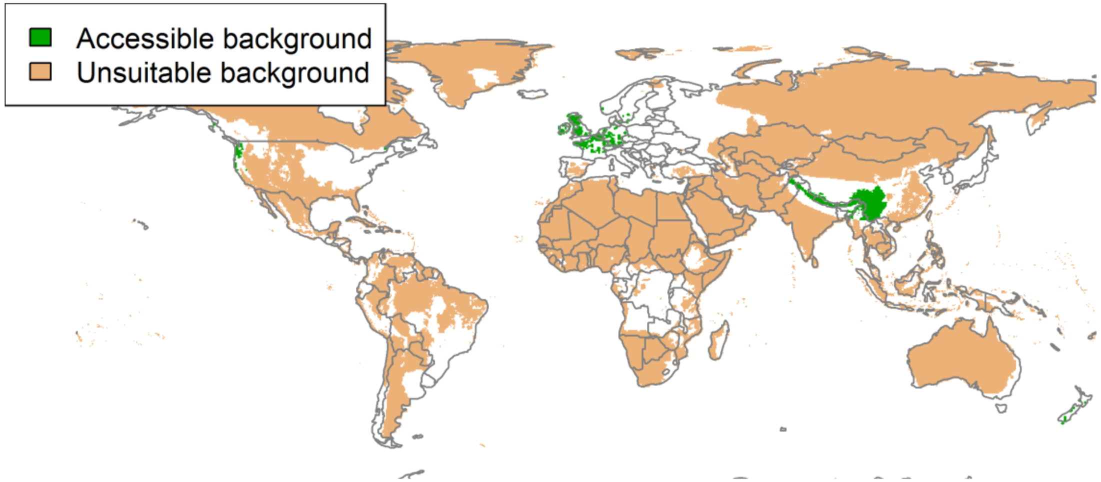
- An accessible background includes places close to *K. polystachya* populations, in which the species is likely to have had sufficient time to disperse and sample the range of environments. We defined the accessible background as a 400 km buffer around the minimum convex polygon bounding native records and a 40 km buffer around non-native records. Accessibility was more restricted in the invaded range to account for stronger dispersal constraint over a shorter residence time, as well as reports of greater reliance on vegetative reproduction in the invaded range (CABI, 2018), which may be less dispersive. Prior testing of the model methods shows the choice of buffer distance is usually not critical to the modelling.

- An unsuitable background includes places with an expectation of environmental unsuitability, e.g. places too cold or dry. Absence from these regions should be irrespective of dispersal constraints, allowing inclusion of this background in the modelling. No specific ecophysiological information was available to define the unsuitable region, but based on expert opinion that temperature and drought are likely to be limits on *K. polystachya* occurrence in Europe unsuitability was defined as:
    - Minimum temperature of the coldest month (Bio6) < -20 °C, OR
    - Mean temperature of the warmest quarter (Bio10) < 4 °C, OR
    - Mean temperature of the warmest quarter (Bio10) > 26 °C, OR
    - Climatic moisture index (CMI) < 0.45.

None of the occurrences fell within the unsuitable background.
Ten random background samples were obtained:

- From the accessible background 533 samples were drawn, which is the same number as the occurrences. Sampling was performed with similar recording bias as the distribution data using the target group approach (Phillips, 2009). In this, sampling of background grid cells was weighted in proportion to GBIF recording density (Figure 1b). Taking the same number of background samples as occurrences ensured the background sample had the same level of bias as the data.
- From the unsuitable background 3000 simple random samples were taken. Sampling was not adjusted for recording biases as we are confident of absence from these regions. Model testing on other datasets has shown that this method is not overly sensitive the number of unsuitable background samples.

Figure 2. The background regions from which ‘pseudo-absences’ were sampled for modelling. The accessible background is assumed to represent the range of environments the species has had chance to sample. The unsuitable background is assumed to be environmentally unsuitable for the species.



Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, seven statistical algorithms were fitted with the default BIOMOD2 settings (except where specified below) and rescaled using logistic regression:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per effect.
- Artificial neural network (ANN)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- Maxent (Phillips et al., 2008)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2’s default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, which were reserved from model fitting. AUC is the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected pseudo-absence.

An ensemble model was created by first rejecting poorly performing algorithms with relatively extreme low AUC values and then averaging the predictions of the remaining algorithms, weighted by their AUC. To identify poorly performing algorithms, AUC values were converted into modified z-scores based on their difference to the median and the median absolute deviation across all algorithms (Iglewicz & Hoaglin, 1993). Algorithms with $z < -2$ were rejected. In this way, ensemble projections were made for each dataset and then averaged to give an overall suitability.

Global model projections were made for the current climate and for the two climate change scenarios, avoiding model extrapolation beyond the ranges of the input variables. The optimal threshold for partitioning the ensemble predictions into suitable and unsuitable regions was determined using the 'minimum ROC distance' method. This finds the threshold where the Receiver-Operator Curve (ROC) is closest to its top left corner, i.e. the point where the false positive rate (one minus specificity) is zero and true positive rate (sensitivity) is one.

Limiting factor maps were produced following Elith et al. (2010). Projections were made separately with each individual variable fixed at a near-optimal value. These were chosen as the median values at the occurrence grid cells. Then, the most strongly limiting factors were identified as the one resulting in the highest increase in suitability in each grid cell. Partial response plots were also produced by predicting suitability across the range of each predictor, with other variables held at near-optimal values.

Results

The ensemble model suggested that at the global scale and resolution of the model suitability for *K. polystachya* was most strongly determined by temperatures of the coldest month and warmest quarter and the climatic moisture index (Table 1, Figure 3). Winter temperatures (Bio6) were optimally around 0-5 °C, while a preference for summer temperatures (Bio10) below 20 °C was apparent. The modelled response to the climatic moisture index indicated a preference for humid conditions in which annual precipitation was at least 70% of potential evapotranspiration.

Global projection of the ensemble model in current climatic conditions indicates that the native and known invaded records all fell within regions predicted to have high suitability (Figure 4). Globally, suitable regions for invasion where the species is not yet present are predicted to occur at high elevations in Africa and South and Central America and in the southern most parts of Australia.

In Europe, the model projects a large region of suitability across western and northern Europe, largely coinciding with places where the species has already established (Figure 5). Additionally, the model indicates potential for further range expansion into regions such as northern Iberia, the British Isles, Scandinavia, the Alps, and the mountains of south east Europe (e.g. Apennines, Dinaric Alps, Carpathians, Caucasus). Uncertainty in this projection is greatest in northeast Europe (Figure 5).

The factors considered by the model to limit suitability vary across Europe in a complex pattern (Figure 6). Broadly speaking, unsuitable parts of southern and eastern Europe were considered to either have too hot summers or to be too dry for the species. In more northerly parts of Europe, the unsuitable regions of France and eastern Germany and Poland were modelled as having too low a climatic moisture index. Since these regions are seemingly thermally suitable, *K. polystacha* might be able to occupy wet micro-habitats such as river banks. Cold winters were only found to be a limiting factor on suitability in northern Scandinavia.

Predictions of the model for the 2070s, under the moderate RCP4.5 and extreme RCP8.5 climate change scenarios, suggest a substantial northwards and uphill retraction of the suitable region, without much gain in suitability in the northernmost regions of Europe (Figure 7-8). This is driven by warmer and drier conditions reducing suitability across northwest Europe.

In terms of Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003), the Atlantic and Alpine are predicted most suitable for invasion in the current climate (Figure 9). Under the future climate scenarios, predicted suitability decreases in all regions except the Arctic. Similar patterns are seen for individual EU member states, depending on which Biogeographical Regions they occupy (Figure 10).

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importances of the fitted model algorithms and the ensemble (AUC-weighted average of the best performing algorithms). Results are the average from models fitted to ten different background samples of the data.

Algorithm	**AUC**	**In the ensemble**	**Variable importance**				
			Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Precipitation seasonality**	**Climatic moisture index**	**Human influence index**
GLM	0.9613	yes	45%	33%	2%	17%	3%
GAM	0.9615	yes	44%	34%	2%	17%	3%
ANN	0.9629	yes	47%	23%	1%	22%	7%
GBM	0.9554	no	20%	31%	0%	22%	26%
MARS	0.9630	yes	48%	29%	2%	21%	1%
RF	0.9440	no	25%	29%	8%	18%	20%
Maxent	0.9464	no	32%	26%	13%	20%	9%
Ensemble	**0.9922**		46%	30%	2%	19%	3%

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the algorithms in the ensemble, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables. Variable codes: bio_6 = mean minimum temperature of the coldest month (°C); bio_10 = mean temperature of the warmest quarter (°C); CMI = climatic moisture index; HII= human influence index; bio_15 = precipitation seasonality. Note that CMI and HII are log+1 transformed.

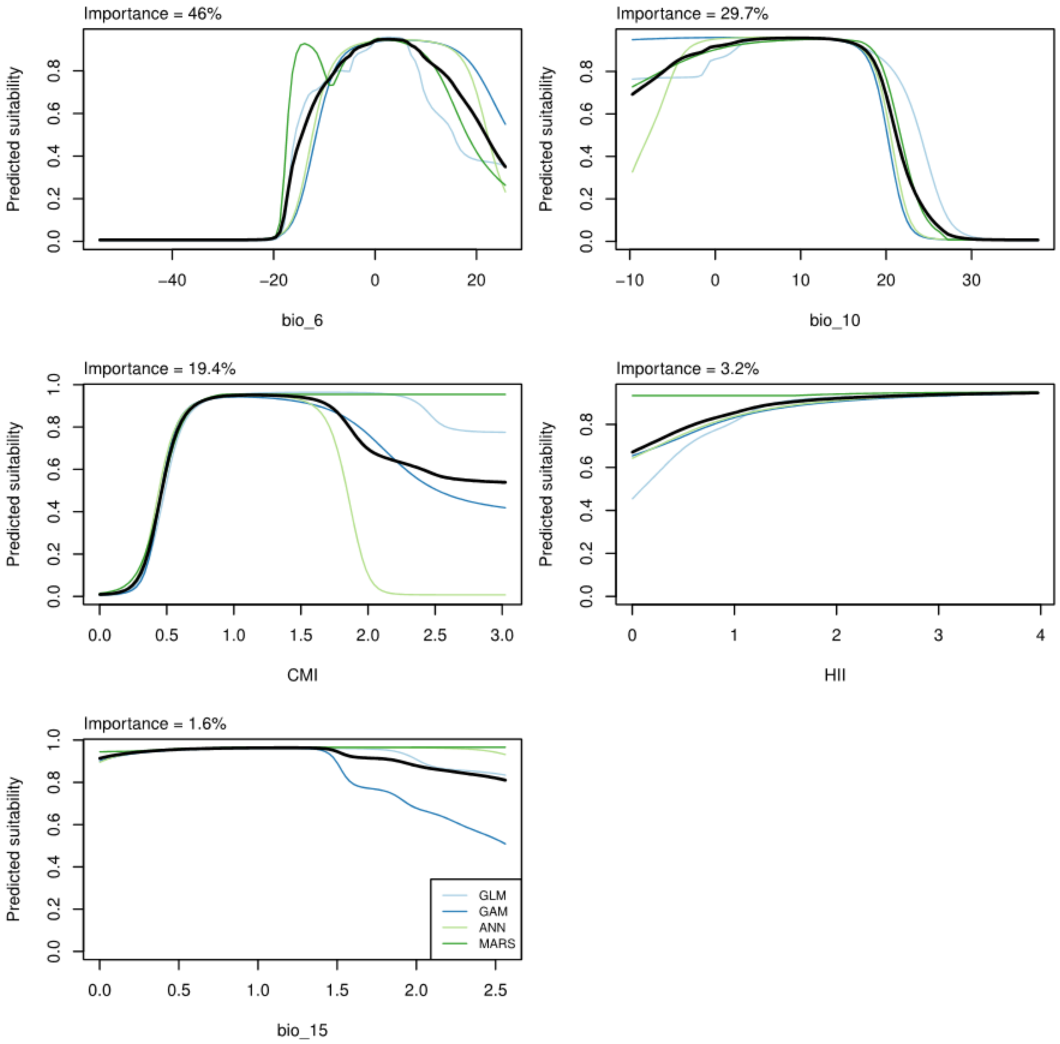

Importance = 46%
Predicted suitability
bio_6
Importance = 29.7%
Predicted suitability
bio_10
Importance = 19.4%
Predicted suitability
CMI
Importance = 3.2%
Predicted suitability
HII
Importance = 1.6%
Predicted suitability
bio_15
GLM
GAM
ANN
MARS

Figure 4. (a) Projected global suitability for *Koenigia polystachya* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Red shading indicates suitability. White areas have climatic conditions outside the range of the training data so were excluded from the projection. (b) Uncertainty in the suitability projections, expressed as the standard deviation of projections from different algorithms in the ensemble model.

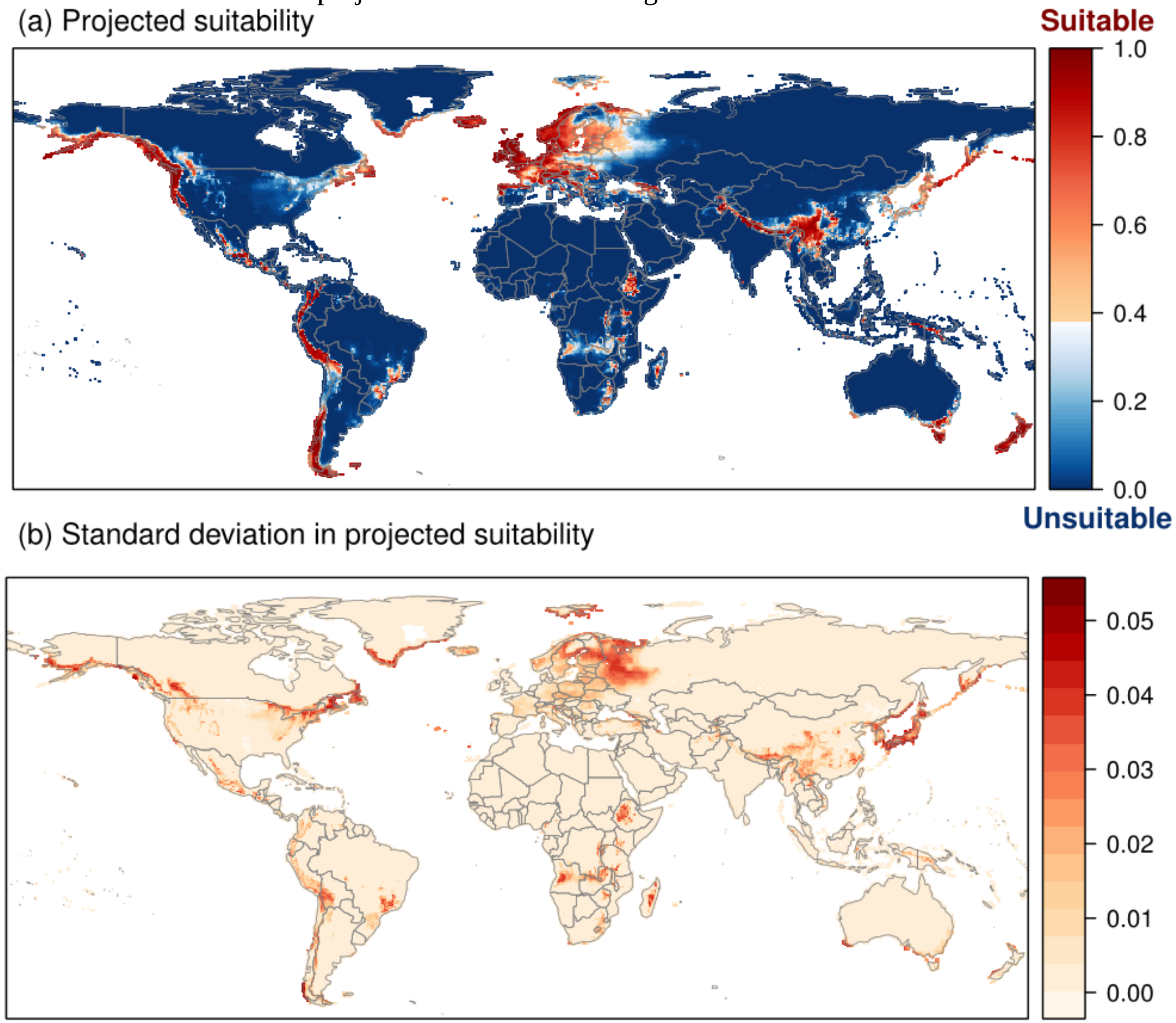


Figure 5. Projected current suitability for *Koenigia polystachya* establishment in Europe and the Mediterranean region. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

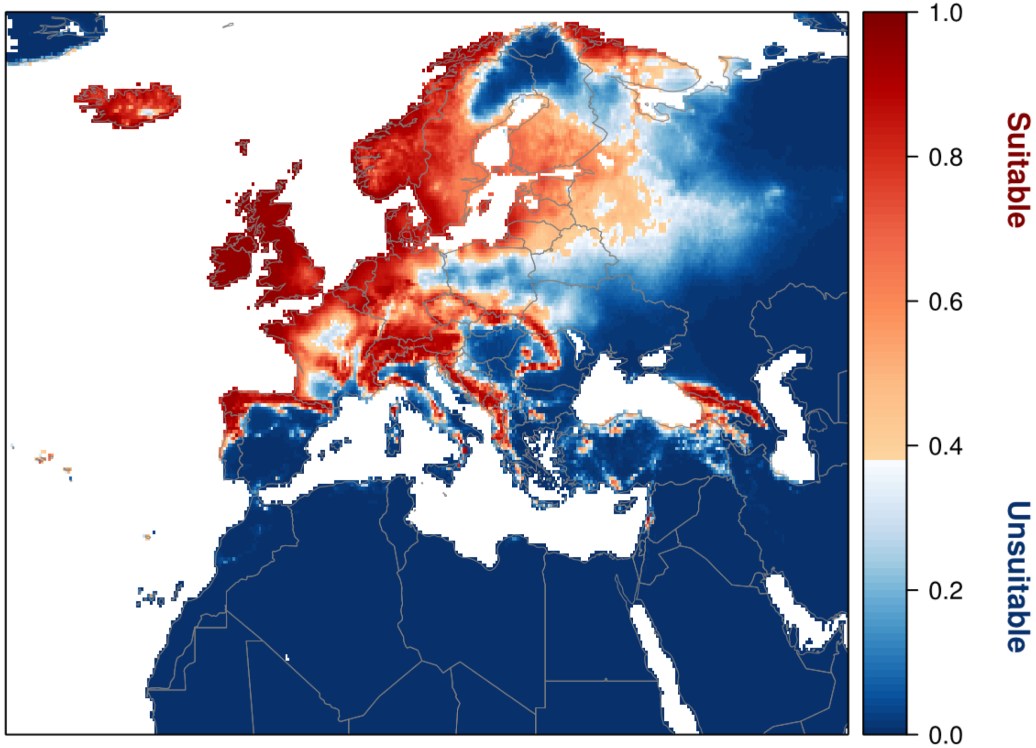


Figure 6. Limiting factor map for *Koenigia polystachya* establishment in Europe and the Mediterranean region in the current climate. Shading shows the predictor variable most strongly limiting projected suitability.

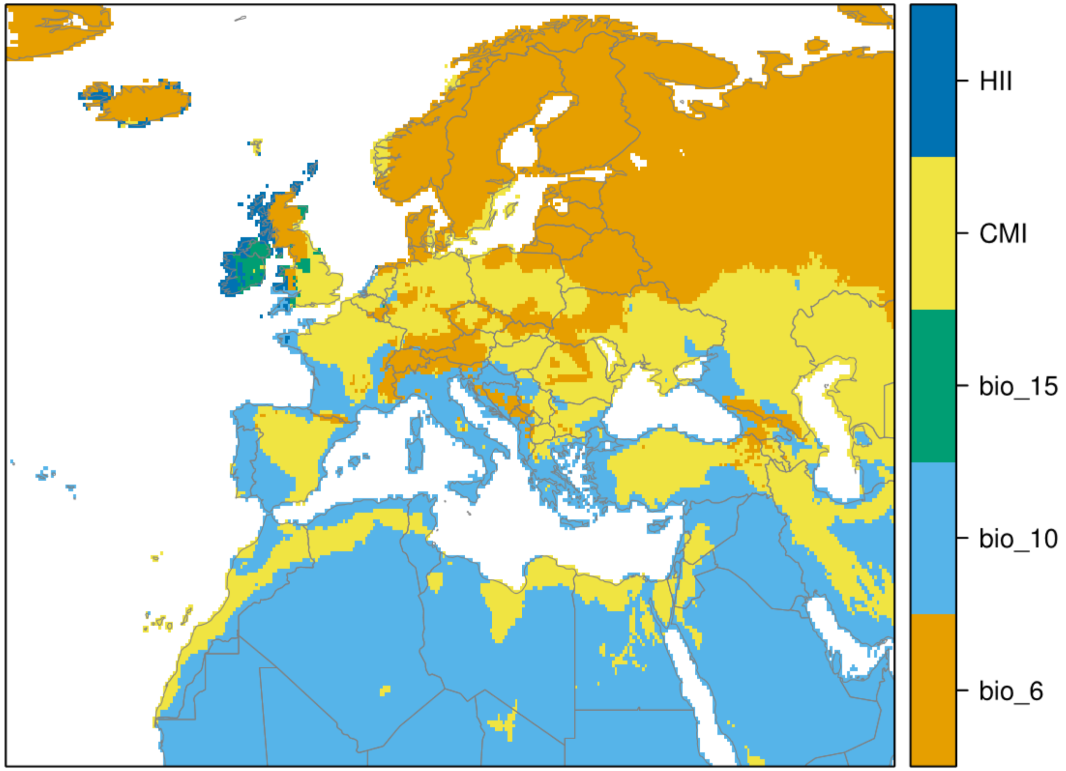


Figure 7. Projected suitability for *Koenigia polystachya* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5, equivalent to Figure 5.

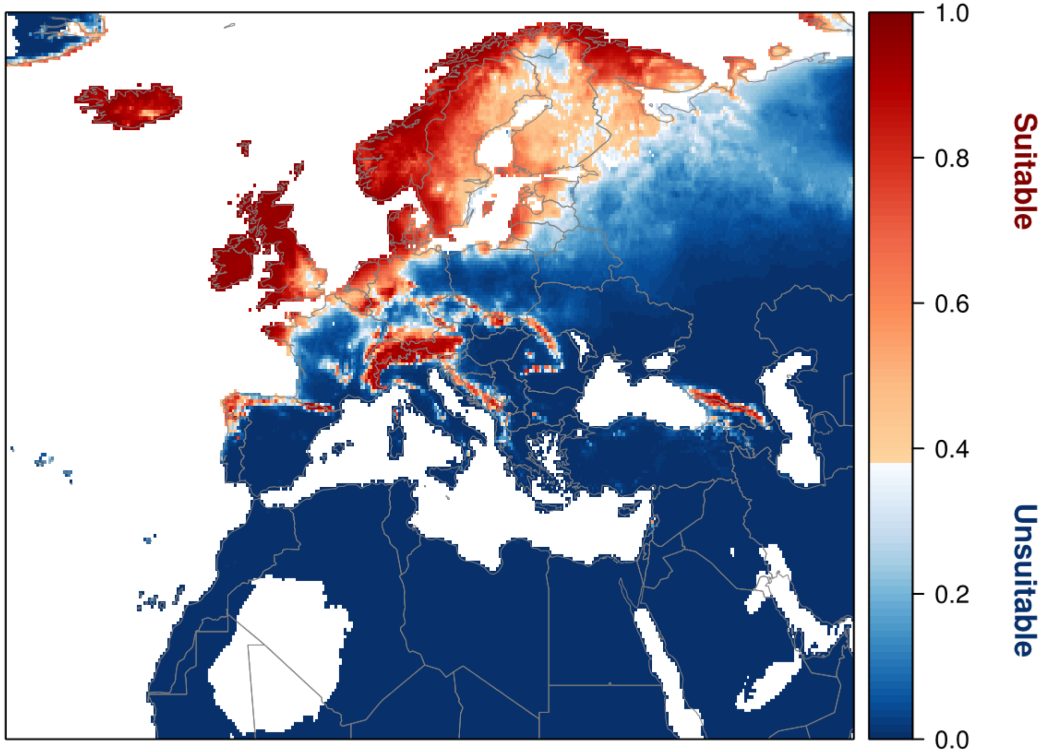


Figure 8. Projected suitability for *Koenigia polystachya* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Figure 5.

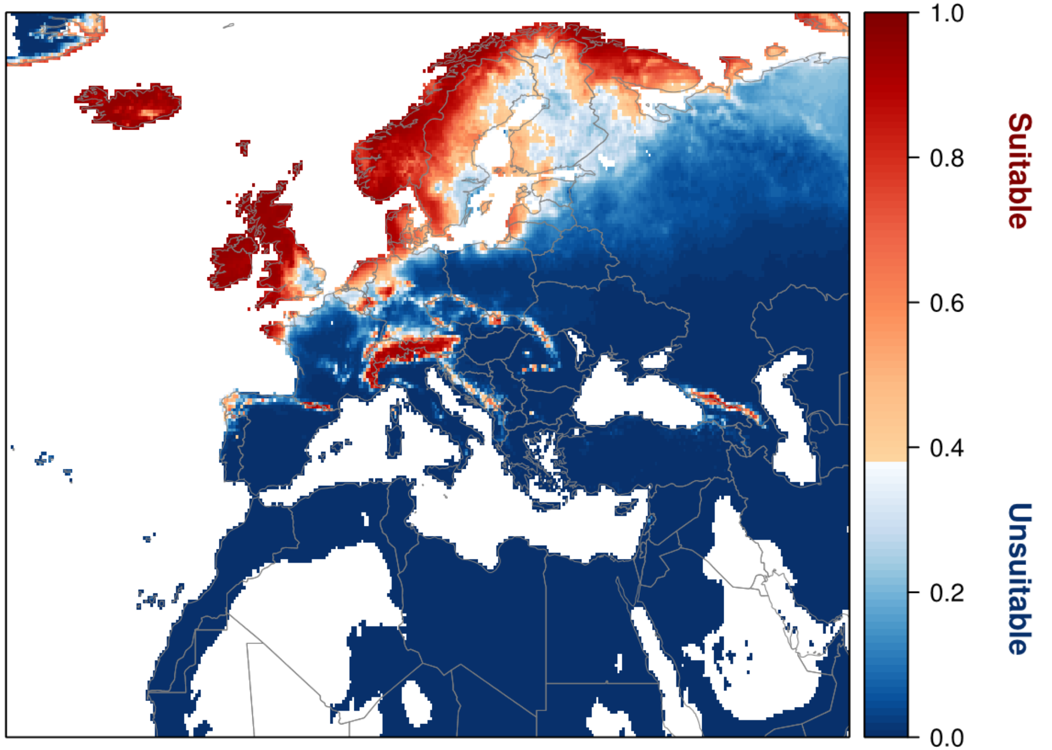
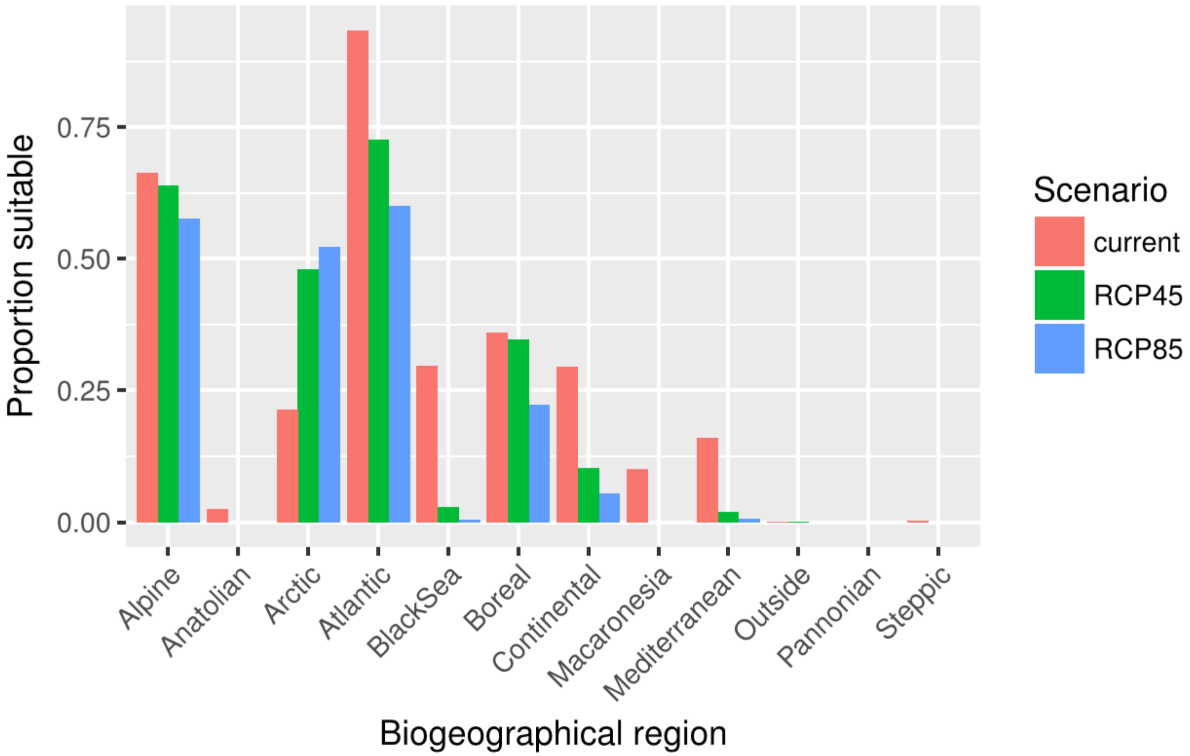

1.0
0.8
0.6
0.4
0.2
0.0
Suitable
Unsuitable

Figure 9. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). The bar plots show the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s under emissions scenarios RCP4.5 and RCP8.5. The coverage of each region is shown in the map below.



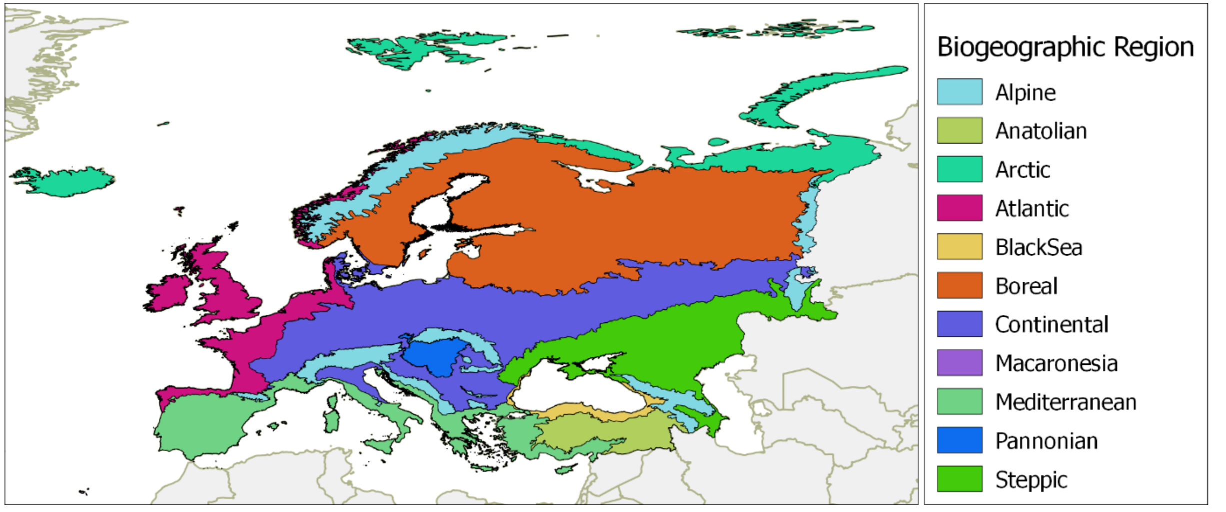
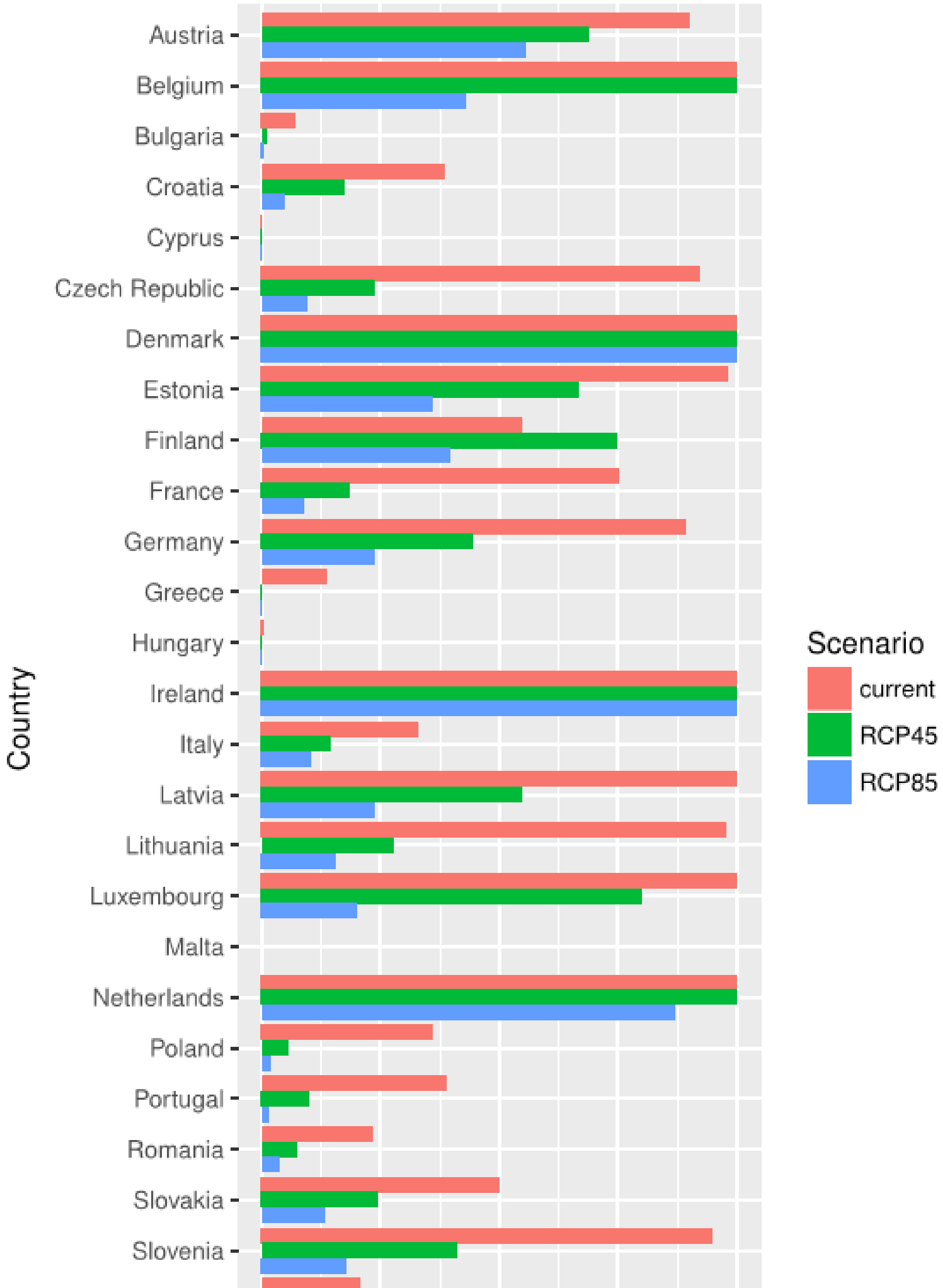

Biogeographic Region
Alpine
Anatolian
Arctic
Atlantic
BlackSea
Boreal
Continental
Macaronesia
Mediterranean
Pannonian
Steppic

Figure 10. Variation in projected suitability among EU28 countries. The bar plots show the proportion of grid cells in each country classified as suitable in the current climate and projected climate for the 2070s under emissions scenarios RCP4.5 and RCP8.5. Malta is excluded as it is outside the predictor grid coverage.


Country
Austria
Belgium
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxembourg
Malta
Netherlands
Poland
Portugal
Romania
Slovakia
Slovenia
Scenario
current
RCP45
RCP85

Caveats to the modelling

Modelling the potential distributions of range-expanding species is always difficult and uncertain.

The modelling here is subject to uncertainty because there was no ecophysiological information available to contribute to definition of the unsuitable background region.

The modelling did not consider other variables potentially affecting occurrence of the species, including soils or biotic interactions.

To reduce the effect of spatial recording biases on the modelling, the selection of the background sample was weighted by the density of vascular plant records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species recording, especially because additional data sources to GBIF were used.

References

CABI (2018) Persicaria wallichii (Himalayan knotweed). *Invasive Species Compendium* CAB International, Wallingford, UK.

Elith, J., Kearney, M., & Phillips, S. (2010) The art of modelling range-shifting species. *Methods in Ecology and Evolution*, **1**, 330–342.

Hargreaves, B.G.H. (1994) Defining and using reference evapotranspiration. *Journal of Irrigation and Drainage Engineering*, **120**, 1132–1139.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., Jarvis, A., Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G., & Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas, Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, **25**, 1965–1978.

Iglewicz, B. & Hoaglin, D.C. (1993) *How to detect and handle outliers.* ASQC Quality Press Milwaukee, WI,

IPCC Working Group I (2013) *Climate Change 2013-The Physical Science Basis: Summary for Policymakers.* Intergovernmental Panel on Climate Change,

Phillips, S.J. (2009) Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. *Ecological Applications*, **19**, 181–197.

Phillips, S.J., Dudík, M., Dudik, M., & Phillips, S.J. (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Source: Ecography*, **31**, 161–175.

WCS & CIESIN (2005) Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Influence Index (HII) Dataset (Geographic). *Society, Wildlife Conservation*, .

Zomer, R.J., Trabucco, A., Bossio, D.A., & Verchot, L. V (2008) Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agr Ecosyst Environ*, **126**, 67–80.