European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes

11-16827

PEST RISK ANALYSIS FOR : *Ludwigia grandiflora*

A Draft PRA had been prepared by Mr Guillaume Fried, and the Expert Working Group was attended by the following experts:
Mr Mustafa Selçuk Basaran, Plant Protection Central Research Institute, Turkey
Mr Alain Dutartre, CEMAGREF, France
Mr Guillaume Fried, LNPV Station de Montpellier, France
Mr Jonathan Newman, Waterland Management Ltd, United Kingdom
Mr Uwe Starfinger, Julius Kühn Institute, Germany
Mr Johan van Valkenburg, Plant Protection Service, The Netherlands
EPPO Secretariat: Ms Sarah Brunel
Comments were received from Ms Iris Stiers, Vrije Universiteit Brussel, Belgium, and Mr Andreas Hussner, University of Duesseldorf, Germany.
Peer review has been undertaken by Ms Schrader, Julius Kühn Institute, Germany.

Picture of *Ludwigia grandiflora*, by Alain Dutartre.

Stage 1: Initiation

1 - Give the reason for performing the PRA

Identification of a single pest

L. grandiflora is widespread and invasive in the South and West of France but its distribution is still very limited in the North and East of France, as well as in Belgium, Germany, Ireland, Italy, the Netherlands, Spain and the UK where invasion is at an early stage. The species could spread to further EPPO countries and have negative impacts on agriculture and the environment.

1b - If other reason, specify

2a - Enter the name of the pest

Pest name (what you enter here will appear as a heading)

Ludwigia grandiflora (Michx.) Greuter & Burdet

The identification of *Ludwigia* species of the section *Oligospermum* s.l. has always been very difficult and resulted in unending taxonomic changes and inextricable synonymy (Dandelot *et al*., 2005a). The *L. uruguayensis* complex comprises a decaploid entity ($2n = 80$) and a hexaploid one ($2n = 48$), differing by quantitative, intergrading morphological features, known to produce hybrids of intermediary morphology in regions of sympatry (Nesom & Kartesz, 2000).

A recent genetic study (Dandelot *et al*., 2005a) showed that *Ludwigia grandiflora* subsp. *hexapetala* (Hook. & Arn.) G.L.Nesom & Kartesz ($2n = 80$) occurs in France.

Synonyms include *Jussiae grandiflora* Michx., *Jussiaea michauxiana* Fernald, nom. illeg., *Jussiaea repens* L. var. *grandiflora* Micheli, *Jussiaea uruguayensis* Cambess, *Ludwigia uruguayensis* (Cambess.) H.Hara, *Ludwigia hexapetala* (Hook. & Arn.) Zardini, H.Y.Gu & P.H. Raven and *Ludwigia uruguayensis* var. major (Hassler) Munz.

Ludwigia grandiflora ressembles and is often confused with *L. peploides*, which often occur together in the same countries. Publications therefore often mention "*Ludwigia* spp.".

2b - Indicate the type of the pest

Non parasitic plant

Perennial aquatic freshwater plant (amphibious hydrophyte, macrophyte).

2c - if other, specify

2d - Indicate the taxonomic position

Kingdom: Plantae
Class: Magnoliopsida (Dicotyledons)
Subclass: Rosidae
Order: Myrtales
Family: Onagraceae

3 - Clearly define the PRA area

The EPPO region

4 - Does a relevant earlier PRA exist?

yes

Plant assessment forms have been produced in California for *Ludwigia hexapetala* (Hook. & Arn.) Zardini, H.Y.Gu & P.H. Raven (Verdone, 2004) using the Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands (Warner *et al.*, 2003).

A risk assessment has also been carried out for Great Britain for *L. grandiflora, L. hexapetala* and *L. peploides* (DEFRA, 2008).

5 - Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?
Not entirely valid

5b - Explain

These risk assessments have been performed in another risk area or only for a part of the EPPO region.

6 - Specify all host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants). Indicate the ones which are present in the PRA area.

In its native range, *Ludwigia grandiflora* is reported in wetlands (Rolon *et al*., 2008), in the transition zone-between aquatic and terrestrial environments (Hernandez & Rangel, 2009).
It colonizes static or slow-flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks. It is also found on sediment bars on river borders and in wet meadows (Laugareil, 2002 ; Zotos *et al*., 2006).

7 - Specify the pest distribution

Native range:
South America: Peru, Argentina, Chile, Costa Rica, Bolivia, Brazil (South), Colombia, Ecuador, Guatemala, Paraguay, Uruguay (CABI, 2010).

Introduced Range:
North America: United States (Alabama, Arkansas, California, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, New Jersey, New York, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington, West Virginia). (USDA, 2010; Boersma *et al*., 2006 in DEFRA, 2008).
Note: in North America, the species is spread across various States, but there are few occurrences reported.
Africa: Kenya (Thendi, 1996 in DEFRA, 2008).
EPPO Region: Belgium (Denys *et al*., 2004), France (Dutartre *et al.*, 2007), Germany (Nehring & Kolthoff, 2011), Ireland (Caffrey, 2009), Italy (Celesti-Grapow *et al*., 2009), the Netherlands (Kleuver & Hoverda, 1995), Spain (Castroviejo *et al*., 1997), United Kingdom (Newman *et al*., 2000).
Note: the species has been eradicated from Switzerland.

<u>In the UK</u>
Ludwigia grandiflora has been noted as a pest species since the middle of the 1990s (Newman *et al*., 2000). It was included in the revised British and Irish flora in 2002 (Preston *et al*., 2002). The situation in 2010 is that there are 13 sites under management (Renals, 2010), but there are likely to be many more occurrences in future due to extensive planting in garden and ornamental ponds (see map in Appendix 1).

<u>In Ireland</u>
The National Biodiversity Data Center website, documenting Ireland's wildlife mentions one record of *L. grandiflora* in the wild (see map in Appendix 1). It is situated in Sneem, in Kerry County, in South-Western Ireland (Caffrey, 2009).

<u>In France</u>
L. grandiflora is very widespread in hundreds of sites in Southern and Western France and more recently has been recorded spreading in some sites in the North and East of France (Dutartre, 2004a, see map in

Appendix 1).

In Germany

The first occurrence of the plant in the wild was found in 2009 in North-Western Lower Saxony (Nehring & Kolthoff, 2011, see map in Appendix 1). A dense growth of the species has been confirmed near Leer in Lower Saxony, in an old branch of the River Leda, a tributary of the River Ems. This stagnant old branch is isolated from the river Leda by an embankment. The branch is 510 m long and on average 30 m wide with a maximum depth of 1 m. The population of *L. grandiflora* was very dense, several stands of different size were found. The old branch has been used for fishing, and several anglers noted that they had first observed the plant in 2004 (Nehring & Kolthoff, 2011).

In Italy

The species was found near Brescia in swamps in 1942 (Arietti, 1942), and was recorded in Lombardia in the Varese Province (Lake Comabbio, Varese, and Brabbia), as well as in Cremona. It has also been found in the Piacentino in Emilia Romana, and in the Veneto (Galasso & Bonali, 2007; Fabris *et al*., 2009).

In Spain

The species is recorded in the Flora Iberica on the Catalan and Valencian coastal areas (Castroviejo *et al*., 1997). In the Communiat Valenciana, the species was first recorded in 1982 where it is quite widely established (Vincente Deltoro, Conselleria de medi Ambient, Aigua, Urbanisme i Habitatge, Communitat Valenciana, pers. comm., 2010, see map in Appendix 1)

In Portugal

In Portugal, *L. grandilfora* is not recorded, only *L. palustris* is recorded (Prof Dr Ana Monteiro, Instituto Superior de Agronomia, pers. comm., 2010).

In the Netherlands

L. grandiflora is reported throughout the country except in the Waddensea Islands. The number of sites remains relatively low, and local abundance varies (Luijten & Odé, 2007) (see map in Appendix 1). The first report of invasive behaviour was in 2000.

In Switzerland

The species was found in a lake near Geneva in 2002 and was eradicated (GREN Biologie appliquée Sarl, 2002), and has not been found since (GREN Biologie appliquée, pers. comm., 2009).

In Belgium

The first occurrence of the species in the wild was in 1983 (Bauchau, 1984). The species is now widespread in Flanders, Northern Belgium (See map in Appendix 1).

Stage 2: Pest Risk Assessment - Section A : Pest categorization

init - -

Go to main Pest Risk Assessment

L. grandiflora has been considered as having high impact on agriculture and the environment by the EPPO prioritization process (Description of the EPPO priotization process Brunel *et al*., 2010).

Stage 2: Pest Risk Assessment - Section B : Probability of entry of a pest

1.1 - Consider all relevant pathways and list them (one by line)

Relevant pathways are those with which the pest has a possibility of being associated (in a suitable life stage), on which it has the possibility of survival, and from which it has the possibility of transfer to a suitable host. Make a note of any obvious pathways that are impossible and record the reasons.

The first observation of *Ludwigia* spp. in the EPPO region was on the river Lez near Montpellier around 1830. The plant was introduced and cultivated at the botanical garden of Montpellier in 1823. According to Martins (1866), one of the gardeners has voluntarily introduced the plant into the river Lez. Another hypothesis is that the plant has been introduced unintentionally into the port of Montpellier Juvenal via the wool industry (Berner, 1971).

- Intentional import as an ornamental aquatic plant for use outdoors

As indicated in the EPPO Decision Support Scheme for quarantine pests, "If the PRA is being conducted on a pest that is intentionally imported, e.g. a plant for planting or a biological control agent, and this is the only pathway of entry, an assessment of its entry potential is not required. However, it is still important to record the volume, frequency and distribution of imports".

L. grandiflora is traded as an ornamental aquatic plant for outdoor use, and is not normally used in aquaria. Trade for ornamental purposes can occur both on the Internet and by direct retail. In general, *L. grandiflora* is likely to be traded under *Jussiaea*, or other erroneous names. In the Netherlands, the species may well be imported under the name *L. peruviana* or *L. peruensis*. In the UK, the species is traded as *Jussiaea grandiflora* and *Jussiaea peploides* (data from UK commercial websites reported by J. Newman, pers. comm., 2010).

According to a recent study analyzing the identity and quantity of aquatic plants imported in 10 EPPO countries between 2005 and 2007 (Brunel, 2009), *L. grandiflora* has been imported as an ornamental plant in France during the sole month of April 2006 from Indonesia (100 units) and from Singapore (170 units). In Austria, the species has been imported from Malaysia (750 units) for the whole year 2006, and in Latvia from Thailand (250 units) from January 2005 until April 2007.

The species is planted in outdoor ponds, and then may transfer to semi-natural and natural habitats (i.e. unintended habitats) of static or slow-flowing waters rivers such as shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks, sediment bars on river borders and in wet meadows (see Q 6). The species is still sold in EPPO countries, and is already naturalized into the wild in Belgium, France, Germany, Ireland, Italy, the Netherlands, Spain, and the UK.

In France, *Ludwigia grandiflora* and *Ludwigia peploides* are not imported anymore because sale and introduction in natural areas is forbidden by law since 2007 (Ministère de l'Ecologie et du Dévelopement Durable, 2007). In Belgium, there is a Royal Decree at the federal level under construction to prohibit the import and export of *L. grandiflora* and *L. peploides* and regional decrees to prohibit the sale, distribution and release into the wild of both species (Ministerial decree in preparation aiming at an action plan for invasive waterplants, H Van Gossum, Agency for Nature and Forest – Flanders, pers. comm., 2011). In Switzerland, there is a federal decree prohibiting the trade of *L. grandiflora* and *L. peploides* (Swiss Confederation, SR 814.911 Ordinance on the Handling of Organisms in the Environment). As of 2011-01-

01, the signatories of the Dutch Code of conduct should stop selling *Ludwigia grandiflora* and *L. peploides* (Anon., 2010).

Although regulated in some countries, the probability of entry by intentional import as an ornamental aquatic plant for use outdoors is very likely, as the species already entered the EPPO region, and continues to enter. Uncertainty is low.

Other pathways that are not considered as relevant

- Intentional import for non ornamental uses

In North America, *L. grandiflora* may be used in bioremediation to remove excess nutrients and herbicides (Bouldin *et al*., 2006 in DEFRA, 2006). Measurements of nitrogen concentrations in invaded sites have not shown any bioremediation potential (experiments described in Dandelot, 2004). There is no evidence in substantial nitrogen reduction in the EPPO region with the use of this species.
There is no information on this pathway for the EPPO region, and it is not considered further in this assessment.

- Contamination of other deliberately planted aquatic plants (e.g. water lilies)

Maki & Galatowitsch (2004) highlighted that some invasive aquatic plants enter Minnesota (USA) as contaminants of other traded ornamental plants. *Ludwigia* spp. were not recorded as contaminants of other ornamental plants, and the risk associated to this pathway is considered minor and is not considered further.

- Natural and human assisted spread are considered in the dedicated section

L. grandiflora can spread either naturally with water currents or assisted by human activities through shipping, angling, etc. Such spread is not considered as a pathway of entry and is considered in the dedicated section (Q 1.32 and 1.33).

Stage 2: Pest Risk Assessment - Section B : Probability of establishment

1.15 - Estimate the number of host plant species or suitable habitats in the PRA area.

Moderate number
Level of uncertainty: low

L. grandiflora colonizes permanent static or slow-flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks. It is also found on sediment bars on river borders and in wet meadows (Laugareil, 2002; Zotos *et al*., 2006).
In the Mediterranean area, the dynamics of the semi-natural water bodies (drought during summer) and increased flow in winter may erode the established plants. This would therefore inhibit the establishment of *L. grandiflora* resulting in colonization of the lower reaches of such river type only.

According to the CORINE Land Cover nomenclature, the suitable habitats are
- Continental waters (water courses, water bodies);
- Banks of continental water, riverbanks/canal sides (dry river beds);
- Wet meadows.

In France, for 567 occurrences where one or the two *Ludwigia* species (*L. grandiflora* or *L. peploides*) were found, Dutartre *et al*. (2007) ranked the colonized habitats:

- slow flowing waters (rivers, and streams): 31.2%
- natural ponds and lakes: 16.7%
- canals and waterways: 14.3%
- oxbow lakes and backwaters: 10.8%
- man made ponds and lakes: 8.3%
- permanent or temporary wetlands: 7.9%
- ditches and ditch networks: 6.2%

- wet meadows: 4.1%
- others: 0.5%

1.16 - How widespread are the host plants or suitable habitats in the PRA area? (specify)
Very widely
Level of uncertainty : low

Freshwater bodies and ecosystems abound in the EPPO region, particularly static or slow-flowing waters, see CORINE Land Cover (2000) map in Appendix 2.
CORINE Land Cover reports in Europe (http://dataservice.eea.europa.eu/dataservice/viewdata/viewpvt.asp):
- 1 082 068 ha of inland marshes (including wetlands, wet margins of ponds and lakes, wet meadows)
- 807 977 ha of water courses (rivers, canals, ditches networks)
- 3 073 442 ha of water bodies (shallow ponds and lakes, oxbow lakes).

1.17 - If an alternate host or another species is needed to complete the life cycle or for a critical stage of the life cycle such as transmission (e.g. vectors), growth (e.g. root symbionts), reproduction (e.g. pollinators) or spread (e.g. seed dispersers), how likely is the pest to come in contact with such species?
Very likely
Level of uncertainty : low

L. grandiflora is pollinated by different insects (bees, beetles, etc.) which are widely present in the EPPO region (Dandelot, 2004). No other species is needed to complete the life cycle of the plant.
Observations *ex situ* showed that without pollinator agents and without wind, none of the two *Ludwigia* species (*L. grandiflora* and *L. peploides*) produce seeds (Dandelot, 2004). However the plant is able to reproduce vegetatively very effectively.

1.18a - Specify the area where host plants (for pests directly affecting plants) or suitable habitats (for non parasitic plants) are present (cf. QQ 1.15-1.17).
This is the area for which the environment is to be assessed in this section. If this area is much smaller than the PRA area, this fact will be used in defining the endangered area.
The EPPO region.

1.18b - How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?
Moderately similar
Level of uncertainty : medium

Ludwigia grandiflora has already established in several EPPO countries (Belgium, France, Germany, Ireland, Italy, the Netherlands, Spain, the UK).

The species is most widespread in France, and particularly in the West of the country under Atlantic climatic conditions. It is also present in the South-East of France, although it is *L. peploides* that dominates there. Both species are increasing in the North-East of France where populations have been observed to be able to survive during winter despite a more continental climate (Dutartre, 2004b).

Although emergent parts of the plant are killed by frost, submerged or buried parts of the plants as well as the rhizomes are reported to survive the winter months explaining the increase of the two *Ludwigia* species further north (Dutartre *et al*., 2007). *Ludwigia* spp. were also observed in the winter of 2009/2010 in outdoor ponds at the Plant Protection Service at Wageningen (J van Valkenburg, pers. comm., 2011).

The EWG considered that the CLIMEX map predicts quite accurately the range at high risk from this species on the basis of the current distribution of the species (see maps in Appendix 3). This map is to be taken as an indication of the potential distribution of the species only. Indeed, there is a lack of data on cold tolerance of *L. grandiflora*, and it is possible that the species could establish in countries with more continental climates. The areas where establishment is considered unlikely may be overestimated by CLIMEX. Because of the early stage of some invasions (e.g. in Ireland, in Germany), it is not possible to use the climate data for the current range to predict the entire area at risk.
Different biogeographical regions of the EPPO region are considered to be suitable for the establishment of *L. grandiflora*:
The Mediterranean basin (Albania, Algeria, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Greece, Israel, Italy, Jordan, Montenegro, Morocco, Spain, Republic of Macedonia, Romania, Tunisia, Turkey, Slovenia) and Atlantic Western Europe (Belgium, France, Ireland, the Netherlands, Portugal, the UK), are susceptible to establishment of this species.
Continental Europe and other parts of Europe (but for which the ecoclimatic index of the species is lower): Austria, Azerbaijan, Czech Republic, North-Western Germany, Denmark, Hungary, Luxembourg, North Western Switzerland, South-Western coast of Norway, Poland, Serbia, Slovakia, Sweden, Russia, Ukraine (Black Sea region).

Thermal ponds or waters with artificially raised temperatures may be additional suitable habitats in countries that are not identified as having suitable overall climates.

1.19 - How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?

Completely similar
Level of uncertainty : low

Both *L. grandilfora* and *L. peploides* are tolerant to a wide range of conditions in terms of nutrient levels, types of substrate (gravel banks or sediments), pH and water quality (Matrat *et al*., 2006). They prefer full light but can tolerate shade (biomass production is reduced under shade); they are limited by flow velocity (greater than 0.25 m/s) (Dandelot, 2004) and by salinity (*L. grandiflora* tolerates up to 6g/L). *Ludwigia* spp. prefer high nutrient conditions (Hussner, 2010) and become dominant in nutrient-rich conditions (Rejamánková, 1992). Hussner (2010) confirms that both *L. grandiflora* and *L. peploides* have a high tolerance to different water levels. The Relative Growth Rate (RGR) of *L. grandiflora* was up to $0.059 \pm 0.002\ d^{-1}$ under experiments, with a minimum at $0.033 \pm 0.004\ d^{-1}$ on drained surface with low nutrient availability (Hussner, 2010).
These abiotic factors are very common in the EPPO region and completely similar to the ones in the current range of the species, and are described below.

Water quality

The following indicative measures have been found in sites in France and Belgium (Stiers *et al*., 2011), and conditions may greatly vary depending on the habitat and the infestation:
O_2: 8 mg/L in summer to 18.3 mg/L in winter/spring in France, 5-12mg/L in summer; 9-12 mg/L in winter/spring in Belgium
pH: 6.2-9.1 in France, the plant develops in acid (Landes in France) and alcaline environments, as well as on silicious (Alpes Maritimes and Var in France) and calcareous (Provence in France) substrates. The same observations are made in Belgium, pH are comprised between 6.6 and 8.3.
Conductivity: references provide measures comprised between 120 and 300 $\mu S\ cm^{-1}$ in acid lakes and ponds (Pellote, 2003; Hoogland, 2004) and 400 and 740 $\mu S\ cm^{-1}$ in alcaline waters (Pellote, 2003 ; Dandelot, 2004). In Belgium, the conductivity varied between 141 and 968 $\mu S\ cm^{-1}$.
Orthophosphates: 0.01-1.065 mg/L (Charbonnier, 1999; Pelotte, 2003; Dandelot, 2004)
Nitrates are not limiting as the species may grow in water with concentrations from 0.01 mg/L.
Total phosphorous: 0.033-0.632 mg/L in Belgium (Stiers *et al*., 2011), 0.02 – 5.0 mg/L (Charbonnier, 1999;

Pelotte, 2003)
Permanganate Index (oxidizing organic and inorganics matters in mg/l O2): 2 – 55 in acid lakes and ponds.
Ammonium (NH_4): 0.004-0.091 mg/L in Belgium.
Chlorophyll a: 5.1-186.9 µg/L in Belgium

Sediments
In France, it was observed that the biomass production was positively correlated with concentration of organic matters and nitrogen (Charbonnier, 1999; Pelotte, 2003). There is no lower limit in the concentration of nutrients in the water for the species to grow (Hussner, 2009). *L. grandiflora* responds to lower nutrients in the sediment with an increase in the root:shoot ratio (Hussner 2009). It is similar for the nutrient contents in sediments: *L. grandiflora* can grow on sediments with very variable concentrations of organic matter, from 2 % in sands up to 22 % in muds on lakes and ponds banks (Pellote, 2003) and low phosphorus and nitrogen concentrations in intersticial water.
Organic matter: 0.2 - 20 % of dry weight
Kjeldahl Nitrogen: 300 – 12 500 mg/kg of dry weight
Total Phosphorous: 200 – 2000 mg/kg of dry weight
Data retrieved from Charbonnier (1999) and Pelotte (2003).

Physical characteristics of waterbodies
Ludwigia spp. colonize lake shores up to 0.8 m above the mean water surface and in 3 m deep waters (Dutartre, 1986; Lambert *et al*., 2009a). Optimal conditions for growth are however between – 0.7 m and + 0.3 m (Dutartre *et al*., 2007).
Concerning sediment type, mud, sand, gravel, clay, peat are suitable substrates.

Water flow velocity
Growth measurements in different sites colonized by *Ludwigia* spp. showed that maximum values of biomass production are obtained in slow flowing rivers or in waterbodies (Dandelot, 2004). For a moderate water flow (30 to 40 cm/s), the biomass production was observed to be reduced by up to 85% in a river in the South-West of France (Charbonnier, 1999; Pelotte, 2003). Static or slow-flowing waters are the optimal habitats.

Salinity experiments
L. grandiflora is not usually found in brackish waters. Under controlled conditions, biomass production was greatly reduced at 6g/L of NaCl (Grillas *et al*., 1992).

1.20 - If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?
N/A
Level of uncertainty : low

1.21 - How likely is it that establishment will occur despite competition from existing species in the PRA area, and/or despite natural enemies already present in the PRA area?
Very likely
Level of uncertainty : low

In favourable aquatic habitats, *Ludwigia grandiflora* often builds up monospecific stands and outcompetes other aquatic species (Dutartre, 2004b). *L. grandiflora* does not only affect submerged species but also emergent native species as the species is able to grow on both the water surface and exposed mud (Stiers *et al*., 2011). The species is also suspected to have allelopathic properties enabling suppression of competing species (Dandelot *et al*., 2008).

Establishment in less favourable habitats may be limited by competition with existing dominant native species (e.g. in oligotrophic situations). Biomass production is reduced in vegetation dominated by tall helophytes like *Phragmites australis*, *Glyceria maxima*, *Phalaris arundinacea* or *Typha angustifolia*, but this does not preclude the survival of the plants (Dandelot, 2004; Haury *et al*., 2009). Tall helophytes do not prevent establishment, but prevent the spread and formation of nuisance populations.

In France, observations showed that Louisiana crayfish (*Procambarus clarkii*) and coypu (*Myocastor coypus*) can eat large quantities of *Ludwigia* spp. (Lambert *et al.,* 2009a). *Altica lythri* Aubé, a beetle (Chrysomelidae) has also been observed to eat leaves of *Ludwigia* in the South-West of France (Petelczyc *et al*., 2006). Two coleoptera of the genus Galerucella have also been observed on leaves of *Ludwigia* spp. (Dauphin, 1996). Observations made in the natural reserve "des marais de Bruges" showed that cattle also eat *Ludwigia* spp. in shallow waters in summer when forage availability declines on the site. Horses have also been recorded to feed rarely on *Ludwigia* spp. in Camargue (Legrand, 2002). These observation remain anecdotal as animals usually avoid eating plants containing saponins.

All these species did not prevent the establishment of *Ludwigia grandiflora*, it is therefore very likely that establishment will occur despite competition from existing species in the PRA area.

1.22 - To what extent is the managed environment in the PRA area favourable for establishment?
Very highly favourable
Level of uncertainty : low

The optimal habitats of *L. grandiflora* are static or slow-flowing waters, and the EWG considered that the slowing down of waters and increase in the water table by creating dams may favor the establishment of the plant. Physical modification (reduction of current velocity) of waterbodies can also enhance the establishment of *L. grandiflora.*

The main method of propagation of *L. grandiflora* is by vegetative fragmentation, so conditions that favour the creation of fragments and their dispersal within water courses will promote establishment elsewhere. Management of water bodies creates open spaces favourable for the establishment of *L. grandiflora*, and may also cut the plant into fragments, enhancing its spread.

1.23 - How likely is it that existing pest management practice will fail to prevent establishment of the pest?
Very likely
Level of uncertainty : low

The establishment of *L. grandiflora* is very likely to happen despite existing management practice. The high regeneration capacity and the plant's ability to form new shoots from single nodes (with or without leaves) or single leaves (Hussner, 2009) - is very likely to result in the widespread and rapid dispersal of the plant after mechanical control. It is in addition unlikely that all viable seeds can be removed during a mechanical control measure, and repeated hand-picking of new sprouted plants is necessary.
The EWG considered that there are no management practices that could prevent the establishment of this plant. Most water bodies that are at risk of colonization are not subject to management, and those with management plans in place would not prevent the establishment of the species.

1.24 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?
Likely
Level of uncertainty : low

Eradication of *L. grandiflora* is very difficult or even impossible in water bodies with heavy infestation. Local eradication is possible if it is started early and the water system is reasonably accessible (Grillas, 2004).
In France as a whole, eradication is not possible anymore, and it is likely that the species would survive eradication programmes. In France, Ancrenaz & Dutartre (2002) report that of 364 management actions, only 14 seemed to have lead to significant decrease of the populations of *Ludwigia* spp.. Additionally, these 14 management sites included locations where the climatic conditions were not favorable for the species because of freezing temperatures.

Elsewhere where the species is still of limited distribution, and in small isolated water bodies, eradication could still be achieved.

In Switzerland, an outbreak was found near Geneva (in the Cavoitanne pond in Laconnex) in 2002. Around 120 m² were colonized by *L. grandiflora* in 4 populations, while the total pond surface was 900 m². The plants were removed manually and put in bags before being incinerated. The pond was monitored, and the same operation was undertaken in 2003 (GREN Biologie Appliquée Sarl, 2003). In 2009, the species was considered eradicated in Switzerland.

In the UK, DEFRA and the Environment Agency have started an eradication project for the 13 sites where *Ludwigia* spp. are recorded. This project started in 2007 and is ongoing as of June 2010. The method used mainly consisted in the use of glyphosate and an adjuvant (DEFRA, 2006). To date, *L. grandiflora* has been eradicated from 3 sites using chemical and manual removal techniques.

In Germany, a limited occurrence was found in 2009. The local nature conservation authorities are planning an eradication (Starfinger, Julius Kühn Institute, pers. comm., 2010). It is expected to be difficult and expensive.

In Belgium, provinces in Flanders are responsible for the mechanical removal of the species in colonized ponds, both in nature reserves and private ponds. In total 272 000 € were spent in 2005 and 140 000 € in 2006 to clear respectively 136 000m^2 and 114 000m^2 of *L. grandiflora* and two other invasive waterplants (*Hydrocotyle ranunculoides* and *Myriophyllum aquaticum*) (De Bruyn *et al*., 2007). Some of these sites are infested again (I. Stiers, personal observation, 2011).

<u>1.25 - How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?</u>
Very likely
Level of uncertainty : low

<u>Life cycle</u>
The species has a high growth rate, and several overwintering strategies (e.g. seeds, persistent vegetative material) (Dutartre *et al*., 2007).

<u>Vegetative reproduction</u>
The species reproduces essentially through intense vegetative reproduction, and can easily regrow from fragments (Dandelot, 2004). Those fragments are buoyant and can easily float away from parent plants. In the Bagnas natural reserve (Hérault, France), the use of a filter allowed to count the production of 41 to 881 cuttings per day, the variability of these figures may be explained by the different seasons and currents (Legrand, 2002). *L. grandiflora* is able to form new shoots from single nodes (with or without leaves) or single leaves (Hussner, 2009). Biomass production can be very rapid, with standing crop values normally reaching 2 kg of dry matter per square meter (Dutartre, 2004b), but in ponds in South-West France, the maximum recorded dry matter reached 3.5 kg per square meter (Pelotte, 2003), although an absolute

maximum of 7 kg of dry mater per square meter has been recorded in South-East of France (Dandelot, 2004). This large biomass then produces a large propagule pressure.

Strategy for survival

The adventitious roots are capable of absorbing atmospheric oxygen, allowing the plant to tolerate anaerobic conditions (Rejamánková, 1992). Hussner (2010) highlighted that both *L. grandiflora* and *L. peploides* reached maximum relative amounts of roots (52.1±1.8% for *L. peploides* and 48.1±4.4% for *L. grandiflora*) under drained and low nutrient conditions, when maximum relative amount of shoots (53.6±3.2% for *L. peploides* and 48.6±1.8% for *L. grandiflora*) was reached under waterlogged and nutrient rich conditions.

Sexual reproduction

L. grandiflora is an outcrossing plant, pollinated by insects, with germination requiring cold stratification.
In populations that produced many fruits, Dandelot (2004) estimated that *L. grandiflora* has a high potential seed output with around 10 000 seeds per m². Forty eight percent to 58% of the produced seeds are viable (Ruaux *et al*., 2009).
In the Loire river, 40±19 seeds were produced per fruits and germination rate is variable between 20 and 55 % in different laboratory storage conditions (Ruaux, 2008). However in South-West France, germination rates are much more variable between 10 and 90% (Dutartre *et al*., 2007). According to the number of seeds produced and the germinations observed, at least in Western France, it could be assumed that a persistent seed bank is formed (Ruaux *et al*., 2009).

1.26 - How likely are relatively small populations to become established?

Very likely

Level of uncertainty : low

Founder populations may have low genetic diversity, but small populations are very likely to become established as the main mean of dispersal of *L. grandiflora* is vegetative reproduction by fragmentation. Even small fragments can form new shoots.
Okada *et al.* (2009) analyzed the genetic diversity of *L. grandiflora* in California and concluded that 95% of the ramets represented a single genet. These results show that populations can originate from one single individual propagule.
Dandelot (2004) reports that all the populations of *L. grandiflora* in the French Mediterranean area could have originated from a single clone.

1.27 - How adaptable is the pest? Adaptability is:

High

Level of uncertainty : low

Ludwigia grandiflora has an inherent highly variable morphology depending on abiotic conditions (Lambert *et al.*, 2010), especially the leave shape and stem size. Three morphological forms are distinguished according to ecological conditions:

- a prostrate small leaved form;
- an actively growing creeping form in the first step of development or in static or slow flowing waters;
- an erected form at later stages, in favorable ecological conditions, in shallow waters.

The plant is mainly aquatic but is also able to colonize damp terrestrial habitats such as riverbanks or wet meadows. It can also grow on nutrient-poor to nutrient-rich soils and sediments (gravel banks, sand bars, mud, peat, etc.) (Matrat *et al*., 2006).

In addition, the species is found in temperate, Atlantic and Mediterranean climates, and if emergent parts of the plant are killed by frost, submerged or buried parts of the plants as well as the rhizomes are reported to survive the winter months (Dutartre *et al*., 2007).

<u>1.28 - How often has the pest been introduced into new areas outside its original area of distribution? Specify the instances if possible in the comment box.</u>

Often

Level of uncertainty : low

L. grandiflora originates from South America.
It has established in Europe in Belgium, in France, in Italy, in Germany, in Ireland, in the Netherlands, in Spain and in the United Kingdom.
The species has also established in Africa in Kenya, and is considered naturalized in North America (see Question 7).

<u>1.29a - Do you consider that the establishment of the pest is very unlikely ?</u>

No

Establishment of the pest has already occurred in some countries of the EPPO region.

<u>1.29b - How likely are transient populations to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment)?</u>

<u>1.29c - The overall probability of establishment should be described.</u>

L. grandiflora has already established in at least 8 countries of the EPPO region, the probability of establishment is therefore very high, and its overall uncertainty is low.
According to the climatic prediction, additional countries are at risk.
Different biogeographical regions of the EPPO region are considered to be suitable for the establishment of *L. grandiflora*:
The Mediterranean basin: Albania, Algeria, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Greece, Israel, Italy, Jordan, Montenegro, Morocco, Spain, Republic of Macedonia, Romania, Tunisia, Turkey, Slovenia
Atlantic Western Europe: Belgium, France, Ireland, the Netherlands, Portugal, the UK, are susceptible to establishment of this species.
Continental Europe and other parts of Europe (but for which the ecoclimatic index of the species is lower): Austria, Azerbaijan, Czech Republic, North-Western Germany, Denmark, Hungary, Luxembourg, North Western Switzerland, South-Western coast of Norway, Poland, Russia, Serbia, Slovakia, Sweden, Ukraine (Black Sea region) (see maps in Appendix 3).

Stage 2: Pest Risk Assessment - Section B : Probability of spread

1.30- How likely is the pest to spread rapidly in the PRA area by natural means?

Moderately likely

Level of uncertainty : medium

Within a catchment: very likely

Vegetative fragments of the plant are known to be dispersed:

- by animals. For example, fragments can be dispersed by coypu (*Myocastor coypus*) according to Haury *et al*. (2009).
- by water flow: on a 10 m wide water way, from 40 to 881 cuttings were recorded daily in a filter (Legrand, 2002).

Fruits of *Ludwigia grandiflora* can be spread easily by flowing water due to their long term buoyancy (Ruaux *et al*., 2009). Fruit buoyancy of *L. grandiflora* was recorded to last more than 3 months in the Loire river (Ruaux, 2008). In static waters, long term buoyancy is more advantageous for dispersal because occasional water movement (through winds, currents, animals, etc.) increases the chances for establishment elsewhere within lakes and ponds.

According to Dandelot (2004), seedlings produced by fertile populations are also dispersed by water far from parent-plants. Dandelot (2004) reports that in France, *Ludwigia* spp. are mainly found downstream in coastal rivers such as Hérault, Tech, Tet, Agly, Orb due to torrential flooding characterizing Mediterranean rivers, progressively displacing populations of *Ludwigia* spp. toward river mouths. The EWG assumed that most populations in flowing waters would originate from ponds and riverside areas not permanently connected with rivers and streams, but occasionally connected by flood conditions.

Some concrete situations in France are well documented:

In the Marais d'Orx (South-West of France), *L. grandiflora* spread over 128 ha in 6 years (Saint Macary, 1998).

In 10 years, about 2/3 of the shore of the Léon pond (Landes) was colonised by *L. grandiflora* (Dutartre *et al.,* 2003).

The Turc pond (Landes) has been covered over 3 hectares in about 10 years (Dutartre, 2004b).

In the Marais Poitevin (West of France), it spread over 500 km of a river and ditch system in 16 years (Dutartre *et al*., 2008).

Between catchments, natural spread is unlikely.

Natural spread between unconnected waterbodies is poorly understood. The species may be spread by waterfowl, but there is no observation of this.

1.31 - How likely is the pest to spread rapidly in the PRA area by human assistance?

Likely

Level of uncertainty : low

The plant is unlikely to move to new watersheds without human assistance, although the influence of waterfowl is unknown.

Ornamental value of the species

Spread can rapidly occur by deliberate planting in new sites by the action of water users because of the ornamental value of the plant. In the Forez Basin, hunters are known to have deliberately planted the species to improve perceived habitat value for waterfowl (A Dutartre, CEMAGREF, pers. comm., 2010). In addition, gardeners would be likely to buy and exchange the plant between themselves.

The more the species is traded, the higher the probability of the species to escape from cultivation and create new populations. Trade of *L. grandiflora* and the situation in EPPO countries is described below:

In France

Although the sale of *L. grandiflora* is forbidden by law, a website selling the plant has been identified: Jardinerie du Pic Vert
http://www.jardindupicvert.com/4DACTION/w_partner/ludwgie_grandes_fleurs_ludwigia_grandiflora.7984na?utm_source=netaff&utm_campaign=netaff&utm_medium=catalog
This nursery is only taken as an example, and the EWG considered that other nurseries are certainly selling the species.

In Germany

In Germany the plant does not seem to be frequent in trade. However, many traders use ambiguous German names and the name "Sumpfheusenkraut" may either correspond to *L. palustris* or to *L. grandiflora (*U. Starfinger, Julius Kühn Institute, Germany, pers. comm., 2010).

In the Netherlands

In the Netherlands a Code of conduct has been signed by the "Unie van Waterschappen" on behalf of all 26 local water boards of the Netherlands, the Ministry of Agriculture, Nature and Food safety, as well as umbrella organisations and various associations representing producers, importers, retailers and garden centres such as DIBEVO, Tuinbranche Nederland, De Nederlandse Bond van Boomkwekers, De Vereniging van Vasteplantenkwekers. Several individual importers and producers of aquatic plants also signed the Code of conduct. The signatories have agreed to refrain from selling several invasive aquatic plants (incl. *L. grandiflora* and *L. peploides*) in the Netherlands as of 1st January 2011. Before the implementation of this code of conduct, *L. grandiflora* could be found in almost all garden centres (J. van Valkenburg, Plant Protection Service, The Netherlands, pers. comm., 2010).

In the UK

All infested sites in the UK have probably resulted from deliberate plantings into ponds and water bodies (Newman, JR pers. comm., 2010).
Specialist aquatic nurseries across the UK still sell *Ludwigia grandifora* mislabelled as *Jussiaea grandiflora* (DEFRA, 2008; J. Newman, Waterland Management Ltd, United Kingdom, pers. comm., 2010). *L. grandiflora* was listed in a proposed ban on sale of various aquatic species in the review of the Wildlife and Countryside Act (1981) proposed by DEFRA in January 2010. It is also listed in a voluntary code of practice adopted by the Ornamental Aquatic Trade Association. The number of plants sold is thought to be relatively few as a result of these proposed schemes.

In Belgium

In Belgium, some nurseries are still selling the plants (under the name *Jussiaea grandiflora* or Waterludwigia). There is a Royal Decree under construction to prohibit the import, sale and export of both *Ludwigia grandiflora* and *L. peploides*. As in in the Netherlands, a Code of conduct is being implemented for *Ludwigia* species as well as for other invasive aquatic species (LIFE project).

In general, the trade of *L. grandiflora* was more important before efforts to limit it this were undertaken (i. e. Code of conduct, ban). The EWG considered that the species could also be traded in other EPPO counrties, or could be in the future.

Management practices

Maintenance work will produce copious amounts of viable plant parts which can be spread by water current or human activities. If particular care concerning the presence of *L. grandiflora* is not taken, existing mechanical water management strategies could favour the spread and invasion of the species by increasing fragmentation (Dutartre, 2004b). The EWG therefore considered that linear connectivity between infested

and non infested sites and improper management practices contribute to spread of the species in these systems.
The species could also be spread by machinery. In the Marais d'Orx (South-West France), construction and maintenance activities of the stream adjacent to the polder spread *L. grandiflora* from the stream by contamination of construction equipment (Dutartre, 1999).

Accidental spread through recreational activities (boating, fishing) is not documented, but is considered as a possible cause of spread of the species within and between catchments because stem fragments can survive two days out of the water and be accidently transported from a colonised site to another site (Dutartre *et.al,* 2007).

1.32 - Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?
Moderately likely
Level of uncertainty : medium

Within a catchment (e.g. a river such as the Loire, or waterways), the high fragmentation ability of the plant and its natural spread by water currents renders its containment difficult.
However between unconnected catchments, the possibility of containment is high, but dispersal through waterfowl remains unknown.

The use of herbicide(s) is reported to provide satisfactory results, although such products may not be used in semi natural habitats. Indeed, in some EU countries (e.g. Germany), the use of plant protection products in or near water bodies is only possible under special authorization.
Suárez *et al.* (2004) report greater than 80% control of *Ludwigia* species in rice crops using the herbicide halosulfuron-methyl. A 75% reduction in the extent of a *Ludwigia* infestation in the Laguna de Santa Rosa was achieved using glyphosate (Pillsbury, 2005 in DEFRA, 2006).
Current methods of containment in the UK rely solely on the use of glyphosate and manual clearance (Renals, 2010).

1.32c - The overall probability of spread should be described.

The overall probability of spread is high, uncertainty is medium.

Stage 2: Pest Risk Assessment - Section B : Conclusion of introduction and spread and identification of endangered areas

1.33a - Conclusion on the probability of introduction and spread.

Since L. *grandiflora* is introduced intentionally as an ornamental plant and is still for sale in some parts of Europe (e.g. France) (see Q. 1.31) and exchanges between gardeners may occur, the probability of introduction to areas of the EPPO region where it is currently not present is high. Direct sale and internet sale within and from other countries clearly provides the greatest risk for spread within the EPPO region.
L. grandiflora has already established in at least 8 countries of the EPPO region, the probability of establishment is therefore very high.
Different biogeographical regions of the EPPO region are considered to be suitable for the established of *L. grandiflora*:
The Mediterranean basin: Albania, Algeria, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Greece, Israel, Italy, Jordan, Montenegro, Morocco, Spain, Republic of Macedonia, Romania, Tunisia, Turkey, Slovenia
Atlantic Western Europe: Belgium, France, Ireland, the Netherlands, Portugal, the UK, are susceptible to establishment of this species.
Continental Europe and other parts of Europe (but for which the ecoclimatic index of the species is lower): Austria, Azerbaijan, Czech Republic, North-Western Germany, Denmark, Hungary, Luxembourg, North Western Switzerland, South-Western coast of Norway, Poland, Russia, Serbia, Slovakia, Sweden, Ukraine (Black Sea region) (see maps in Appendix 3).
L. grandiflora is capable of growing in a wide range of aquatic environments. It possesses inherent characteristics enabling rapid vegetative spread between connected water bodies. Where present, the probability of short distance spread is very high as vegetative spread is very effective for local colonization. Human activity is principally responsible for long distance spread.
The overall probability of spread is high, uncertainty is medium.

1.33b - Based on the answers to questions 1.15 to 1.32 identify the part of the PRA area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

The endangered area consists of static or slow-flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks, sediment bars on river borders and wet meadows of the countries where climatic conditions are suitable.
Aquatic habitats of the Mediterranean and Atlantic Western countries of the EPPO region are considered the most at risk (excluding water bodies in the Mediterranean area that dry out during summer) and continental Europe is also considered at risk.

Stage 2: Pest Risk Assessment - Section B : Assessment of potential economic consequences

2.1 - How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?

Major

Level of uncertainty : low

Most data were gathered in France and it is difficult to separate the impacts of *L. grandiflora* or *L. peploides* in these situations (see picture in Appendix 4).
While the impacts on crop yields and/or quality to cultivated plants are minor, the control costs are major.

Impacts on crops

Ludwigia grandiflora and *L. peploides* are very rarely present in rice crop. In a survey made in rice crops in Camargue in 2010, *L. peploides* was only found once in a rice producing area (Marnotte, CIRAD, pers. comm., 2011). *Ludwigia grandiflora* and *L. peploides* therefore do not cause a direct impact on rice production, but may indirectly be a nuisance when blocking irrigation ditches and canals.
In addition, Suárez *et al.* (2004) report greater than 80% control of *Ludwigia* species in rice crops using the herbicide halosulfuron-methyl, and the EWG considered that *L. grandiflora* would be managed with current herbicide treatment in such crop.

Impact on pastures

By outcompeting wetland grasses, *L. grandiflora* can reduce grazing space for livestock in wet meadows (Dutartre, 2004a). This effect is increased by the low palatability of *L. grandiflora* for livestock, as cattle and horses only eat the plant when no other species is available. An experiment made in invaded pastures in "Barthes de l'Adour" (South-West of France) showed that the livestock did not eat the plants, probably in relation to the very low palatability of *L. grandiflora* and the very small dimensions of the plants in the meadows (Dutartre, CEMAGREF, pers. comm., 2011). This leads to loss of pasture space and impedes farmers to get attribution of agri-environmental financial incentives developed in the framework of the Common Agricultural Policy.

Control costs

L. grandiflora interferes with agricultural production, ecosystem services and human use of water bodies (e.g. deterioration of dams and infrastructures, loss of recreation areas, increase in flood risk, etc.). For these reasons, management activities have been undertaken, some costs are presented below.

Standard calculation of control costs is extremely difficult as it greatly depends on the characteristics of the sites and of the infestations (Lambert *et al*., 2009a).
In the West of France, for the period 1990-2003, the cost range of pulling techniques, expressed in tonnes of fresh biomass (Million, 2004), were as follows for both *L. grandiflora* and *L. peploides*:

- Mechanical removal: 51 to 64 € were used for highly invaded sites with very dense biomass.
- Manual removal: 1100 to 1330 € are used for new infestations, and for removal of small isolated patches over larger areas after initial mechanical extraction.

In the wet part of Marais Poitevin, yearly costs of waterprimrose management is about 200 000 to 220 000 € for manual interventions of river banks (Dutartre *et al*., 2008; Nicolas Pipet, Interdepartemental Institution of Sèvre Niortaise watershed, pers. comm., 2011).
In France, in the lower part of the Loire-Bretagne water basin, where both *L. grandiflora* and *L. peploides* were present, total costs of 66 management actions have been estimated for the year 2006 to be 340 000 €. Unit costs vary from a few hundred euros to about 50 000 € for one of them (Lambert *et al*., 2009b).

In Belgium sums of 140 000 and 126 000 € were respectively spent in 2005 and 2006 to clear 25 ha invaded with *L. grandiflora* (De Bruyn *et al*., 2007).

Reprofiling of banks
In the natural reserve of the Méjean (Hérault, France), mechanical removal of plants from a 5 m wide and easily accessible canal followed by manual removal was very effective and was estimated to cost 4 300 € /km of canal. In the Bagnas natural reserve (Hérault, France), the costs were higher, varying from 21 510 € /km for one year with a return to the initial situation in a small canal, to 23 160 € /km for 2 years, to contain the species in a larger canal (Legrand, 2002).

Mechanical removal
Costs between different places may greatly vary, as noted in this table comparing costs of mechanical removal in different ponds in the West of France (Legrand, 2002). The costs in the table below correspond to one intervention:

Site	**Date**	**Type of material**	**Surface managed (ha)**	**Volume extracted (m3)**	**Cost**
Etang du Turc	1992	Agricultural claw	~ 3	5 600	53 050 € cost of the operation
Etang de Léon (*Ludwigia grandiflora* and *Myriophyllum aquaticum*)	1994	Agricultural claw	1,1	1 870	45 720 € cost of the operation
Etang de Moliets (*Myriophyllum aquaticum* and *Ludwigia grandiflora*)	1996	Agricultural claw	3	885	27 860 € cost of the operation
Etang de Garros	1997	Agricultural claw	2	775	22 800 € /ha
Marais charentais	2000	Agricultural claw			3 350 € /ha cost estimated
Marais charentais	2000	Mechanical digger			2 130 € /ha cost estimated
Jaunay	1997	Mechanical digger			2170 € to 2 200 € /km of riverbank depending on the density of populations, cost without removal of the plant

Manual removal
Costs of manual removal are difficult to compare from one site to another, information is provided by Legrand (2002) and Million (2004).
Annual costs on the Mayenne (over 30 km), on the Sarthe (over 45 km) and on the Oudon (9.2 km) of manual removal with one manager and 6 operators add up to 76 000 € in total in 2004 and decreased to 54 000 € in 2006 and include removal, transport and recycling (Lambert *et al.*, 2009b). In the Landes, those costs varied between 7 700 to 22 000 € per year.

In the Marais Poitevin, the annual cost for the manual removal since 2000 added up to 200 000 to 220 000 €. The length of the river bank managed increases each year. In 1994 it was only several km, while in 2010 about 1200 km of river and channel banks were cleaned (Nicolas Pipet, Interdepartemental Institution of Sèvre Niortaise watershed, pers. comm., 2011).

Chemical management costs
The cost of control in the UK between 1998 and June 2010 for a total of 2.38 ha was 27 320 GBP including method development costs, which is equivalent to 11 467 GBP/ha (Renals, 2010). These costs are ongoing until eradication will be achieved.

2.2 - How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?
Minor
Level of uncertainty : low

Impacts on crop yields and/or quality are restricted to loss of grazing areas in wet meadows. *L. grandiflora* and *L. peploides* are not expected to cause direct impacts on rice crop, but may indirectly be a nuisance by blocking irrigation canals and ditches. In France, only 4.1% of the 567 sites invaded by *Ludwigia* spp. are wet meadows (Dutartre *et al*., 2007).

2.3 - How easily can the pest be controlled in the PRA area without phytosanitary measures?
With much difficulty
Level of uncertainty : low

Prohibition measures
The existing legislation in European countries and preventing actions (e.g. through Codes of conduct) are detailed in Q. 1.31. Since legislations or prevention actions were implemented only a few years ago, no conclusion can be drawn on their effectiveness. However, if phytosanitary measures are implemented in countries where *Ludwigia grandiflora* is not yet established, they could be effective.

Control measures
In the UK, out of 13 contaminated sites, 3 eradication actions have been successful to date using glyphosate (Renals, 2010). Using mechanical and chemical methods can result in local eradication which decreases the risk of spread.
In the Marais Poitevin (West of France), regular management actions, although not succeeding in eradicating the plant, bring the population to an acceptable level so that impacts are minor. Eradication can nevertheless probably only be achieved in small isolated water bodies.

2.4 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?
Major
Level of uncertainty : low

Control costs would be similar to those already spent in infested parts in EPPO countries where *L. grandiflora* occurs (see Q. 2.1).

2.5 - How great a reduction in consumer demand is the pest likely to cause in the PRA area?
Minimal
Level of uncertainty : low

Not relevant.

2.6 - How important is environmental damage caused by the pest within its current area of distribution?

Major

Level of uncertainty : low

Evidence for environmental damage is mainly provided from France (see picture in Appendix 4).

The dominance of *Ludwigia* spp. leads to local loss of floral biodiversity, as well as faunal biodiversity (for macro-invertebrates and fishes) (Dandelot, 2004).

In several ponds in the Landes region (South-West of France), decreases of *Potamogeton natans*, *Myriophyllum spicatum*, *Iris pseudacorus* and *Ludwigia palustris* have been observed as a consequence of competition with *Ludwigia grandiflora* and *Lagarosiphon major* (Dutartre, 2002).

Using floristic relevés analysis in different areas of a marsh colonized by *L. grandiflora* in Brittany, Haury *et al*. (2009) showed that, in similar conditions, *Ludwigia grandiflora* can outcompete *Phalaris arundinacea*, *Glyceria maxima*, *Phragmites australis* and *Polygonum hydropiper*. Haury *et al.* (2009) also showed that it reduced the number of species.

On the Loire river, impact on species richness and structure of invaded communities varies: no significant effect has been reported within the river (aquatic habitat) whereas on the river borders that become drier, species richness and diversity of communities are negatively correlated with the abundance of *L. grandiflora* (Ruaux, 2008). Cover percentages of *Ludwigia* spp. were generally high and only few other species occurred but with limited cover. Where both *L. grandiflora* and *L. peploides* occurred together, *L. grandiflora* was dominant in three out of four stands (Ruaux, 2008).

Reductions of macroinvertebrates and fish populations have also been recorded in France (Grillas *et al*., 1992; Dutartre *et al*., 1997), the dense populations of *Ludwigia* spp. constituting a barrier for the movement of the fish (Legrand, 2002).

In Belgian ponds the cover of *L. grandiflora* has caused a reduction in native species richness. A decrease of 70% has been measured from uninvaded plots to heavily invaded plots. The submerged vegetation was the most vulnerable to the invasion. Significant changes in native species abundance following invasion were found for the submerged *Ceratophyllum demersum* and for the emergent *Alisma plantago-aquatica* and *Lycopus europaeus* (Stiers *et al*., 2011). Uninvaded ponds supported a more distinct invertebrate community, including species (e.g. Ephemeroptera) that are rare or missing from invaded *L. grandiflora* ponds. Under the litter of the invasive species, dipterans of the genus *Chironomus* and naidid oligochaetes were common and they are known to be able to tolerate oxygen stress (Stiers *et al*., 2011).

Preliminary observations also show that *L. grandiflora* is not only integrated in the native plant-pollinator network but shows a dominance in terms of frequency of pollinator visits (I. Stiers, pers. obs., 2001).

An analysis of the distribution of *Ludwigia* spp. in France shows that habitats under threat by this species include at least 12 habitats of interest for the European Commission (Habitat Directive 92/43/EEC), and 3 types of wet habitats (aquatic vegetations of the *Nymphaeion albae,* swamp vegetations with tall helophytes, prairial vegetations and flooded forests (Dutartre *et al.,* 2007)).

Ludwigia spp. cause many significant changes of ecological processes and structures in the following way :

- the high biomass production leads to the slowing of water flow (Dutartre, 1988) in channels, ditches and shallow rivers, causing increased sedimentation, which may lead to increased flood risk by reduction of channel carrying capacity, particularly in autumn. This may lead to modifications of flora and fauna communities, fish disappearing in dense beds, etc. In static open waters, the slow rate of litter decomposition can lead to shallowing of the water body and succession to swamp and marsh type vegetation.
- reduction in oxygen concentrations: in static waters, dense stands prevent the transfer of oxygen

between water and the atmosphere, reduction in light availability for submerged plants reduces photosynthetic oxygen production and consumption of oxygen by *Ludwigia* spp. root respiration results in severe deoxygenation which is harmful to aquatic fauna. Concentrations of oxygen inferior to 1 mg/L have been recorded in waters where *Ludwigia* spp. are present (Dandelot *et al*., 2005a).
- decreases in pH are common due to the suppression of submerged aquatic photosynthetic processes (Dandelot *et al*., 2005b)
- change in hydrological regimes of water bodies (Dandelot, 2005b).

Ludwigia grandiflora is characterized as a transformer species sensu Richardson *et al*. (2000). This trait is confirmed by the evidence presented above. The level of environmental damage caused by the presence of dense infestations of the species is considerable.

2.7 - How important is the environmental damage likely to be in the PRA area (see note for question 2.6)?

Major

Level of uncertainty : low

Environmental impact is assumed to be the same wherever the species grows in suitable conditions. The range of habitats under threat includes threatened or vulnerable habitats in much of the PRA area.

2.8 - How important is social damage caused by the pest within its current area of distribution?

Moderate

Level of uncertainty : low

Effects on tourism and local recreational uses (swimming, boating, fishing, hunting, leisure, etc.) are large. Stands of *Ludwigia* spp. can be very dense, with highly branched and very solid stems of several metres long, preventing passage for fish and users of the water (Dutartre *et al.,* 2007). A national survey on the perceived nuisances of *Ludwigia* spp. in about 500 sites in France was performed by Ancrenaz & Dutartre in 2002. The perceived threats are expressed in percentages by users for different types of environments and are presented below:

Type of environment, usage	Threats
Fishing	33.5%
Hunting	12.2%
Boating	9.4%
Others (comprising 17 other perceived types of nuisances)	34%
Ecological interest (high biodiversity)	5.6%
Nature reserve and Natura 2000 areas	5.3%

Note: these statements only reflect respondents' perception.

The major perceived threats appear to be fishing, hunting and boating. Risks of flooding due to dense stands may increase due to the presence of large plant beds in rivers (Dandelot, 2004).

In some agricultural ditch networks in the West of France, dense stands of *L. grandiflora* cause damage to irrigation and drainage use of the waterbodies, it is for example the case in the wet part of the Marais Poitevin (Nicolas Pipet, Interdepartmental Institution of Sèvre Niortaise watershed, pers. comm., 2011). Flood risks may be increased by the reduction of channel carrying capacity, particularly in autumn (Dandelot, 2004).

Floating mats of this plant can increase mosquito populations by making the larvae inaccessible to mosquito-eating fish (Pillsbury, 2005 in DEFRA, 2006) and creating static water beneficial to mosquito development.

2.9 - How important is the social damage likely to be in the PRA area?
Moderate
Level of uncertainty : low

Social impact is assumed to be the same wherever the species grows in suitable conditions (see question 2.8).

2.10 - How likely is the presence of the pest in the PRA area to cause losses in export markets?
Impossible/very unlikely
Level of uncertainty : low

Not relevant.

2.16a - Conclusion of the assessment of economic consequences

Ludwigia grandiflora causes significant problems in areas where it has been introduced. It is considered as invasive in France, in Italy, in California, etc. According to Dandelot (2005b), it can be defined as a ''transformer'' species *sensu* Richardson *et al*. (2000).

In France, *Ludwigia grandiflora* has several types of impacts (Dutartre, 2004) :
- Changes in physical characteristics of waterbodies: a reduction in water flow causing problems to irrigation or drainage, accelerated sedimentation or accumulation of litter;
- Local reduction in biodiversity: the species forms monospecific stands that outcompete indigeneous aquatic freshwater plants, and impact animal species;
- Chemical quality of water: dissolved oxygen level below 1 mg/L, pH decreases;
- Social impact: dense stands of *L. grandiflora* prevent several activities such as hunting, fishing, water sports, etc. Dense mats can create favorable conditions for mosquito development, as well as increased risks of flooding.

2.16 - Referring back to the conclusion on endangered area (1.33) :
Identify the parts of the PRA area where the pest can establish and which are economically most at risk.

It colonizes static or slow-flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks. It is also found on sediment bars on river borders and in wet meadows (Laugareil, 2002 ; Zotos *et al*., 2006).
Aquatic habitats of the Mediterranean and Atlantic Western countries of the EPPO region are considered the most at risk (excluding water bodies in the Mediterranean area that dry out during summer) and continental Europe is also considered at risk.

Stage 2: Pest Risk Assessment - Section B : Degree of uncertainty and Conclusion of the pest risk assessment

2.17 - Degree of uncertainty : list sources of uncertainty

The overall uncertainty of the assessment is low, owing to the very detailed information available in France.

The areas of uncertainty identified are the following:

- the exact climatic requirements and cold tolerance of the species;
- natural spread by waterfowl;
- the extent of human assisted spread via contaminated equipment or deliberate planting;

Further area of research to be investigated:
- the possible use of a biological control agent.
- tolerance of anoxia (vegetative material and seed) ;
- effects of water level on potential establishment and spread ;
- critical density of competitive tall helophytes.

2.18 - Conclusion of the pest risk assessment

Short summary on pest:
Ludwigia grandiflora is a perennial aquatic plant which forms very dense (almost impenetrable) mats. …

Entry, pathways:
Intentional import as an ornamental aquatic plant for use outdoors
Although regulated in some countries, the probability of entry by intentional import as an ornamental aquatic plant for use outdoors is very likely, as the species already entered the EPPO region, and continues to enter. Uncertainty is low.

Establishment:
L. grandiflora has already established in at least 8 countries of the EPPO region, the probability of establishment is therefore very high, uncertainty is low.
According to the climatic prediction, additional countries are at risk.

Spread:
The overall probability of spread is high, uncertainty is medium.

Economic impacts: major impacts considering the management cost, low uncertainty. Any economic benefit of the introduction of this plant as an ornamental aquatic plant is heavily outweighed by management costs.
Environmental impacts: major, low uncertainty. Invasion of slow flowing waters, loss of biodiversity degradation and modification of aquatic ecosystem including protected habitats.
Social impact: moderate, with low uncertainty. Where it occurs, it has an impact on recreational activities, it can also create favorable conditions for mosquito development, increased risk of flooding.
The part of the EPPO region which seem the most economically at risk are the Atlantic and Mediterranean areas, as well as the Black sea area.

Endangered area:
It colonizes static or slow-flowing waters: rivers, shallow ponds and lakes, canals, oxbow lakes, wet margins of ponds and lakes, wetlands, ditch networks. It is also found on sediment bars on river borders and in wet meadows (Laugareil, 2002 ; Zotos *et al*., 2006).
Aquatic habitats of the Mediterranean and Atlantic Western countries of the EPPO region are considered the most at risk (excluding water bodies in the Mediterranean area that dry out during summer) and continental Europe is also considered at risk.

The risk of establishment of *Ludwigia grandiflora* in aquatic habitats, and negative impacts on their vegetation and use, justifies measures to prevent its further spread in the EPPO region.
The pest qualifies as a quarantine pest.

Stage 3: Pest Risk Management

3.1 - Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?
No

Major economic and environmental risks and moderate social risks have been identified.

3.2a - Pathway :
- Intentional import as an ornamental aquatic plant for use outdoors. This can also include intentional import of the species for any purpose (e.g. phytoremediation).

3.2 - Is the pathway that is being considered a commodity of plants and plant products?
Yes

3.3 - Is the pathway that is being considered the natural spread of the pest?
No

3.9 - Is the pathway that is being considered the entry with human travellers?
No

3.10 - Is the pathway being considered contaminated machinery or means of transport?
No

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest? (if yes, specify the measures in the box notes)
No

3.11 - Is the plant the commodity itself?
Yes

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?
Yes
Possible measures: internal surveillance and/or eradication campaign.

Prohibition of the import, selling, planting, holding, movement, causing to grow in the wild of the plant.
Due to the high invasiveness of *L. grandiflora,* there is a ban of trade of this species (and of *L. peploides*) in France since 2007 (Ministère de l'écologie et du développement durable, 2007), as well as in Portugal (Decreto Lei 565/99). There are proposals for ban in Belgium and the UK. In the Netherlands a Code of conduct is being implemeted to prevent the sale of these species (effective since January 2011).

Management of the species
Management methods have been developed in France, with eradication at early stages of infestation, which should be adopted by countries where infestation is at an early stage, and countries where the species is not present should be aware of these. The following management measures are recommended:
- Integrated management plan for the control of existing infestations
The main control options are: mechanical and manual control and herbicide application. These options can

be integrated together. Nevertheless, herbicides are usually prohibited in most aquatic ecosystems. Temporary drying out of waterbodies could also be implemented under Mediterranean climates, but is not possible in all situations and may have enviornmental impacts.
- Monitoring/surveillance and emergency plans: Early detection in the countries at risk. In the UK, a rapid response system has been in place since 2008 to manage existing populations and new observations of *Ludwigia* spp.
- Obligations to report findings, in the whole EPPO region, especially in Western Europe. This is currently not implemented.
- Proposal of alternative non invasive aquatic species for use as ornamental plants.
- Legal obligation to remove invasive plants from private properties.
- Publicity: public awareness campaigns about the impacts of the plant with the information not to use it as an ornamental, or for phytoremediation.

See the EPPO Standard PM 3/67 *'Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported'*.

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?
Yes

Prohibition of the import, selling, planting, holding, movement, causing to grow in the wild of the plant is the most efficient measure.

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?
No

In countries where the species is already widespread, control measures of infestations within countries are not sufficient if the plant is spreads from existing populations present in gardens. Prohibition of selling is therefore necessary combined with public awareness campaigns to prevent spread from existing garden populations in countries at high risk.

The possibility of eradication or effective control for large populations in large lakes and flowing systems is very low. However success is possible in small isolated ponds and other static water bodies.

When *L. grandiflora* is not yet established in a country, prohibition of selling may be sufficient combined with the knowledge on action plans for early intervention in case the plant occurs.

3.32 - For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?
yes

National measures
Prohibition of selling, planting, holding, movement, causing to grow in the wild of the plant in the EPPO region is necessary. Moreover, the plant has to be controlled where it occurs.
If these measures are not implemented by all countries, they will not be efficient since the species could spread from one country to another.
In addition, it has to be combined with international measures.

International measures
Prohibition of import into the EPPO region and within the countries of plants labeled as *Ludwigia grandiflora* and those labeled with all other synonyms and misapplied names in use, as well as subspecies.

3.32b - List the combination of measures

The combination of measures is:

At the international level: prohibition of import of the species, with the listing of the species as a quarantine pest.

At the national level:
- Prohibition of selling, planting, holding, movement, causing to grow in the wild of the plant combined with
- management plans for early warning,
- obligation to report findings,
- eradication and containment,
- public awareness campaign.

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The estimated value of the species to the trade is low and interference of the prohibition of the species with trade is considered as quite low. There is already a ban of trade in France, and alternative aquatic plants can be proposed to substitute this species as an ornamental. There will be a ban in the Netherlands as well in January 2011 through a Code of conduct, and proposals of ban have been submitted in Belgium and the UK.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Considering the high cost of the control of the plant, compared to the benefit its trade generates, the measures are very cost-effective. Furthermore, *L. grandiflora* is not an important commodity.

Sellers of aquatic plants are not familiar with such legislation, nor is the public, but this case could raise awareness. Non invasive substitution plants could be proposed. For instance substitution plants have been proposed in Belgium (Branquart, 2008) and for the Mediterranean part of France (AME, 2003).

Concerning internal surveillance and/or eradication campaign, the effectiveness of these measures is considered to be limited for invasive alien plants as there are currently no early warning systems in place within countries.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?
Yes

Prohibition of selling, planting, holding, movement, causing to grow in the wild of the plant combined with management plans for early warning, eradication and containment, and public awareness.

3.41 - Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

Intentional import of the plant for ornamental purposes: high probability, with low uncertainty
Intentional import for phytoremediation: very low probability, with high uncertainty

Major pathway is intentional import of the plant (either for ornamental or other uses).

International measures

Prohibition of import and trade in the EPPO region and within the countries will effectively prevent further introduction into the EPPO region combined with accurate identification of the species.

National measures

Prohibition of the import, selling, planting, holding, movement, causing to grow in the wild of the plant may effectively prevent further establishment and spread within the EPPO region.

Integrated management plan for the control of existing infestations

It is potentially highly effective if coupled with prohibition measures. Uncertainty concerns commitment to long-term implementation.

This would require:

- Monitoring/surveillance in the countries where it is invasive or present (Belgium, France, Germany, Ireland, the Netherlands, the United Kingdom, Italy, Spain), and surveillance in the countries at risk where it is not reported.
- Early warning consisting of exchanging information with other countries, and rapid response (as it has been implemented in the UK).
- Control of existing populations.
- Public awareness: aquatic plants producers and sellers shall be informed of the problem and work should be undertaken with them to explain the prohibition of the species, and inform consumers. Administration should also be warned that the plant shall not be used as a phytoremediation species.

Monitoring and review

Performance of these measure(s) should be monitored in countries to ensure that the aim is being achieved. This is often carried out by inspection of the commodity on arrival, noting any detection in consignments or any entries of the pest to the PRA area. Monitoring of on going eradication campaigns and management activities should also be undertaken to optimize control measures.

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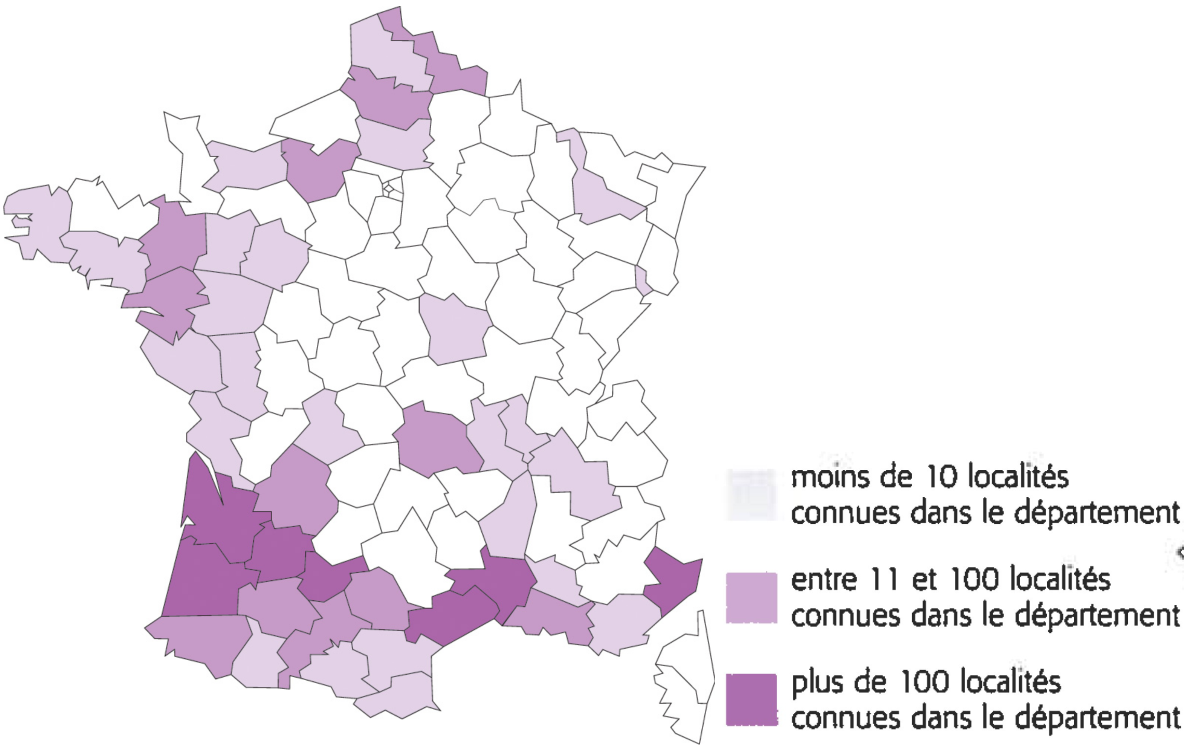
Appendix 1

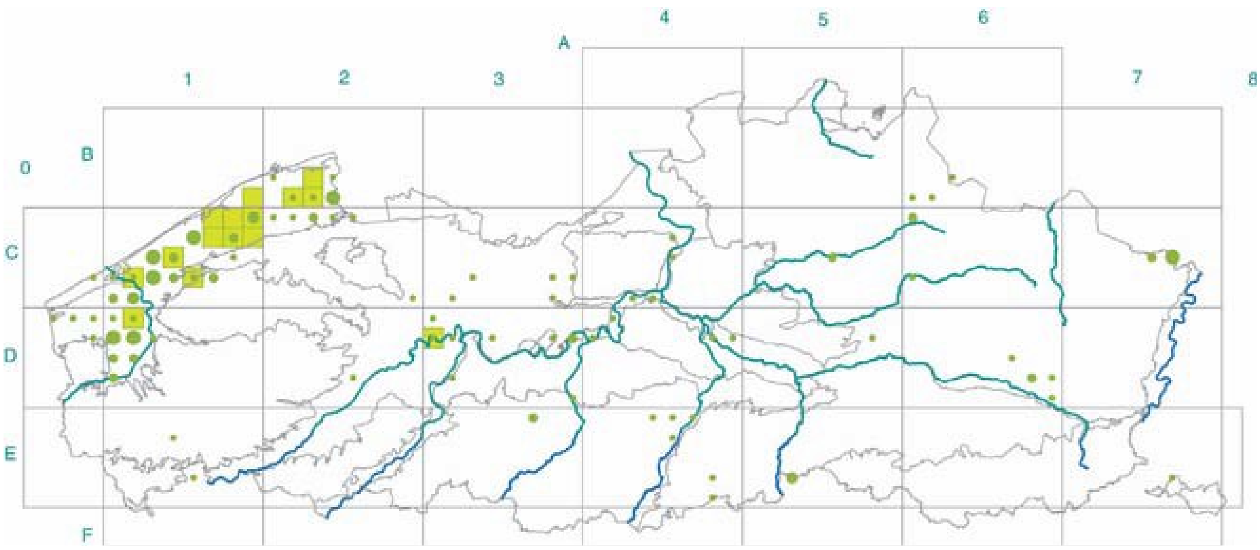
Distribution maps of *Ludwigia grandiflora*

In France



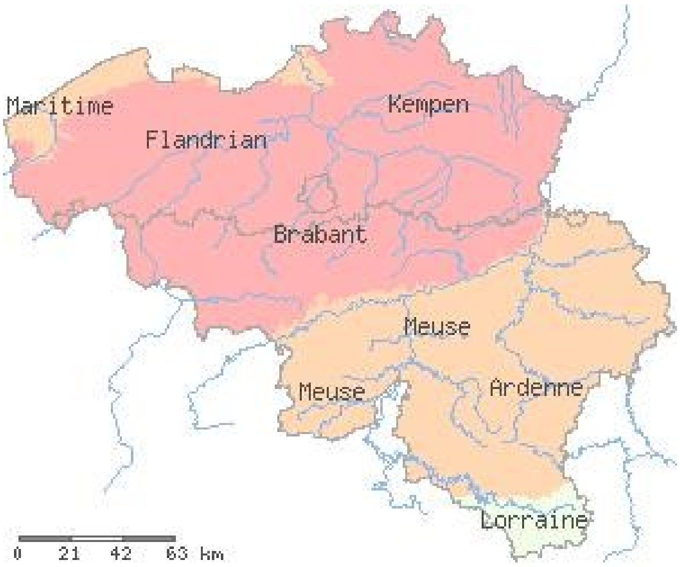
Map of established populations of *L. grandiflora* and *L. peploides* in France
Source: Dutartre A (2004) *Ludwigia peploides* (Kunth.) P.H. Raven *Ludwigia grandiflora* (Michaux) Greuter & Burdet. Les jussies. In : Muller, S. (coord.) *Plantes invasives en France*. Museum national d'Histoire naturelle, Paris (Patrimoines naturels, 62), pp. 76-81.

In Belgium



Map of established populations of *L. grandiflora* in Flanders (BE)

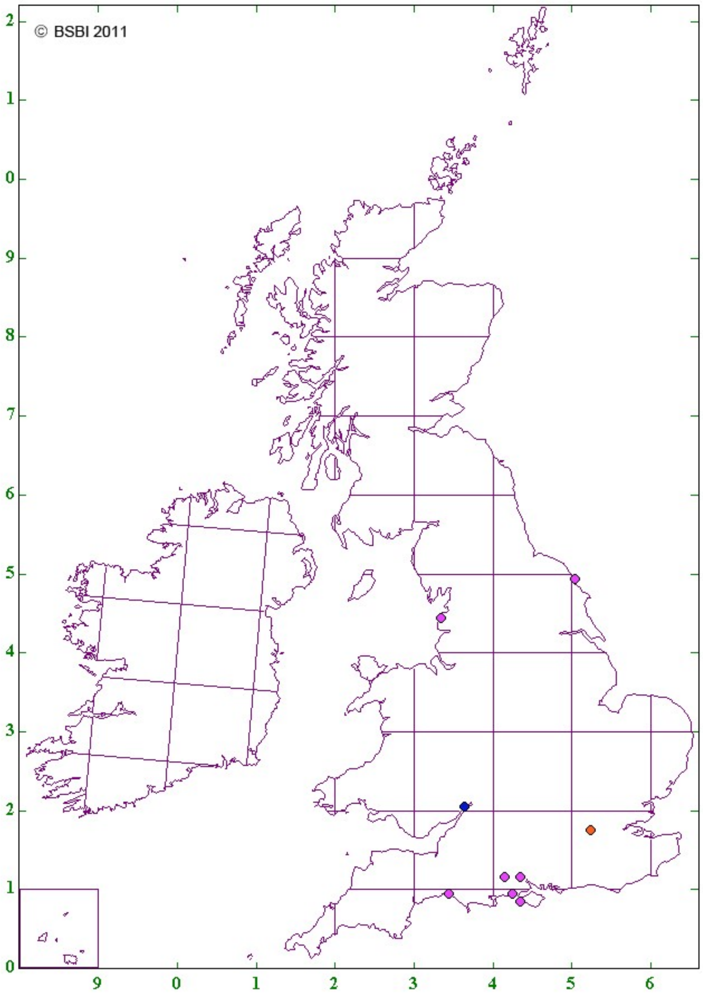
Source: Denys L, Packet J & Van Landuyt W (2004) Neofyten in het Vlaamse water: signalement van vaste waarden en rijzende sterren. *Natuur.focus* **3(4):** 120-128.
http://www.provant.be/binaries/Artikel%20Neofyten%20-natuurfocus%204-2004_tcm7-16941.pdf



absent from district
isolated populations (1-5 localities per district)
widespread (>5 localities per district)
Map of established populations of *L. grandiflora* in Belgium

Source: Branquart E, Stiers I, Vanderhoeven S, Van Landuyt W, Van Rossum F, Verloove F, (2010) Harmonia database: *Ludwigia grandiflora*, Harmonia version 1.2, Belgian Forum on Invasive Species
http://ias.biodiversity.be/species/show/11

In the UK



Hectad map of *Ludwigia grandiflora* in GB and Ireland
-1930 (0 hectads); 1930-1969 (0 hectads); 1970-1986 (0 hectads); 1987-1999 (2 hectads); 2000-2009 (8 hectads); 2010- (0 hectads)

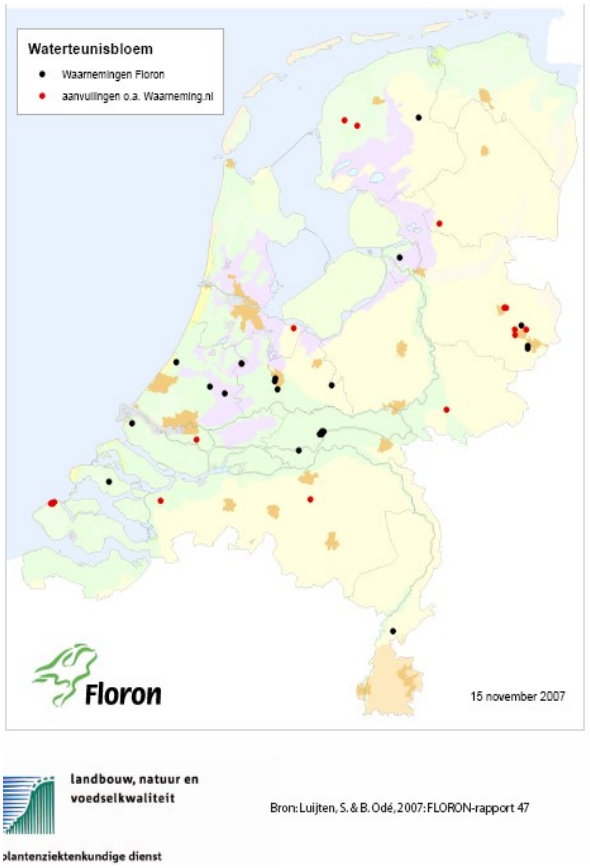
Source: Botanical Society of the British Isles Mass Scheme.
http://www.bsbimaps.org.uk/atlas/map_page.php?spid=9941.0&sppname=Ludwigia%20grandiflora&commname=

Ireland

Occurrence of *Ludwigia grandiflora* in Ireland. Distribution maps of invasive species and problematic plants in the National Invasive Species Database as of 07/12/2010.

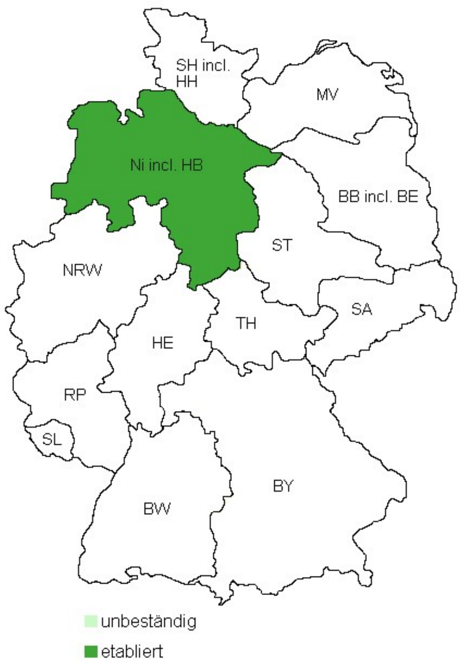
Source: National Biodiversity Data Center, documenting Ireland's wildlife. http://invasives.biodiversityireland.ie/wp-content/uploads/Inv-distribution-maps-Dec-102.pdf

In the Netherlands



Map of distribution of *L. grandiflora* in the Netherlands

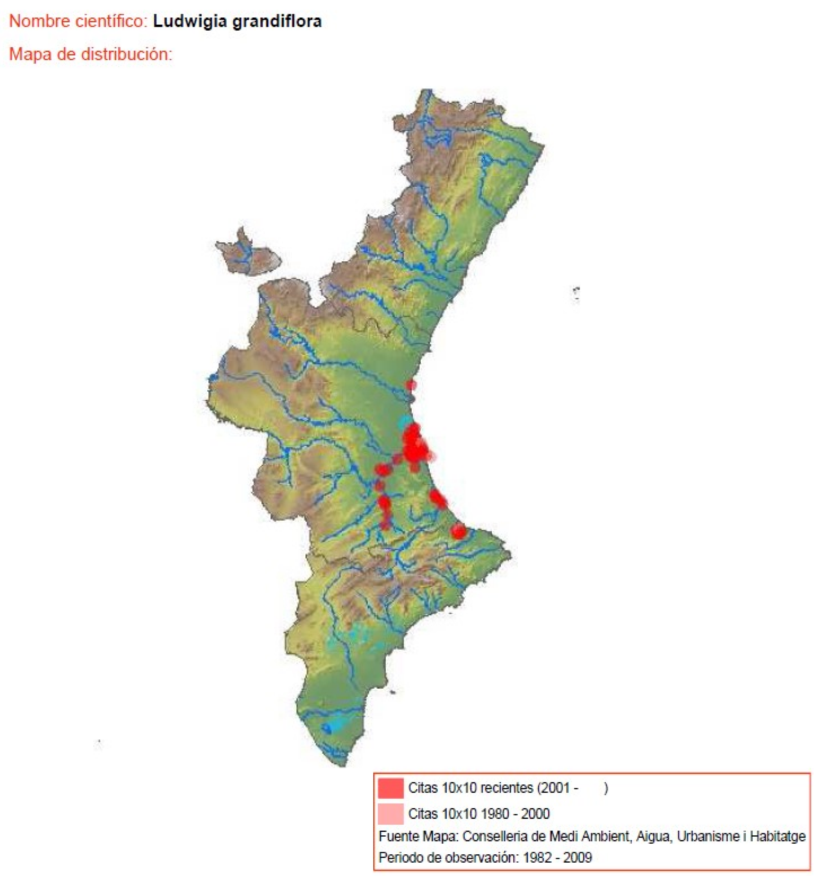
In Germany



Map of occurrence of *Ludwigia grandiflora* in Germany

Source : Hussner A (2009) Erstnachweis von *Ludwigia grandiflora* in Deutschland. http://www.aquatischeneophyten.de/AquatischeNeophytenNRW.de/Webseiten%20neu%20deutsche%20Version/Ludwigia%20grandiflora.htm

In Spain, province of Valencia

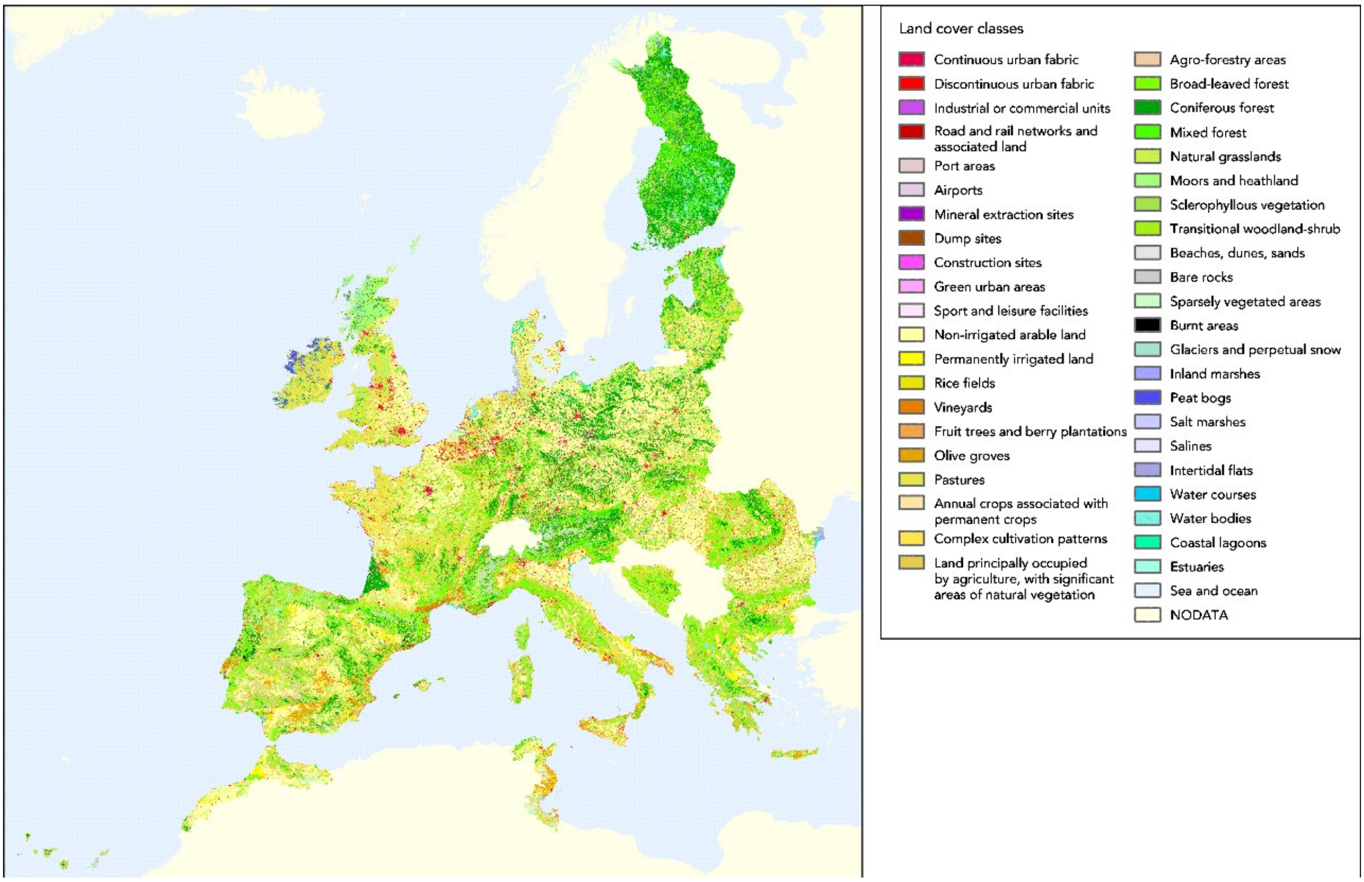


Map of occurrence of *L. grandiflora* in the province of Valencia (Spain)
Source : Vincente Deltoro, Conselleria de medi Ambient, Aigua, Urbanisme i Habitatge, Communitat Valenciana, 2010.

Appendix 2

CORINE Land Cover classification

Available at:
http://www.eea.europa.eu/data-and-maps/figures/corine-land-cover-2000-geographic-view-1



Corine land cover 2000 geographic view, European Environment Agency

Appendix 3

Climatic prediction for *Ludwigia grandiflora* with CLIMEX

The CLIMEX model is a computer programme aiming to predict the potential geographical distribution of an organism considering its climatic requirements. It is based on the hypothesis that climate is an essential factor for the establishment of a species in a country. CLIMEX provides tools for predicting and mapping the potential distribution of an organism based on:

(a) climatic similarities between areas where the organism occurs and the areas under investigation (Match Index),

(b) a combination of the climate in the area where the organism occurs and the organism's climatic responses, obtained either by practical experimentation and research or through iterative use of CLIMEX (Ecoclimatic Index).

For *Ludwigia grandiflora*, a compare location analysis has been undertaken.
Following the Climatic Mapping Decision Support Scheme (DSS) developed in the framework of PRATIQUE, as *L. grandiflora* is already established in 8 countries of the EPPO region, there is a low uncertainty that the climate in the area suitable for establishment is completely or largely similar to the climate where the pest is currently present. Mapping climatic suitability is therefore used to highlight areas where the climate is particularly suitable in the EPPO region.

Distribution of the species

Native range:

South America: Argentina, Chile, Costa Rica, Bolivia, Brazil (South), Colombia, Ecuador, Guatemala, Peru, Paraguay, Uruguay (CABI, 2010).

Introduced Range :

North America: United States (Alabama, Arkansas, California, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, New Jersey, New York, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington, West Virginia). (USDA, 2010; Boersma *et al*., 2006 in DEFRA, 2008).
Note: in North America, the species is spread across various States, but there are few occurrences reported.
Africa: Kenya (Thendi, 1996 in DEFRA, 2008).
EPPO Region : Belgium (Denys *et al*., 2004), France (Dutartre *et al.*, 2007), Ireland (Caffrey, 2009), Italy (Celesti-Grapow *et al*., 2009), Germany (Nehring & Kolthoff 2011), the Netherlands (Kleuver & Hoverda, 1995), Spain (Castroviejo *et al*., 1997), United Kingdom (Newman *et al*., 2000).

This perennial aquatic plant flowers from June to September in the South of France.

Phenology of the species

Alain Dutartre indicated that the vegetative development of the populations started in March-April in the South Western part of France, but remains dependant upon the temperatures, higher temperatures leading to an earlier development of the plant. The higher productivity periods are concentrated between the end of May and the end of August.
The minimum temperatures for growth are not known precisely, but could be around 12°C to 15°C (temperatures for water). The maximum temperature limiting the growth of the plant should be superior to 30°C.

Species parameters

The parameters used in the CLIMEX model for *L. grandiflora* are summarized in Fig. 1. The role and meaning of these parameters are fully described in Sutherst *et al*. (2004), and their values are discussed

below. It should be noted that the meteorological data used in this model represent long-term monthly averages, not daily values. This means that it is not possible to compare directly values derived using the model with instantaneous values derived through direct observations. This applies mostly to parameters relating to maximum and minimum temperatures.
The climatic requirements of *L. grandiflora* were derived by fitting the predicted distribution to the known distribution in the USA, and then comparing the predicted and known distributions within Europe. Taking the distribution in the USA introduces a bias as the species is exotic in USA, but precise data are not available in South America. The climatic prediction therefore also proposed a minimal distribution area that could be underestimated.

☐ Moisture Index					
☑ Temperature Index					
DV0	DV1	DV2	DV3		
12	20	30	34		
☐ Light Index					
☐ Diapause Index					
☑ Cold Stress					
TTCS	THCS	DTCS	DHCS	TTCSA	THCSA
-1	-0.006	6	-0.0001	0	0
☑ Heat Stress					
TTHS	THHS	DTHS	DHHS		
36	0.001	0	0		
☐ Dry Stress					
☐ Wet Stress					
☐ Cold-Dry Stress					
☐ Cold-Wet Stress					
☐ Hot-Dry Stress					
☐ Hot-Wet Stress					
Day-degree accumulation above DV0					
DV0	DV3	MTS			
12	34	7			
Day-degree accumulation above DVCS					
DVCS	*DV4	MTS			
1	100	7			
Day-degree accumulation above DVHS					
DVHS	*DV4	MTS			
34	100	7			
Degree-days per Generation					
PDD					
0					

Fig 1: CLIMEX parameters used for *L. grandiflora*

In CLIMEX, stress indices indicate negative population growth potential and vary between 0 and ∞, where a value of 100 or greater indicates lethal conditions. When threshold conditions are exceeded, stresses accumulate on a compounding weekly basis. The thresholds and accumulation rates are user-defined parameters. Wet stress is not considered since the species is aquatic.

Dry stress and wet stresses
Being aquatic, the plant is highly dependent upon the presence of standing water. As this is a function of precipitation, evaporation, meso-topography and human practices, the presence of standing water was treated separately from the other climatic factors. Dry and wet stresses were therefore not activated.

Temperature index
If emergent parts of the plant are killed by frost, submerged or buried parts of the plants as well as the rhizomes are reported to survive the winter months explaining the increase of the two *Ludwigia* further north (Dutartre *et al*., 2007). *Ludwigia* spp. were also observed in the winter of 2009/2010 in outdoor ponds at the Plant Protection Service at Wageningen (J van Valkenburg, pers. comm., 2011).
There is very few information about its thermal requirements, no experiments have been undertaken to our knowledge on this topic. When considering the distribution of the species originating from South America and able to colonize Ireland or Northern France, it is deducted that the species has a large thermal amplitude.

The range of temperatures was therefore kept wide.
The minimum threshold for population growth, DV0, was set to 12. The minimum temperature for maximum growth rates (DV1) was set to 20°C and the upper temperature threshold for maximum growth rates (DV2) was set to 30°C. The maximum threshold for population growth (DV3) was set to 34°C.

Cold stresses
The reported frost sensitivity of *L. grandiflora* suggested that a cold stress temperature model might be appropriate. TTCS is set to -1 °C at the rate (THCS) of -0.006, this is to say that the species begins to accumulate stress when weekly temperatures drop below -1 °C, as emergent parts of the plant are killed by frost. These parameters allow the species to be present in New York State in the USA.
Additionally to be sensitive to a cold stress, the species might be sensitive to the fact that temperatures are not high enough to allow it to photosynthesise enough to offset minimum respiration demands. The parameters are therefore set (separately from the cold stress index) to 6 for DTCS. This parameter is set upon with an accumulation rate of -0.0001 (DHCS) since the species is supposed to accumulate this stress slowly.

Heat stress
The heat stress is set to 36°C. It is assumed that the stress accumulates moderately rapidly, and the rate is set to -0.001 (THHS).

Climex simulation for *Ludwigia grandiflora*

The areas estimated to be climatically suitable for *L. grandiflora* under current climatic conditions are illustrated for the world (see Fig 2), and for the European and Mediterranean area (see Fig 3).
The potential distribution of this species includes:
The Mediterranean basin: Albania, Algeria, Bosnia & Herzegovina, Bulgaria, Cyprus, Croatia, Greece, Israel, Italy, Jordan, Montenegro, Morocco, Spain, Republic of Macedonia, Romania, Tunisia, Turkey, Slovenia
Atlantic Western Europe: Belgium, France, Ireland, the Netherlands, Portugal, the UK, are susceptible to establishment of this species.
Continental Europe and other parts of Europe (but for which the ecoclimatic index of the species is lower): Austria, Azerbaijan, Czech Republic, North-Western Germany, Denmark, Hungary, Luxembourg, North Western Switzerland, South-Western coast of Norway, Poland, Russia, Serbia, Slovakia, Sweden, Ukraine (Black Sea region).

This prediction is nevertheless considered as a rough estimate, considering the lack of information on the thermal requirements of the species.

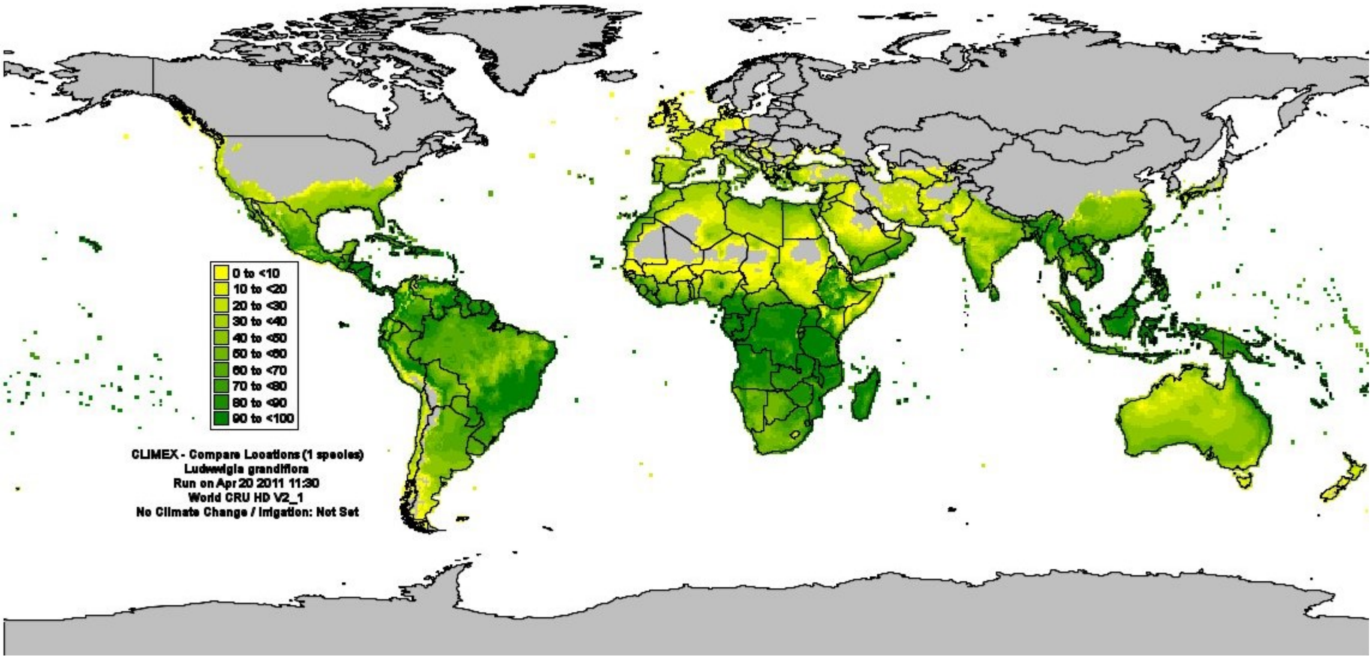


Fig 2: Climex map for *L. grandiflora* for the world

When fitting the predicted distribution to the known distribution in the USA, it appears that the predicted area in New York State (Fig. 3) matches the distribution provided by USDA (2010) (Fig 4).

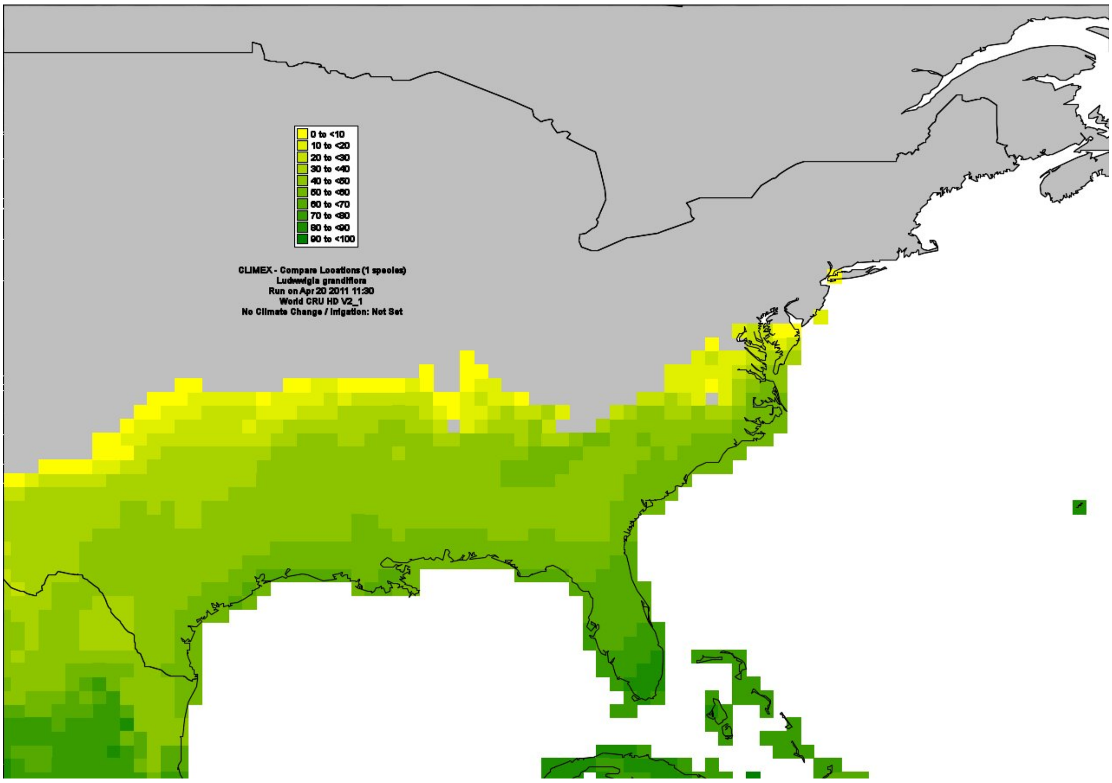


Fig 3: Climex map for *L. grandiflora* for the Eastern USA.

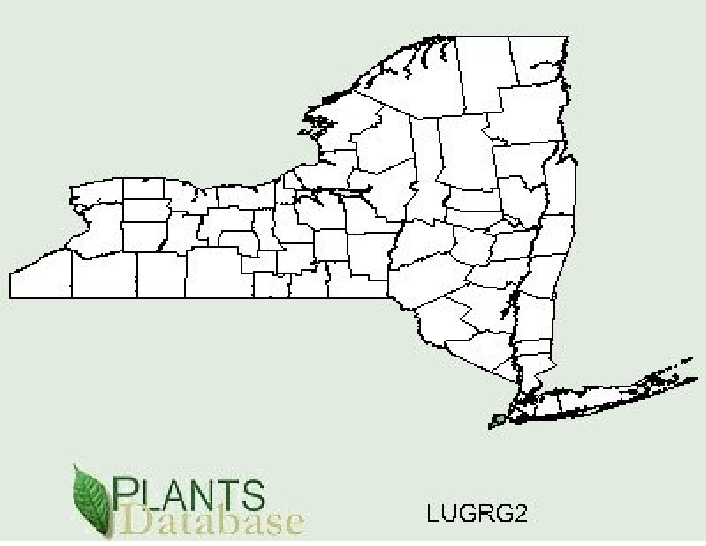


Fig 4: Distribution of *Ludwigia grandiflora* subsp. *grandiflora* in New York State, according to USDA (2010).
http://plants.usda.gov/java/county?state_name=New%20York&statefips=36&symbol=LUGRG2

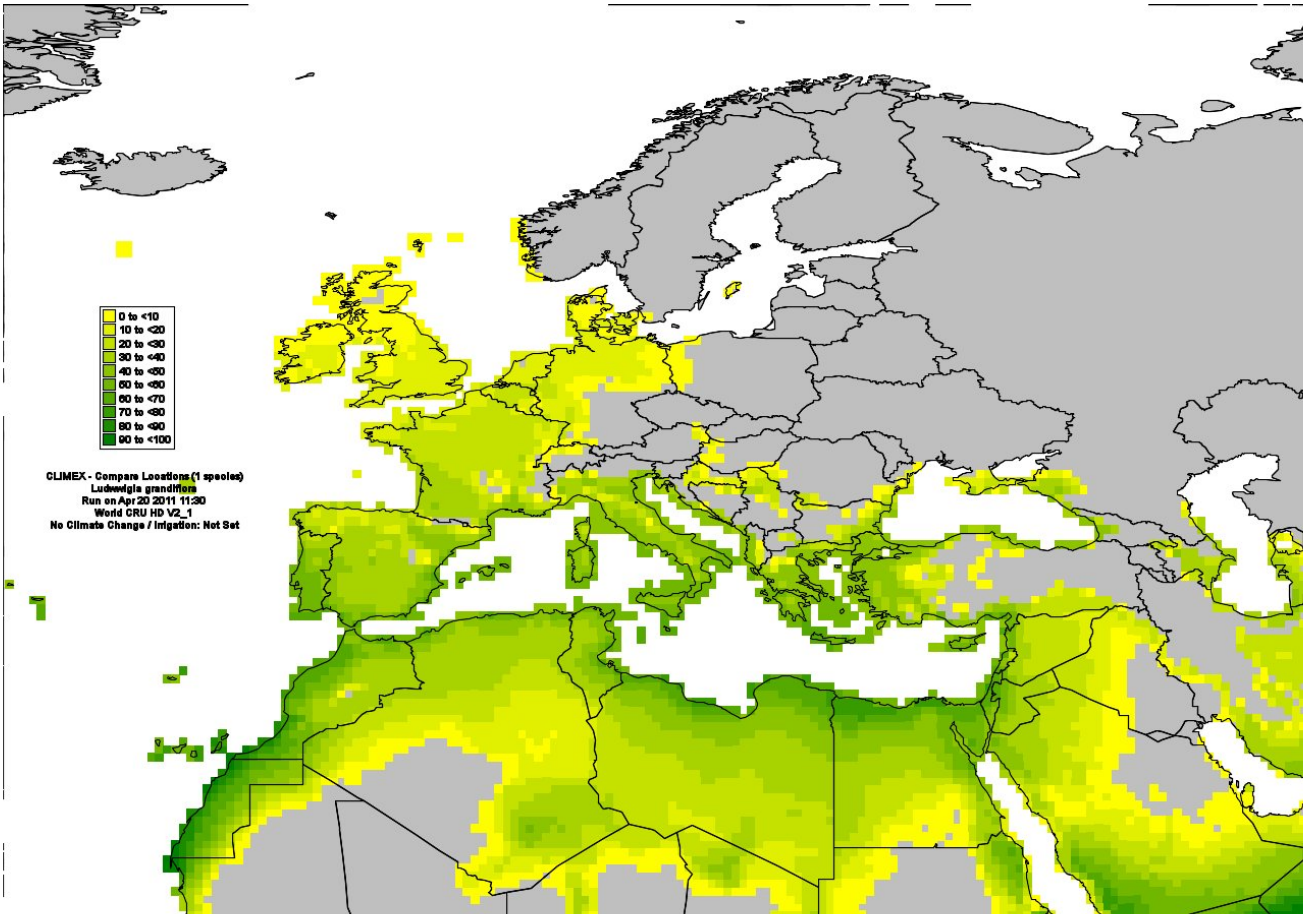


Fig 5: Climex map for *L. grandiflora* for the EPPO region

The current distribution of *L. grandiflora* is fully consistent with the projected Ecoclimatic index (see appendix 2 for maps of the occurrence of the species in individual countries). The northern boundary of the potential distribution in Europe is defined by cold stress, since this is the most limiting factor.

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Appendix 4

Picture of *Ludwigia grandiflora*

Invasion by *Ludwigia* spp. In the Scamandre reserve in the South of France, 2002.
Picture Franck Billeton