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Report of a Pest Risk Analysis for: *Ludwigia grandiflora*

This summary presents the main features of a pest risk analysis which has been conducted on the pest, according to EPPO Decision support scheme for quarantine pests.

Pest: ***Ludwigia grandiflora***
PRA area: The PRA area is the EPPO region (see map www.eppo.org).

Assessors:	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.
Date:	Expert working group 06-2010, core member consultation 06-2011

STAGE 1: INITIATION

Reason for doing PRA:	*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.
Taxonomic position of pest:	Kingdom: Plantae Class: Magnoliopsida (Dicotyledons) Subclass: Rosidae Order: Myrtales Family: Onagraceae *Ludwigia grandiflora* ressembles and is often confused with *L. peploides*, which often occur together in the same countries. Publications therefore often mention "*Ludwigia* spp.".

STAGE 2: PEST RISK ASSESSMENT

Probability of introduction

Entry

<u>Geographical distribution:</u>	*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. Details about the situation in EPPO countries where the species is present as well as maps are available in the PRA record (10-16827).
<u>Major host plants or habitats:</u>	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).
<u>Which pathway(s) is the pest likely to be introduced on:</u>	*L. grandiflora* is most likely to enter the EPPO region through intentional import as an ornamental aquatic plant for use outdoors. *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. 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. **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.** The EWG considered other pathways as unlikely: - Intentional import for non ornamental uses - Contamination of other deliberately planted aquatic plants (e.g. water lilies)

Establishment

Plants or habitats at risk in the PRA area:	According to the CORINE Land Cover nomenclature, the habitats at risk are - Continental waters (water courses, water bodies); - Banks of continental water, riverbanks/canal sides (dry river beds); - Wet meadows. Freshwater bodies and ecosystems abound in the EPPO region, particularly static or slow-flowing waters, see CORINE Land Cover (2000) map in Appendix 1.
Climatic similarity of present distribution with PRA area (or parts thereof): 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 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 2). 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.
Characteristics (other than climatic) of the PRA area that would favour establishment:	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). 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.

In favourable aquatic habitats, *Ludwigia grandiflora* often builds up monospecific stands and outcompetes other aquatic species (Dutartre, 2004b). The species is suspected to have allelopathic properties enabling suppression of competing species (Dandelot *et al*., 2008).

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. 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.

L. grandiflora 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.

Finally, 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).

<u>Which part of the PRA area is the endangered area:</u>

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.

POTENTIAL ECONOMIC CONSEQUENCES

How much economic impact does the pest have in its present distribution:

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

<u>Impacts on crops</u>
Ludwigia grandiflora and *L. peploides* are very rarely present in rice crop and therefore do not cause a direct impact on rice production, but may indirectly be a nuisance when blocking irrigation ditches and canals. In addition, 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.

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.). 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*., 2009). Some costs are presented below, additional figures are available in the PRA record for *L. grandiflora* (10-16827).
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 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).
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.

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

Social impacts

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).

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.

Describe damage to potential hosts in PRA area:

The range of habitats under threat includes threatened or vulnerable habitats in much of the PRA area.

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

How much economic impact would the pest have in the PRA area:

Control costs could be similar to those already spent in infested parts of the PRA area. Environmental and social impacts are supposed to be the same wherever the species grows in suitable conditions.

CONCLUSIONS OF PEST RISK ASSESSMENT

Summarize the major factors that influence the acceptability of the risk from this pest:

Estimate the probability of entry:	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.
Estimate the probability of establishment:	*L. grandiflora* has already established in at least 8 countries of the EPPO region, the probability of establishment is therefore very high, the uncertainty is low. According to the climatic prediction, additional countries are at risk. In addition, the overall probability of spread is high, uncertainty is medium.
Estimate the potential economic impact:	**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.
Degree 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.
OVERALL CONCLUSIONS	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

IDENTIFICATION OF THE PATHWAYS

Pathways studied in the pest risk management	• 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).

Other pathways identified but not studied none

IDENTIFICATION OF POSSIBLE MEASURES
Possible measures for pathways

Intentional import as an ornamental aquatic plant for use outdoors.
Measures related to consignments:

Measures related to the crop or to places of production:
<u>International measures</u>
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.

<u>National measures</u>
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.

<u>Integrated management plan for the control of existing infestations</u>
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.

<u>Monitoring and review</u>
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.

EVALUATION OF THE MEASURES IDENTIFIED IN RELATION TO THE RISKS PRESENTED BY THE PATHWAYS

Degree of uncertainty Low

CONCLUSION:
Recommendation for possible measures:
PC= Phytosanitary certificate, RC=Phytosanitary certificate of re-export

Pathway 1:	Prohibition

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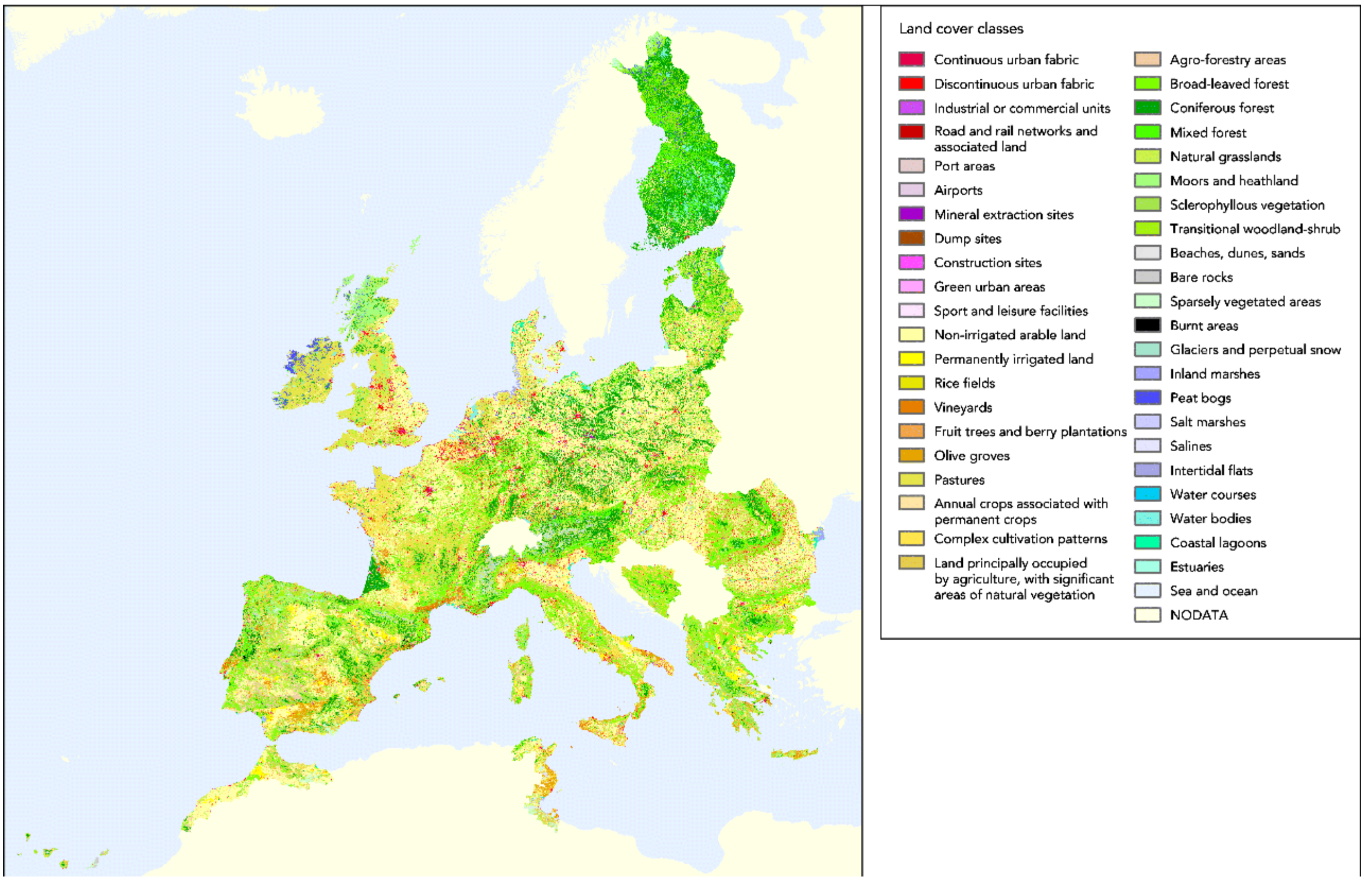
Appendix 1

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 2

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.

<u>Distribution of the species</u>
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.

<u>Phenology of the species</u>
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.

1 <u>Species parameters</u>
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.

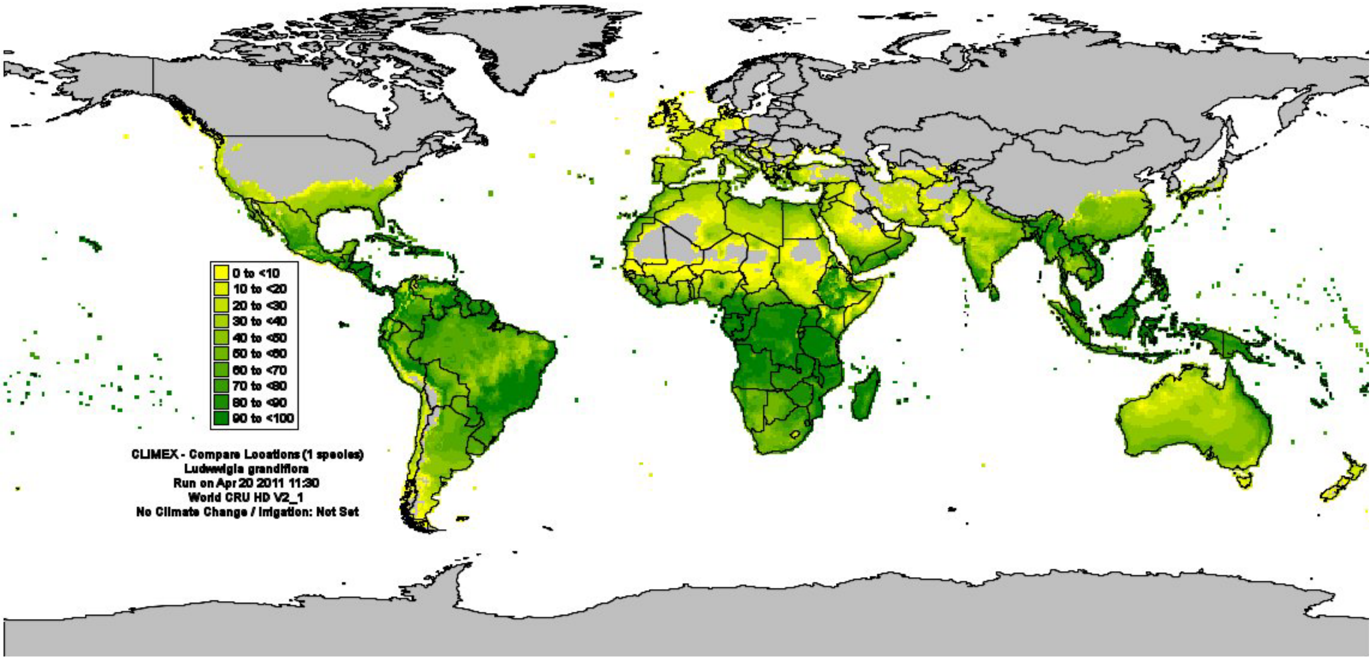


Fig 2: Climex map for *L. grandiflora* for the world

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).

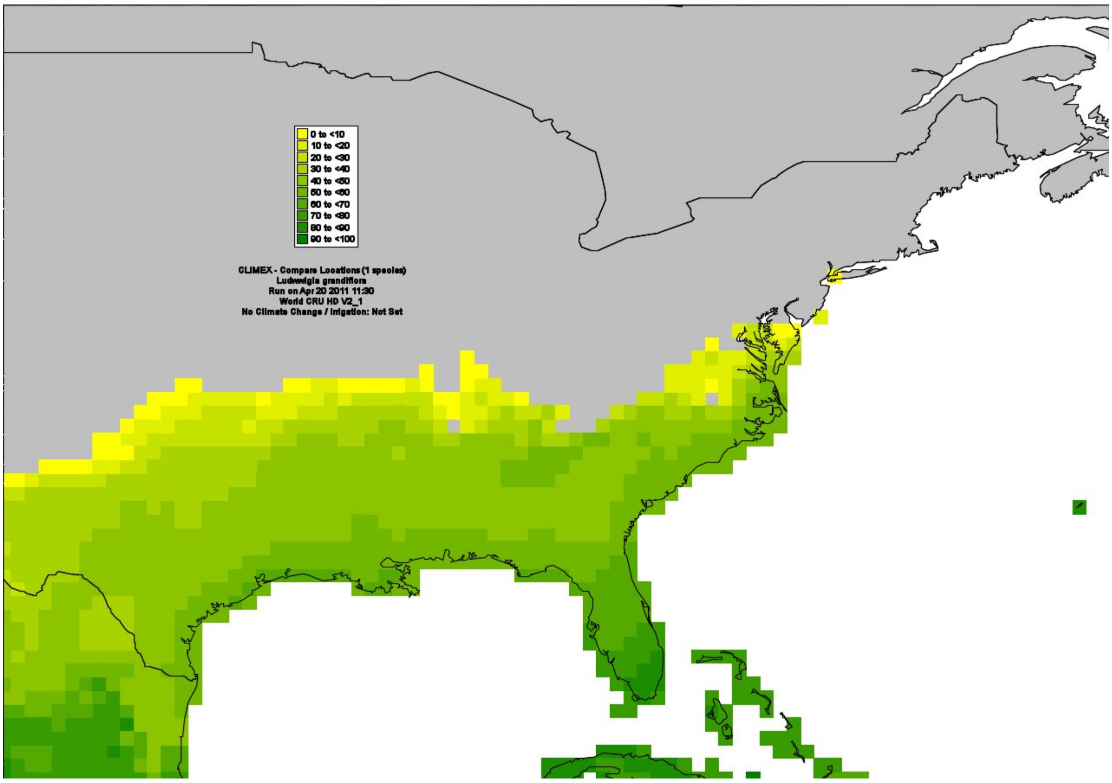


Fig 3: Climex map for *L. grandiflora* for the Eastern USA.

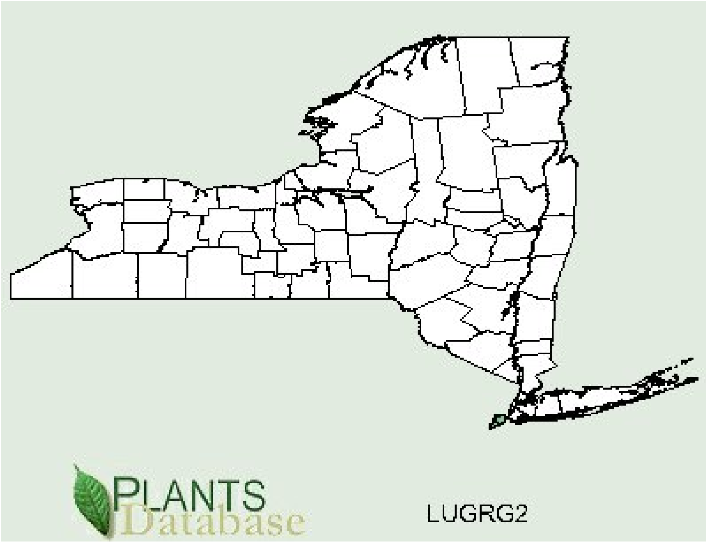


Fig 4: Distribution of *Ludwigia grandiflora* subsp. *grandiflora* in New York State, according to USDA (2010).
http://plants.usda.gov/java/county?state_name=New%20York&statefips=36&symbol=LUGRG2

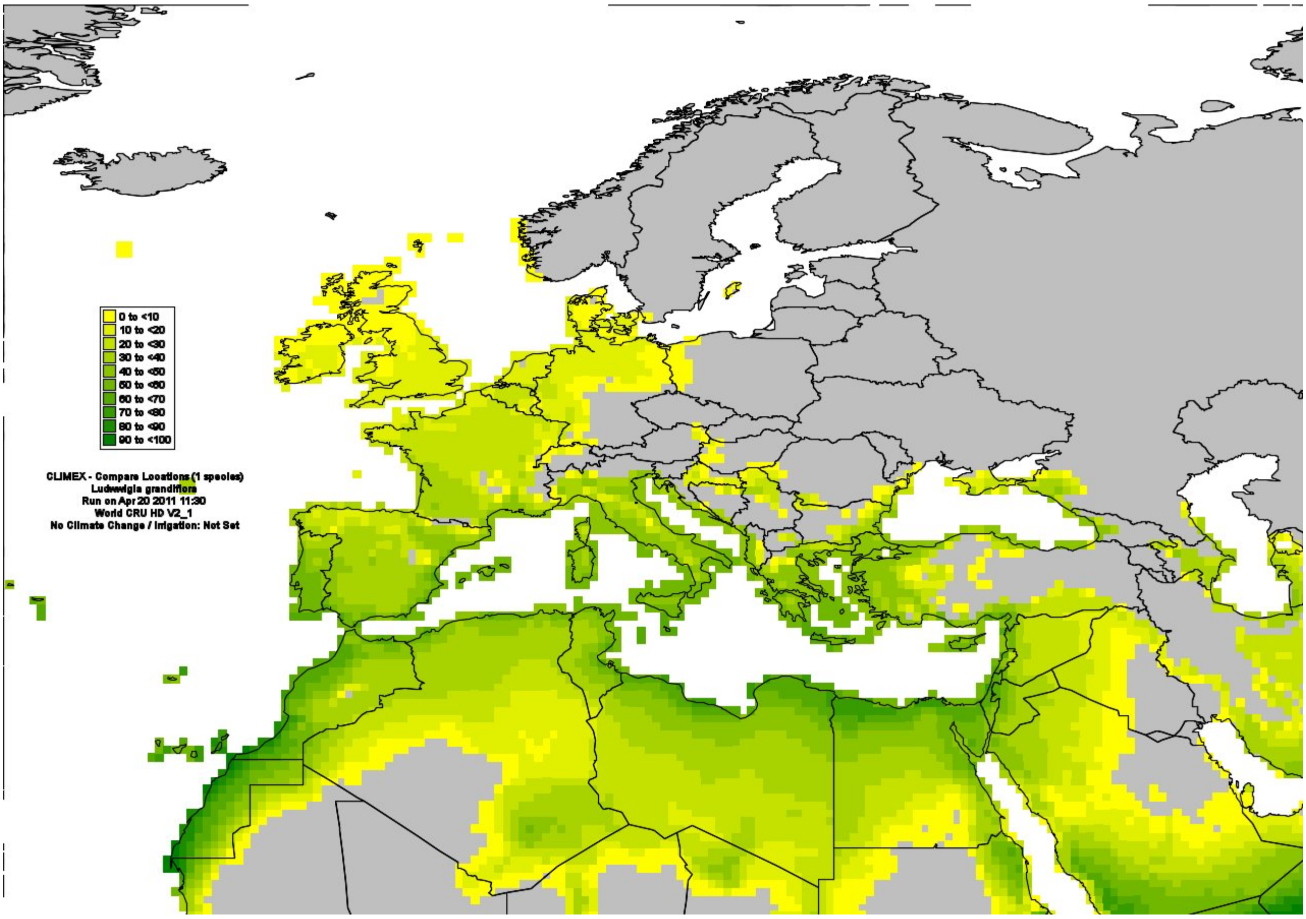


Fig 5: Climex map for *L. grandiflora* for the EPPO region

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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