EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

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Pest Risk assessment for ***Gymnocoronis spilanthoides***

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This pest risk assessment scheme has been specifically amended from the EPPO Decision-Support Scheme for an Express Pest Risk Analysis document PM 5/5(1) to incorporate the minimum requirements for risk assessment when considering invasive alien plant species under the EU Regulation 1143/2014. Amendments and use are specific to the LIFE Project (LIFE15 PRE FR 001) 'Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014'.

Photo: *Gymnocoronis spilanthoides* encroaching into a rice field in Italy (Claudio Ballerini).

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

Pest risk assessment for *Gymnocoronis spilanthoides* (D.Don ex Hook. & Arn.) DC.

This PRA follows EPPO Standard PM5/5 Decision support scheme for an Express Pest Risk Analysis

PRA area: EPPO region

First draft prepared by: Paul Champion

Location and date: Paris (FR), 2016-10-03/07

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The pest risk assessment for *Gymnocoronis spilanthoides* has been performed under the LIFE funded project:

LIFE15 PRE FR 001

Mitigating the threat of invasive alien plants to the EU through pest risk analysis to support the Regulation 1143/2014

In partnership with

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

And

NERC CENTRE FOR ECOLOGY AND HYDROLOGY

Review Process

- This PRA on *Gymnocoronis spilanthoides* was first drafted by Paul Champion

- The PRA was evaluated under an expert working group at the EPPO headquarters between 2016-10-03/07

- Following the finalisation of the document by the expert working group the PRA was peer reviewed by the following:

  (1) The EPPO Panel on Invasive Alien Plants (October and November 2016)
  (2) The EPPO PRA Core members (December 2016)
  (3) The Scientific Forum on invasive alien species (2017)[1]

Approved by the IAS Scientific Forum on 19/03/2018

[1] Additional information has been included in the original document following review from the Scientific Forum on invasive alien species

Contents

Summary 6
Stage 1. Initiation 9
Stage 2. Pest risk assessment 10
1. Taxonomy 10
2. Pest overview 11
3. Is the pest a vector? 14
4. Is a vector needed for pest entry or spread? 14
5. Regulatory status of the pest 14
6. Distribution 15
7. Habitats and their distribution in the PRA area 17
8. Pathways for entry 18
9. Likelihood of establishment in the natural environment PRA area 22
10. Likelihood of establishment in managed environment in the PRA area 23
11. Spread in the PRA area 23
13. Potential impact in the PRA area 27
14. Identification of the endangered area 28
15. Climate change 29
16. Overall assessment of risk 31
17. Uncertainty 33
18. Remarks 34
19. References 34
Annex 1: Projection of climatic suitability for *Gymnocoronis spilanthoides* establishment 39
Appendix 2 Biogeographical regions in Europe 50
Appendix 3. Relevant illustrative pictures (for information) 51
Appendix 4. Distribution maps of Gymnocoronis spilanthoides 58

Summary of the Express Pest Risk assessment for "*Gymnocoronis spilanthoides*"

PRA area: EPPO region (see https://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm.)

Describe the endangered area:

The endangered area includes countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria. The endangered area includes the Mediterranean and Continental biogeographic regions.

Based on the current distribution modelling of the species, there is potential for establishment in the southern EPPO countries. The highest potential for establishment is in the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria. To a lesser extent, there is the potential for establishment in the Atlantic zones of Portugal, Spain and France and small areas of the Black Sea (Georgia) (see Appendix 1). All water bodies not enclosed in ice for prolonged periods (more than 1 month) during the winter months, including thermally abnormal waters in other EPPO countries could provide potential habitats for *G. spilanthoides*. Habitats within the endangered area include slow moving rivers, canals, irrigation and drainage systems, lakes and reservoirs, which are widespread within the EPPO region. Impact is likely to be greatest in the warmer parts of its range based on the findings of Burnett (2008).

At present *G. spilanthoides* has been reported outside of cultivation in Italy and thermal waters in Hungary.

Main conclusions

The results of this PRA show that *G. spilanthoides* poses a high risk to the endangered area (the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria) with a high uncertainty. However, the Expert Working Group made this statement while considering the modelling is likely to give an underestimate of the potential range, with other uncertainties arising from the relatively recent naturalization with consequent limited ecological information.

Entry and establishment

In the EPPO region, *G. spilanthoides* is reported outside of cultivation in Italy and Hungary. The overall likelihood of *G. spilanthoides* entering the EPPO region is high with low uncertainty. The species is traded from outside the region and within the EPPO region.

Potential impacts in the PRA area

Most of the information on impacts is based on data from outside the EPPO region and thus can only be a proxy to the potential impacts within the EPPO region. Within its introduced range, *G. spilanthoides* obstructs water bodies by increasing flooding, impeding navigation and other water uses. Ecological effects include displacement of native vegetation and associated fauna. In addition, water quality may deteriorate as a result of dense mats smothering the water surface and rapid decomposition of plant material. As these impacts are mostly based on observations of other similar sprawling emergent species, uncertainty is assessed as high.

Although present in the EPPO region, there are no reported studies that have evaluated the ecological or economic impact of *G. spilanthoides* in the region. This species has been regarded as a transformer species by Török *et al.* (2003), and *G. spilanthoides* appears to radically modify aquatic and wetland systems in which it has invaded outside of the EPPO region (Personal Observation, Paul Champion, 2016). Impacts in the EPPO area will likely be attenuated by climatic suitability, but, in areas where *G. spilanthoides* is able to establish and spread, impacts are likely to be similar unless the species is under phytosanitary control. For example, many of the impacts on biodiversity relate to ecosystem processes such as decomposition and the alteration of nutrient cycling, which, assuming that *G. spilanthoides* is able to reach the levels of abundance required for these impacts to be displayed, can be assumed to occur in these areas to the same extent as in the current area of distribution.

Europe has several atypical aquatic thermal habitats and this may expand impacts into areas that would otherwise be considered climatically unsuitable by coarse environmental modelling. For example, *G. spilanthoides* occurs in the Hungarian thermal canals where the presence of the plant is probably related to planting for harvesting at a later date. If these waters are connected to more typical waters they may act as a permanent source of propagules (this has been shown for *Pistia stratiotes*, Hussner *et al*., 2014).

The potential impacts of *G. spilanthoides* on biodiversity and ecosystem services may be compared to the actual negative impacts seen with *Alternanthera philoxeroide*s, due to the similar life form and function (EPPO, 2015). This would include the displacement of native plant species and a negative impact on invertebrate species coupled with alterations of macrophyte decomposition rates.

The text within this section relates equally to EU Member States and non-EU Member States in the EPPO region.

Climate change

By the 2070s, under climate change scenario RCP8.5, projected suitability for G. spilanthoides increases substantially. Many of the regions currently projected to be marginally suitable move towards high suitability, while the region of marginal suitability extends in western Europe as far north as Ireland. Therefore, the model suggests climate change could facilitate expansion of the invaded range of the species in Europe (to include the Alpine, Atlantic, Continental, and Mediterranean biogeographical regions and Albania, Bosnia and Herzegovina, Croatia, France, Greece, Italy Ireland, United Kingdom, Spain, Belgium, Netherlands, Germany, Slovenia, Montenegro), even though conditions in northern Europe are unlikely to become optimal.

Phytosanitary measures

The results of this PRA show that *G. spilanthoides* poses a high risk to the endangered area (the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria) with a high uncertainty.

Phytosanitary risk for the *endangered area* (Current/future climate) **Pathway for entry** Plants for planting: High/High Contamination of machinery/ leisure equipment: Low/Low Likelihood of establishment in natural environment: High/High Likelihood of establishment in managed environment: High/High Spread: Moderate/high **Impacts (current area of distribution)** Biodiversity and environment: High/High Ecosystem services: Moderate/High Socio-economic: Moderate/High **Impacts (PRA area)** Biodiversity and environment: High/High	High X	Moderate	Low

Ecosystem services: Moderate/High Socio-economic: Moderate/High			
Level of uncertainty of assessment (current/future climate) **Pathway for entry** Plants for planting: Low/Low Contamination of machinery/ leisure equipment: Low/Low Likelihood of establishment in natural environment: Low/Low Likelihood of establishment in managed environment: Low/Low Spread: Moderate/High **Impacts (current area of distribution)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High **Impacts (PRA area)** Biodiversity and environment: High/High Ecosystem services: High/High Socio-economic: High/High An overall high uncertainty rating has been given due to the lack of ecological studies. While the species has aggressively invaded some areas there are some discrepancies. This species has failed to establish in climatically suitable habitats in the USA and South East Asia despite its presence in the trade.	High X	Moderate	Low

Remarks

Inform EPPO or IPPC or EU

- Inform NPPOs that surveys are needed to confirm the distribution of the plant, in particular in the area where the plant is present; and on the priority to eradicate the species from the invaded area. In addition, surveys should be conducted within the EPPO region to confirm if the plant is only grown in aquaria and not in outdoor ponds.

Inform industry, other stakeholders

- Encourage industry to assist with public education campaigns associated with the risk of aquatic non-native plants.

Specify if surveys are recommended to confirm the pest status

- Surveys should be conducted to confirm the current distribution and status of the species within the endangered area and this information should be shared within the PRA area.

Express Pest Risk assessment:

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***Gymnocoronis spilanthoides* (D. Don ex Hook. & Arn.) DC.**

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Date: 14 August 2016

Stage 1. Initiation

Reason for performing the PRA:

Gymnocoronis spilanthoides currently has a very limited naturalised distribution in the EPPO region. However, recent deliberate introductions of the species throughout the world (e.g. New Zealand and Australia), highlights the potential risk for further introduction and spread into the EPPO region. Further spread is predicted as the species is traded within the EPPO region (Brunel, 2009). In Europe, *G. spilanthoides* was first reported as naturalised[2] in a thermally influenced system of canals in 1988 in Hungary (Szabó, 2002) and in drainage channels in 2015 in Italy (Ardenghi *et al.*, 2016). Although *G. spilanthoides* has a tropical to subtropical native range (South America), it has proved to be extremely hardy in naturalised populations of other regions (Parsons & Cuthbertson, 2001), emerged plants tolerate frosts of up to -5 °C and it can survive as a submerged plant under ice (Paul Champion, Personal Observation, 2016). Consequently, *G. spilanthoides* is likely to have a much greater potential range within the EPPO region than is currently observed. Dense emergent beds of *G. spilanthoides* sprawling over shallow margins of water bodies limit the growth of submerged and other emergent plant species. These beds prevent wind induced mixing of the water column causing reductions in dissolved oxygen that may result in anoxia with serious effects on fish and invertebrate species. The plant also increases evapotranspiration resulting in water loss. These dense plant beds can impede water flow, promoting flooding, also obstructing navigation and recreation (Parsons & Cuthbertson, 2001).

Gymnocoronis spilanthoides is included on the EPPO Observation List created in 2012. This list contains plant species that present a medium risk or for which information currently available is not sufficient to make an accurate risk assessment. The EPPO status of *G. spilanthoides*, the presence of the species in the EPPO region, and the continued availability of this plant for purchase within EPPO countries, coupled with a warming climate, mean that a PRA is required.

PRA area: EPPO region (see https://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm.)

[2] The term naturalised is used following the definition of Richardson et al., (2000). Naturalized plants: Alien plants that reproduce consistently (cf. casual alien plants) and sustain populations over many life cycles without direct intervention by humans (or in spite of human intervention); they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, seminatural or human-made ecosystems.

Stage 2. Pest risk assessment

1. Taxonomy: *Gymnocoronis spilanthoides* (D.Don ex Hook. & Arn.) DC., Kingdom Plantae; Phylum Tracheophyta; Class Liliopsida; Order: Asterales; Family: Asteraceae (Compositae), Tribe: Eupatorieae; Subtribe: Adenostemmatinae.

EPPO Code: GYNSP

Synonymy: *Alomia spilanthoides* D.Don ex Hook., *Alomia spilanthoides* D.Don ex Hook. & Arn., *Gymnocoronis attenuata* DC., *Gymnocoronis spilanthoides* var. *attenuata* (DC.) Baker, *Gymnocoronis subcordata* DC., *Piqueria attenuata* (DC.) Gardner, *Piqueria subcordata* (DC.) Gardner Ref: The Plant List (http://www.theplantlist.org/tpl1.1/record/gcc-39812)

Common name: Senegal tea (plant), Germany: Falscher Wasserfreund, Hungary: *vízibojt*, Latin America: jazmin del banado (swamp jasmine), China: 裸冠菊 luo guan ju, English names used in plant trade: temple plant, spade-leaf plant, water snowball (USA), Giant green hygro, costata

Plant type: Emergent amphibious aquatic perennial herb

Related species in the EPPO region: *Eupatorium cannabinum* (Eupatorieae: Asteraceae)

2. Pest overview

Introduction

Gymnocoronis spilanthoides is a perennial emergent aquatic or wetland herb, which can also grow in a submerged form. The native range of the species is South America (Brazil, Argentina, Paraguay, Uruguay, Bolivia and Peru), mostly centred around Uruguay and Paraguay (King & Robertson, 1987). Within its indigenous range, *G. spilanthoides* is reported as a principal weed in Argentina by Holm *et al.* (1979).

The earliest confirmed records of *G. spilanthoides* naturalised outside of the native range are from Australia in 1980, Hungary in 1988, New Zealand in 1990, Japan in 1995, Taiwan in 2001, mainland China in 2007 and Italy in 2015 (Parsons & Cuthbertson, 2001; Szabó, 2002; Webb *et al.*, 1995; Kadono, 2004; Wu *et al.*, 2010; Gao & Lui, 2007; Ardenghi *et al.*, 2016). *Gymnocoronis spilanthoides* was first recorded in the Australian trade in the mid-1970s (Parsons & Cuthbertson, 2001). It is therefore a relatively recent naturalised species, presumably being introduced outside of its native range in the aquarium and ornamental pond plant trade (Champion & Clayton, 2001). *Gymnocoronis spilanthoides* is sold as an ornamental aquarium plant in the PRA area (Brunel 2009) who reported it being sold in the Netherlands, France, Hungary, Switzerland and Estonia. Ardenghi *et al.* (2016) report it as being sold over the internet in Italy. It is also sold in the UK as an ornamental pond plant (www.Aquaessentials.co.uk). *Gymnocoronis spilanthoides* can grow as either an emergent or submerged species, with submerged plants tolerant of ice-over (based on observations in New Zealand) also producing viable seed within its introduced range with the potential to grow as an annual in colder areas (Personal communication Paul Champion, 2017). Based on the current distribution modelling of the species, there is potential for establishment in the southern EPPO countries (Appendix 1). Based on the current species distribution modelling, the highest potential for establishment is in the countries bordering the Adriatic Sea and the Eastern Mediterranean as well as parts of Morocco and Algeria. To a lesser extent, there is the potential for establishment in the Atlantic zones of Portugal, Spain and France and small areas of the Black Sea (see Appendix 1). All water bodies not enclosed in ice for prolonged (1 month or longer) periods during the winter months, including thermally abnormal waters in other EPPO countries could provide suitable habitats for *G. spilanthoides*. The suitable area is likely to increase under likely scenarios of climate change (e.g., Hallstan, 2005).

Environmental requirements

In the introduced range, *Gymnocoronis spilanthoides* grows in slow moving rivers (including tidally influenced areas), reservoirs, irrigation channels, ponds, lakes, canals and ditches. It often establishes on the water body margins or in shallow water, then forming floating mats that can smother small water bodies (Appendix 3, Fig. 1 and 2). It also grows in marshes and swamps, especially where nutrient enriched (CRC 2003). In cooler parts of its introduced range, *G. spilanthoides* is a summer-green, dying back to a perennial rootstock or to submerged plants, even under ice (NZPCN, 2013, Champion, Personal Observation). Burnett (unpublished PhD thesis 2008) cultivated *G. spilanthoides* in Hamilton, New Zealand (37.8°S) with water temperature fluctuations between 7 and 23°C. He then manipulated temperatures either 2, 4 or 6°C above or below ambient (Burnett *et al.* 2007) in separate tanks all otherwise experiencing outdoor ambient conditions. *Gymnocoronis spilanthoides* survived all treatments and all measured growth parameters (stem number, height, percentage cover, biomass) increased with increasing temperature. All treatments apart from +6°C died off to basal rootstocks during winter. The southernmost naturalised *G. spilanthoides* population was the Waimakariri River margin in Canterbury, New Zealand (43.4°S). Ardenghi *et al.* (2016) reported Italian sites in the northwest (45.2°N) experienced hot summers (monthly mean summer ~30°C) and relatively cold winters (monthly mean January <-1°C). Seed set has been recorded at many New Zealand, Australian and the Italian sites (NZPCN, 2013; Vivian-Smith *et al.*, 2005; Panetta, 2010; Ardenghi et al., 2016), with low numbers of seed set. However, germination rates were high over a range of fluctuating temperatures 5/15, 10/20 to 25/15 or at 25°C (Vivian-Smith *et al.*, 2005; Ardenghi *et al.*, 2016). Seed bank persistence was estimated to be more than 16 years until viability was reduced below 1%, but would be much shorter if exposed to daylight (Panetta, 2010). Some field sites are situated on tidally influenced rivers, but tolerance to salinity is unknown. *Gymnocoronis spilanthoides* has high growth rates under ideal conditions, measured at shoot growth of 150 mm per week in New South Wales (Parsons & Cuthbertson, 2001).

Habitats

Within its introduced range, *G. spilanthoides* grows in wetlands, particularly degraded waterways (CRC, 2003) forming marginal clumps on the edge of slow flowing or still water bodies, also forming dense sprawling floating mats in rivers (including tidally influenced areas) and reservoirs, irrigation channels, ponds, lakes, canals and ditches (Appendix 3, Fig. 3). It also grows in marshes and swamps, especially where nutrient enriched (CRC, 2003). It established but did not persist in a rice field in Italy (Personal Communication, N. Ardenghi, 2016) (see Appendix 3, Fig. 4). See also the **Environmental requirements** section above.

Identification

Gymnocoronis spilanthoides is an emergent perennial herb, either forming upright bushes up to 1.5 m tall, tangled sprawling floating mats or occasionally fully submerged in shallow water (Appendix 3, Fig. 5). Plants reproduce by seed (flowers are pollinated by insects) and vegetative fragmentation, with detached stems rooting at the nodes and thus forming new colonies. Stems are pale green (rarely reddish), either round or six- to eight-angled in cross section, erect or scrambling, up to 1.5 m long and 20 mm across, with hollow internodes, inflated and buoyant (Appendix 3, Fig. 6). Leaves lanceolate or ovate, opposite, 50 to 200 mm long 25 to 75 mm wide, serrate with wavy margins, veins pinnate. Submerged foliage usually entire but wavy margins, petiolate, 10 to 70 mm long. Inflorescence glandular hairy, terminal, a cyme of capitula (flowerheads). Capitula discoid, with white (or pinkish) florets, 3.5 to 4 mm long, subtended by a single row of green involucral bracts, 15 to 20 mm across, highly scented and very attractive to butterflies (Appendix 3, Fig. 7). Fruit an achene, lacking a pappus, pale brown, slightly curved with prominent ribs, 1.2 mm long, 0.5 mm across (Parsons & Cuthbertson, 2001; NZPCN, 2013; Ardenghi *et al.*, 2016). Seed set variable, 6 to 19% of florets producing seed (Vivian-Smith *et al.*, 2005). Adventitious roots commonly developing on the nodes. Based on other species (*Ludwigia grandiflora* and *Myriophyllum aquaticum*) these stem fragments may be less than 1 cm in length as long as one node is present (Hussner, 2009). As a white flowered aquatic species, *G. spilanthoides* could potentially be misidentified for *Alternanthera philoxeroides*, though for this species the flowers are more compact, the petals are shorter in length and the leaves are shorter.

Symptoms

Dense, rapidly growing mats of *G. spilanthoides* exclude other plants and the animals that rely on them (Personal communication Paul Champion, 2017). It can completely smother small water bodies (CRC, 2003). Mats promote flooding by obstructing flow, also affecting irrigation, navigation and recreational use. Water quality, especially dissolved oxygen, may decline as a result of high plant turnover and decomposition (CRC 2003) and respiration of adventitious roots.

Relevant PRAs

Australia: Weber & Panetta (2006) included this species in a Weed Risk Assessment (WRA) for Australia concluding that *G. spilanthoides* posed the greatest threat to aquatic ecosystems of the five species assessed. Victorian Resources online (2015) rated this species in the highest risk category for 6 of the 15 invasiveness characters. Champion *et al*., (2008) used a modified Champion & Clayton (2000) model and scored this species 88 out of a maximum of 130, the fifth highest ranked weed species assessed, recommending that it should be removed from the plant trade. A WRA for Australia using the Pheloung *et al.* (1999) model was conducted under the Pacific Island Ecosystems at Risk (PIER) program. This resulted in a high score of 7 (reject the plant for import) and the conclusion that the species was "likely to be of high risk to the Pacific" (PIER 2009).

New Zealand: A risk assessment has been produced where the species scored 57 points out of a maximum of 100 points, scoring highly in ecological adaptation, competitive ability, potential impact on natural areas and water use. It therefore is ranked as a high risk species (Champion & Clayton, 2000).

Europe (overall): The current PRA is being conducted under the LIFE project (LIFE15 PRE FR 001) within the context of European Union Regulation 1143/2014, which requires that a list of invasive alien species (IAS) be drawn up to support future early warning systems, control and eradication of IAS. Based on Australian and New Zealand WRA assessments, Champion *et al.* (2010) regarded *G. spilanthoides* as an aquatic plant species of concern in Europe.

USA: UDSA APHIS (2012) undertook a WRA in the USA, with this species scoring 16 for establishment and spread out of a potential score of 25 (potential: uncertainty index of 0.17) and with an impact potential score of 3.4 (highest score 5), rating it as a high risk, with a 84.3% probability of becoming a major invader there. PIER (2009) report a WRA score of 7 with the conclusion that the species had a high pest risk. *Gymnocoronis spilanthoides* was evaluated for Florida using a modified version of the AWRA. Under this assessment *G. spilanthoides* scored 17, indicating a high probability of invasion (Invasive Plant Working Group, 2016).

Socio-economic benefits

Gymnocoronis spilanthoides is widely sold as an ornamental species within the EPPO region, including internet trade (Brunel, 2009; Ardenghi *et al.*, 2016).

Gymnocoronis spilanthoides is used in aquaria where it is grown as a submerged plant (sold as giant green hygro or costata) (Kasselmann, 2003; Tropica, 2016), and as an ornamental plant for outdoor ponds (sold as water snowball or Senegal tea plant) (Speichert & Speichert, 2007). There are several varieties sold, including plants with red stems and variegated foliage. Brunel (2009) and Ardenghi *et al.* (2016) report this species being traded in the EPPO region. Brunel (2009) reports that 753 individual plants were imported into the EPPO region (Netherlands, France, Hungary, Austria and Estonia), though the period of these imports is not specified.

The species is also traded informally between aquatic plant enthusiasts. Plants are released intentionally (including by traders for the purposes of wild harvesting) or unintentionally (unintentional disposal of plant material where *G. spilanthoides* is a contaminant) into the field.

The Ornamental Aquatic Trade Association (UK based) carried out a survey with its members in August 2016 requesting advise on the number of plants and value that they had sold in the calendar year for 2015. Thirty-three members responded to this survey and detailed that in total 75, 700 *G. spilanthoides* plants were sold in the UK in 2015 with a value of GBP 112 955.

According to van der Valk et al. (2018), the total trade value of *Gymnocoronis spilanthoides* as pond and aquarium plant in the Netherlands is estimated to be more than 20,000 euro/year.

The species is highly regarded as an ornamental pond plant as its flowers are very attractive to some butterflies, especially monarch butterflies in Australasia and USA (Speichert & Speichert 2007) and Kadono (2004) reports the plant is cultivated by butterfly enthusiasts in Japan. Kadono (2004) also reports the plant being promoted in Japan for water purification. Boppré and Colegate (2015) highlight that the attraction to butterflies may be due to the pyrrolizidine alkaloid esters contained in the plant.

3. Is the pest a vector?	**No**
4. Is a vector needed for pest entry or spread?	**No**

5. Regulatory status of the pest

Europe (overall):
Gymnocoronis spilanthoides was included on the EPPO "Alert List" in 2009. It was removed from this list and transferred to the "Observation List" in 2012. *Gymnocoronis spilanthoides* was also assessed under an all-taxa horizon scanning exercise designed to help prioritise risk assessments for the "most threatening new and emerging invasive alien species" in Europe (Roy *et al.*, 2015); *G. spilanthoides* scored 625 using this protocol and represented a high probability of arrival, establishment, spread and threat to biodiversity and associated ecosystem services across the EU within the next ten years.

Japan:
Gymnocoronis spilanthoides is designated as an invasive alien species according to the Invasive Alien Species Act of Japan **(**Muranaka *et al.*, 2005).

New Zealand:
Gymnocoronis spilanthoides is listed on the National Plant Pest Accord prohibiting it from sale and commercial propagation and distribution and it is declared an unwanted organism under the Biosecurity Act 1993 (Hicks 2001). It is subjected to eradication programmes by regional councils throughout its New Zealand range (Champion *et al.*, 2014). It is listed as an "Environmental Weed" by Howell (2008).

Australia:
Gymnocoronis spilanthoides is on the Federal Alert List for Environmental Weeds, a list of 28 non-native plants that threaten biodiversity and cause other environmental damage. Although only in the early stages of establishment, these weeds have the potential to seriously degrade Australia's ecosystems. It is subject to statutory management in most Australian States including ACT, NSW, Queensland, South Australia, Western Australia, Tasmania and Lord Howe Island (Parsons & Cuthbertson, 2001). Csurhes & Edwards (1998) evaluated this species as a potential environmental weed, with a low probability of achieving eradication.

USA:
Gymnocoronis spilanthoides is not on the Federal or any State Noxious Weed list (USDA National Resources Conservation Service 2016).

6. Distribution

Continent	***Distribution*** *(list countries, or provide a general indication , e.g. present in West Africa)*	***Provide comments on the pest status in the different countries where it occurs*** *(e.g. widespread, native, introduced….)*	***Reference***
Africa	Senegal doubtful species record		Parsons & Cuthbertson (2001)
America	Brazil, Argentina, Paraguay, Uruguay, Bolivia, Peru Central America (Mexico) – other *Gymnocoronis* species	Native to South America.	King & Robinson (1987), Turner (1997), WSSA (2012)
Asia	Japan, China, Taiwan India – not naturalised doubtful species records.	Introduced, invasive in Japan and Taiwan.	Kodono (2004), Gao & Liu (2007), Wang *et al.* (2010), Wu *et al.* (2010), Parsons & Cuthbertson (2001)
Europe	Italy, Hungary Biogeographical regions: Continental and Pannonian	Introduced (established in thermal waters in Hungary); recorded in Italy (2015).	Ardenghi *et al.* (2016), Szabó (2002), GBIF
Oceania	Australia, New Zealand	Introduced and invasive	Parsons & Cuthbertson (2001), Webb *et al.* (1995)

Introduction
Gymnocoronis spilanthoides has a native range within South America (Brazil, Argentina, Paraguay, Uruguay, Bolivia and Peru), mostly centred around Uruguay and Paraguay (King & Robertson, 1987) and is becoming an invasive alien species in several regions of the world (Appendix 4, Fig 1 & 2). The species is problematic in Australia, New Zealand, Japan, China and Taiwan and has recently naturalised in Italy.

Africa
Reported from Senegal by Parsons & Cuthbertson (2001), but there are no GBIF records of the plant in Africa. They report its use in folk medicine there. The record may refer to the misapplication of the vernacular name.

Central and South America
Gymnocoronis spilanthoides has a native range within South America (Brazil, Argentina, Paraguay, Uruguay, Bolivia and Peru), mostly centred around Uruguay and Paraguay (King & Robertson, 1987) (Appendix 4, Fig 2). Records of this species from Central American countries likely refer to another species *G. latifolia* (or up to four species depending on the taxonomy) (Turner, 1997).

North America
Gymnocoronis spilanthoides is cultivated in the USA but is not reported as naturalised there (WSSA 2012). Records of the species from Mexico likely refer to another species.

Asia
Reported from India (reputedly the source of introduction to Australia through the aquarium trade) by Parsons & Cuthbertson (2001), but no GBIF records of the plant. Relatively recent records of naturalisation in Japan (in 1995), Taiwan (in 2001) and mainland China (in 2007) (Kadono, 2004; Wu *et al.*, 2010; Gao & Lui, 2007; Wang *et al.*, 2010). Kadono (2004) reports this species as rapidly naturalising occurring from Kyushu to central Japan. See Appendix 4, Fig 3 and 4.

Europe
Gymnocoronis spilanthoides was reported as casual in 1988 in Hungary, occurring in the thermal waters of Lake Héviz and ditches near Keszthely (Szabó, 2002, Lukács *et al.*, 2016). However, the expert working group prefer to define this occurrence as naturalised in thermal waters. Ardenghi *et al.*, (2016) report two naturalised occurrences in north-western Italy (Lombardia region). The population in Italy stretches along the water body to 519 m, and occupies the whole canal width (1-4 m) (Ardenghi *et al.*, 2016). See Appendix 4, Fig 5.

Oceania
Gymnocoronis spilanthoides was first reported as a naturalised species in Australia, reported from Taree in NSW in 1980 (Parsons & Cuthbertson, 2001). It has since spread in NSW and also naturalised in the states of Victoria and Queensland. It has been eradicated from ornamental pond site in Perth and Margaret River in Western Australia, the only know sites in that state (Hussey *et al.*, 2007). In New Zealand, *G. spilanthoides* was first recorded as naturalised on the Papakura Stream in South Auckland in 1990 (Timmins & Mackenzie, 1995) and has since been found through much of lowland North Island and two South Island sites, the furthest south being in Canterbury (43.4°S). See Appendix 4, Fig 6.

7. Habitats and their distribution in the PRA area

Habitats	**EUNIS habitat types**	**Status of habitat (eg threatened or protected)**	**Present in PRA area (Yes/No)**	**Comments (e.g. *major/minor habitats* in the PRA area)**	***Reference***
Freshwater bodies (e.g. canals, ponds, rivers (slow-moving), streams, canals, ditches, irrigation channels, estuaries, reservoirs, and lakes)	C1: Surface standing waters (C.12, C1.3, C1.62, C1.63) C2: Surface running waters (C2.1, C2.3, C2.4)	Protected *pro parte*: e.g. Annex 1 Only threatened habitats potentially impacted are 22.13 (naturally eutrophic lakes) and 24.53 (Mediterranean rivers)	Yes	Major habitats within the PRA area	Parsons & Cuthbertson (2001), Hicks (2001)
Wetlands (e.g. vegetation fringing and emergent in freshwater bodies, eutrophic and mesotrophic swamps and marshes)	C3: Littoral zone of inland surface waterbodies (C3.1, C3.2, C3.42, C3.5)	None listed.	Yes	Major habitats within the PRA area	Australian Government (2016)

Within its introduced range, *G. spilanthoides* grows in wetlands, particularly degraded waterways (CRC, 2003) forming marginal clumps on the edge of slow flowing or still water bodies, also forming dense sprawling floating mats in rivers (including tidally influenced areas) and reservoirs, irrigation channels, ponds, lakes, canals and ditches (Appendix 3, Fig. 3). It also grows in marshes and swamps, especially where nutrient enriched (CRC, 2003). It established but did not persist in a rice field in Italy (Personal Communication, N. Ardenghi, 2016) (see Appendix 3, Fig. 4).

Many freshwater bodies and wetland sites are protected within the EPPO region. Freshwater habitats are detailed within the Habitats Directive 1992 and the Water Framework Directive 2000. Such habitats often harbour rare or endangered species.

8. Pathways for entry *(in order of importance)*

Possible pathways	**Pathway: Plants for planting** **(CBD terminology: Escape from confinement)**
Short description explaining why it is considered as a pathway	*Gymnocoronis spilanthoides* is used in aquaria where it is grown as a submerged plant (sold as giant green hygro or costata) (Kasselmann, 2003; Tropica, 2016), and as an ornamental plant for outdoor ponds (sold as water snowball or Senegal tea plant) (Speichert & Speichert, 2007). There are several varieties sold, including plants with red stems and variegated foliage. Brunel (2009) and Ardenghi *et al.* (2016) report this species being traded in the EPPO region, therefore this is the most 'likely' entry pathway. Brunel (2009) reports that 753 individual plants were imported into the EPPO region (Netherlands, France, Hungary, Austria and Estonia), though the period of these imports is not specified. The species is also traded informally between aquatic plant enthusiasts. Plants are released intentionally (including by traders for the purposes of wild harvesting) or unintentionally (unintentional disposal of plant material where *G. spilanthoides* is a contaminant) into the field. The Ornamental Aquatic Trade Association (UK based) carried out a survey with its members in August 2016 requesting advise on the number of plants and value that they had sold in the calendar year for 2015. Thirty-three members responded to this survey and detailed that in total 75, 700 *G. spilanthoides* plants were sold in the UK in 2015 with a value of GBP 112 955.
Is the pathway prohibited in the PRA area?	Not currently prohibited in the PRA area.
Has the pest already been intercepted on the pathway?	Yes, reported as being traded by Brunel (2009) and Ardenghi *et al.* (2016).
What is the most likely stage associated with the pathway?	Both emergent and submerged live plants would be traded. Potentially seed (achenes) could be traded (for example https://lv1047801943.fm.alibaba.com/product/160191767-0/Senegal_teaplant_Gymnocoronis_spilanthoides_Live_Aquatic_Plant.html), but currently most propagation is by vegetative propagation.
What are the important factors for association with the pathway?	Plants may be widely available by mail order and presumably sold in aquarium and pond plant outlets. The volume produced within the EPPO compared with volume imported is unknown.
Is the pest likely to survive transport and storage in this pathway?	Yes. As an import for ornamental purposes; plant survival and fitness is essential for the intended use.
Can the pest transfer from this pathway to a suitable habitat?	Yes, through human agency (i.e. intentional introductions or the unintentional disposal of plants into wild habitats). Intentional release into the wild for harvesting later was thought to have been the main pathway in Australia. The species could be misused and

	introduced directly into freshwater bodies and ecosystems (e.g. stream, lakes, dams). The unintended habitats are freshwater bodies and wetland ecosystems (semi-natural and natural waterbodies). Plants used in confined waterbodies could spread to unintended habitats very easily through human activities as well as through natural spread by floods downstream. Improper disposal of aquarium contents has been a source of introduction of aquatic plants in some countries, even if it is considered as an accidental pathway of introduction (e.g. *Cabomba caroliniana* in the Netherlands, see the EPPO PRA on the species.
Will the volume of movement along the pathway support entry?	The species is commercially produced within the EPPO region (The Netherlands; http://aquafleur.nl/index.html) and therefore the volume of movement from outside the region will not support entry unless production ceases or is reduced within the EPPO region. Note this is just one example of a producer and there are likely to be more producers in NL, DK and BE.
Will the frequency of movement along the pathway support entry?	As above.

Likelihood of entry	Low	Moderate	High X
Likelihood of uncertainty	Low X	Moderate	High

As the species is imported as a commodity, all European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Possible pathways	**Pathway: Contaminant of machinery** **(CBD terminology: Transport -stowaway)**
Short description explaining why it is considered as a pathway	It is possible that the import of drain clearing machinery could spread *G. spilanthoides*, particularly as seeds, although this is most unlikely to be significant pathway into the EPPO region. In addition to seeds, stem fragments could grow into viable plants if they remain moist. Based on other species (*Ludwigia grandiflora* and *Myriophyllum aquaticum*) these stem fragments may be less than 1 cm in length as long as one node is present (Hussner, 2009).
Is the pathway prohibited in the PRA area?	Not currently prohibited in the PRA area. However, there are campaigns within the EU to raise awareness of the movement of invasive alien plants by this pathway. For example, the "Check, Clean and Dry" campaign in Great Britain (see http://www.nonnativespecies.org/checkcleandry/) highlights the need to inspect and treat recreational material following use.
Has the pest already been intercepted on the pathway?	No.
What is the most likely stage associated with the pathway?	Seed and stem fragments.
What are the important factors for association with the pathway?	Potential pathway for localised spread from *G. spilanthoides* naturalised populations.
Is the pest likely to survive transport and storage in this pathway?	Yes. Seed likely to retain viability in machinery. Vegetative fragments would desiccate over time and potentially lose viability.
Can the pest transfer from this pathway to a suitable habitat?	Yes. Where equipment is contaminated, left untreated and then transferred to another region (pond, lake or river for example), seed and stem fragments can transfer to new areas.
Will the volume of movement along the pathway support entry?	No. Within the EPPO region the current occurrence of naturalised populations of *G. spilanthoides* is very low, leading to the probability of movement through this pathway being very low.
Will the frequency of movement along the pathway support entry?	As above.

Likelihood of entry	Low X	Moderate	High
Likelihood of uncertainty	Low X	Moderate	High

All European biogeographical regions will have the same likelihood of entry and uncertainty scores.

Possible pathways	**Pathway: Contaminant of leisure equipment** **(CBD terminology: Transport -stowaway)**
Short description explaining why it is considered as a pathway	It is possible that the import of recreational equipment (e.g. fishing or canoeing gear) could spread *G. spilanthoides*, particularly as seeds, although this is most unlikely to be significant pathway into the EPPO region. In addition to seeds, stem fragments could grow into viable plants if they remain moist. Based on other species (*Ludwigia grandiflora* and *Myriophyllum aquaticum*) these stem fragments may be less than 1 cm in length as long as one node is present (Hussner, 2009).
Is the pathway prohibited in the PRA area?	Not currently prohibited in the PRA area. However, there are campaigns within the EU to raise awareness of the movement of invasive alien plants by this pathway. For example, the "Check, Clean and Dry" campaign in Great Britain highlights the need to inspect and treat recreational material following use.
Has the pest already been intercepted on the pathway?	No.
What is the most likely stage associated with the pathway?	Seed and stem fragments.
What are the important factors for association with the pathway?	Potential pathway for localised spread from *G. spilanthoides* naturalised populations.
Is the pest likely to survive transport and storage in this pathway?	Yes. Seed likely to retain viability in leisure equipment contaminated with sediment. Vegetative fragments would desiccate over time and potentially lose viability.
Can the pest transfer from this pathway to a suitable habitat?	Yes. Where equipment is contaminated, left untreated and then transferred to another region (pond, lake or river for example), seed and stem fragments can transfer to new areas.
Will the volume of movement along the pathway support entry?	No. Within the EPPO region the current occurrence of naturalised populations of *G. spilanthoides* is very low, leading to the probability of movement through this pathway being very low.
Will the frequency of movement along the pathway support entry?	As above.

Likelihood of entry	Low X	Moderate	High
Likelihood of uncertainty	Low X	Moderate	High

All European biogeographical regions will have the same likelihood of entry and uncertainty scores.

9. Likelihood of establishment in the natural environment PRA area

Current estimates of geographic potential

Based on the current distribution modelling of the species, there is potential for establishment in the southern EPPO countries (see countries detailed below) (see Appendix 1). The highest potential for establishment is in the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria. To a lesser extent, there is the potential for establishment in the Atlantic zones of Portugal, Spain and France and small areas of the Black Sea (see Appendix 1). All water bodies not enclosed in ice for prolonged periods (1 month or longer) during the winter months, including thermally abnormal waters in other EPPO countries could provide potential habitats for *G. spilanthoides*. Habitats within the endangered area include slow moving rivers, canals, irrigation and drainage systems, lakes and reservoirs which are widespread within the EPPO region. The overall impact of the species, i.e. on biodiversity and ecosystem services, is likely to be greatest in the warmer parts of its range based on the findings of Burnett (2008).

The Expert Working Group considers that although the native range of *G. spilanthoides* is essentially tropical, it can survive and be problematic in much cooler environments outside of its native range. It is tolerant of frosts and can survive as a submerged aquatic under ice (Personal Communication, Paul Champion, 2016). Due to the early stage of establishment with few naturalised records, the modelling is likely to give (Appendix 1, Figure 5) an underestimate of the potential range.

However, at present the species is only reported occurring in the thermal waters of Lake Héviz and ditches near Keszthely (Hungary) and two recent occurrences in north-western Italy (Lombardia region) in the EPPO region (Szabó, 2002, Lukács *et al.*, 2016, Ardenghi *et al.*, 2016).

Previous estimates of geographic potential

The USDA APHIS (2012) WRA states the following relating the geographic potential:

"Based on three climatic variables [precipitation, temperature and humidity], we estimate that about 23 percent of the United States is suitable for the establishment of *G. spilanthoides*. This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *G. spilanthoides* represents the joint distribution of Plant Hardiness Zones 7-13, areas with 20-100+ inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, humid subtropical, marine west coast, humid continental warm summers, and humid continental cool summers".

"The area likely represents a conservative estimate as it uses three climatic variables to predict the area of the United States that is suitable for establishment of the species. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. *Gymnocoronis spilanthoides* grows in areas of wet marshy soils and in areas with still or very slowly moving waters. It seems unlikely to establish or be problematic in any other types of habitats".

Climate matching predictions from Australia either have the predicted range extending from NSW to NT and northern WA (CRC 2003) or more southern distribution extending into mid Queensland (SA 2011).

The USDA APHIS (2012) and South Australia (2011) modelling predicts that *G. spilanthoides* could naturalise through much of the EPPO region, excepting Alpine, Boreal, Steppic and Anatolian (see appendix 2, Figure 1). The Hungarian naturalised populations are thermally influenced (Szabó, 2002) and therefore may not reflect other aquatic habitats available in the Pannonian biogeographical region. Conversely, the recent naturalised populations in North West Italy (Ardenghi *et al.*, 2016), within the Continental biogeographical region may indicate the suitability of these habitats for *G. spilanthoides.* Brunel (2009) possibly underestimated the likelihood of *G. spilanthoides* establishment as a naturalised species as she assumed this species was only grown in aquaria and could not be planted outdoors. Consequently a moderate to high risk for the EPPO region was identified for this species in the future.

Uncertainty rating is low, even though there are few incursions within the EPPO region, but there is evidence of invasion of similar habitats in Australasia and eastern Asia. USDA APHIS (2012) WRA rates the uncertainty around likelihood of establishment/invasiveness outside of its native range as negligible.

Where the species is present in natural habitats in Australia and New Zealand the Köppen-Geiger climate classification matches that of the occurrence in Italy (cfa and cfb).

Rating of the likelihood of establishment in the natural environment	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low* X	*Moderate*	*High*

10. Likelihood of establishment in managed environment in the PRA area

Gymnocoronis spilanthoides is traded and normally established in protected conditions, for example under glass. The species can establish in managed environments including thermally influenced water, irrigation channels, reservoirs, rice paddies, drainage ditches etc. Plants are tolerant of mechanical damage, such as mowing and cutting, which may enhance spread through production of viable fragments spread by water movement, contaminated machinery or livestock hooves (Australian Government, 2016).

Uncertainty rating is low even though there have only been incursions in drains, canals and one rice field (see Ardenghi *et al.*, 2016) within the EPPO region, but there is evidence of invasion of similar habitats in Australasia and eastern Asia.

Rating of the likelihood of establishment in managed environment	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low* X	*Moderate*	*High*

11. Spread in the PRA area

Gymnocoronis spilanthoides is a relatively recently naturalised species within its non-native range. Kadono (2004) reports this species as rapidly naturalising in Japan presumably as a result of both natural and human assisted spread. This species is likewise naturalised at a wide number of Australian and New Zealand sites, but phytosanitary measures (being prevention and control) are in place in both countries. Human assisted spread is regarded as the main dispersal pathway, with subsequent localised spread as a result of natural (e.g. flood events) and additional human assisted pathways. Ardenghi *et al.* (2016) rate the spread potential of *G. spilanthoides* as high (500 – 1000 m from the maternal plant, following the guidance of Brunel et al., 2010) with a low uncertainty rating.

Natural spread

Gymnocoronis spilanthoides can reproduce by seed and vegetative fragments. Seed set has been recorded at the Italian **sites** (Ardenghi et al., 2016), Both can be naturally dispersed by flowing water or wind/wave action on still water bodies, with both seed and fragments being buoyant (Parsons & Cuthbertson, 2001). There is no data on the distance propagule may spread, but potentially they may spread 500 – 1000 m from the maternal plant (following the guidance of Brunel et al., 2010). Spread by this method would be restricted to the catchment where introduced.

Seed are relatively large and there are no structures that promote spread by wind or epizoochory (e.g. hooks or mucilage). Therefore, apart from hydrochory, there are few other natural mechanisms for propagule spread, apart from movement of sediment contaminated with seed by waterfowl or other animal feet (Green, 2016). Spread by this pathway appears unlikely.

Human assisted spread

The potential for human-mediated introductions means that new populations could appear anywhere within the EPPO area, with establishment subject to introduction of plants to suitable biotic and abiotic conditions. Introductions could be deliberate, for 'ornamental' or beautification purposes, to attract butterflies (Speichert & Speichert, 2007; Kadono, 2004), or through seeding of waterbodies for subsequent harvest to supply the aquarium industry (Petroeschevsky & Champion, 2008). Accidental introductions may occur through disposal of either aquarium or ornamental pond garden waste. Seed or small plant fragments could also be moved between waterbodies through recreation or drain cleaning works. Even tiny pieces of vegetation including leaf fragments can give rise to new colonies (CRC, 2003; van Oosterhout, 2010). In such cases spread distances are likely to be relatively localised, but if left unchecked such processes could grow exponentially. These pathways for the spread of invasive species have prompted the "Check, Clean and Dry" Campaign in the UK (http://www.nonnativespecies.org/checkcleandry/) and other regional information portals (EUBARnet, 2013). Similar "Clean, Drain and Dry" campaigns have been employed in the USA (Stop Aquatic Hitchhikers, http://www.protectyourwaters.net), Canada (British Colombia) (http://bcinvasives.ca/) and New Zealand (http://www.mpi.govt.nz/funding-and-programmes/other-programmes/campaigns/check-clean-dry/) to increase awareness of this potential pathway.

Gymnocoronis spilanthoides is used in aquaria where it is grown as a submerged plant (sold as giant green hygro or costata) (Kasselmann, 2003; Tropica, 2016), and as an ornamental plant for outdoor ponds (sold as water snowball or Senegal tea plant) (Speichert & Speichert, 2007). There are several varieties sold, including plants with red stems and variegated foliage. Brunel (2009) and Ardenghi *et al.* (2016) report this species being traded in the EPPO region, therefore this is the most 'likely' entry pathway.

The rating of magnitude of spread is moderate as secondary spread appears to be limited to deliberate human spread rather than accidental. The uncertainty rating is moderate as currently *G. spilanthoides* is in an early stage of invasion within the EPPO region and it is currently unknown if spread will increase over time.

Rating of the magnitude of spread	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate* X	*High*

12.01 Impact in the current area of distribution

Impacts on biodiversity and the environment

Most of the information on impacts is based on data from outside the EPPO region and thus can only be a proxy to the potential impacts within the EPPO region. The potential impacts of *G. spilanthoides* on biodiversity and ecosystem services may be compared to the actual negative impacts seen with *Alternanthera philoxeroide*s, due to the similar life form and function (EPPO, 2015). This would include the displacement of native plant species and a negative impact on invertebrate species coupled with alterations of macrophyte decomposition rates.

Ardenghi *et al.* (2016) rate the negative impacts of *G. spilanthoides* in Italy as medium to low (with three levels in total) for the environment, agriculture and infrastructure based on limited current impacts encountered there.

CRC (2003) states that "*G. spilanthoides* threatens biodiversity and causes other environmental damage. Although only in the early stages of establishment, this weed has the potential to seriously degrade Australia's ecosystems. Because *G. spilanthoides* grows very quickly, it can rapidly cover water bodies with a floating mat, excluding other plants and the animals that rely on them. Water quality may decline if large amounts of plant die off and rot under water".

Due to dense shading and prevention of wind induced mixing, dense populations can result in decreased dissolved oxygen levels in the water column, similar to *Alternanthera philoxeroides* (see the EPPO PRA on *Alternanthera philoxeroides* https://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRAdocs_plants/15-20714_PRA_Alternanthera_philoxeroides.pdf).

This species has been regarded as a transformer species by Török *et al.* (2003), and *G. spilanthoides* appears to radically modify aquatic and wetland systems in which it has invaded outside of the EPPO region (Personal Observation, Paul Champion, 2016). The species modifies the aquatic system by forming dense, rapidly growing mats of *G. spilanthoides* displace and exclude other native plants, and the animals that rely on them (Personal communication Paul Champion, 2017).

At present According to the available information, to-date there are no impacts recorded on red list species and species listed in the Birds and Habitats Directives.

The EWG consider that this species has a high magnitude of impact in the current area of distribution based on repeated observations of the dense mat forming habit of the species in natural environments. A high rating of uncertainty is given to reflect the lack of scientific studies on the ecological impact of the species in these habitats.

Rating of the magnitude of impact in the current area of distribution	*Low*	*Moderate*	*High* X
Rating of uncertainty	*Low*	*Moderate*	*High* X

12.02 Impacts on ecosystem services

Ecosystem service	Does the IAS impact on this Ecosystem service? Yes/No	Short description of impact	Reference
Provisioning	Yes	**Potential** impacts on rice production, increased risk of flooding agricultural land with loss of agricultural production and decreasing effectiveness of irrigation channels. Emergent plants will increase evapotranspiration.	Sainty & Jacobs (2003); Champion *et al.* (2002)
Regulating	Yes	Displacement of other aquatic/wetland vegetation and associated fauna.	CRC (2003), Australian Government (2016)
Supporting	Yes	Reduced water quality and low dissolved oxygen concentration under thick mats of this plant, which changes the habitat, and influencing the species within the water body.	CRC (2003)
Cultural	Yes	Thick marginal mats of this plant may obstruct water body access and recreational activities	CRC (2003)

Negative impacts on ecosystem services are hard to assess, given that many descriptions in the literature relate to potential impacts or impacts of sprawling emergent weeds with a similar native range such as *A. philoxeroides* and *Myriophyllum aquaticum* (e.g., Dugdale & Champion, 2012; Hussner & Champion, 2012).

However, as an aquatic plant species that can form smothering mats, impacts on ecosystem services can be potentially significant. These impacts can include a reduction in native species, reduced water quality and impede recreational activities due to the mat forming habit of the species. Based on the expertise of the EWG and the personal observations of the negative impact of *G. spilanthoides* in the natural environment a moderate rating of magnitude of impact is given with a high level of uncertainty. The high level of uncertainty reflects the lack of published scientific studies on the impact of the species on ecosystem services.

Rating of the magnitude of impact in the current area of distribution	*Low*	*Moderate* X	*High*
Rating of uncertainty	*Low*	*Moderate*	*High* X

12.03. Describe the adverse socio-economic impact of the species in the current area of distribution

Gymnocoronis spilanthoides has been recorded as colonising a rice field in Italy (Ardenghi *et al.*, 2016) and potentially could have economic impacts relating to crop yields unless managed. The effects of flooding will potentially be made much worse because infestations block drainage channels – though financial figures for this are lacking. Recreational activities (for example, preventing access to the water body), irrigation and navigation may also be affected (Parsons & Cuthbertson 2001).

These impacts are hard to assess, given that many descriptions in the literature relate to potential impacts or impacts of similar sprawling emergent weeds with a similar native range such as *Alternanthera philoxeroides* and *Myriophyllum aquaticum* (e.g., Dugdale & Champion, 2012; Hussner & Champion, 2011).

The potential economic impact could be significant if the species establishes and spreads in the EPPO region; especially when consideration is given to the loss of earnings and costs associated with management for other aquatic species. Based on a national survey in France, the cost of water primrose (*Ludwigia* spp.) and waterweed (*Elodea* spp.) were estimated at nearly €8 million a year (low estimate) (Chas & Wittmann, 2015). The annual cost of just one such species, *Hydrocotyle ranunculoides* to the British economy alone was estimated at €33 million (Williams *et al*., 2010).

In addition to actual costs, the labour required to manage potential infestation of *G. spilanthoides* may be high. For example, in a management programme of *Ludwigia grandiflora* in Germany, the removal of 25 tonnes of biomass required 120 person hours mainly as a result of hand removal (Hussner *et al*., 2016).

There are no known direct human health impacts associated with the species.

The rating of impact has been scored as moderate as the occurrence of the species will require management and thus associated costs. The potential impact of the species blocking waterways and colonising rice fields may also incur negative costs. The rating of uncertainty has been assessed as high due to the lack of specific information on *G. spilanthoides* ecology and impacts.

Control methods

The species can be controlled using mechanical and chemical methods (see section 3. Risk management).

Rating of the magnitude of impact in the current area of distribution	*Low*	*Moderate* **X**	*High*
Rating of uncertainty	*Low*	*Moderate*	*High* **X**

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? **Yes**

Although present in the EPPO region, there are no reported studies that have evaluated the ecological or economic impact of *G. spilanthoides* in the region. This species has been regarded as a transformer species by Török *et al.* (2003), and *G. spilanthoides* appears to radically modify aquatic and wetland systems in which it has invaded outside of the EPPO region (Personal Observation, Paul Champion, 2016). Impacts in the EPPO area will likely be attenuated by climatic suitability, but, in areas where *G. spilanthoides* is able to establish and spread, impacts are likely to be similar unless the species is under phytosanitary control. For example, many of the impacts on biodiversity relate to ecosystem processes such as decomposition and the alteration of nutrient cycling, which, assuming that *G. spilanthoides* is able to reach the levels of abundance required for these impacts to be displayed, can be assumed to occur in these areas to the same extent as in the current area of distribution.

Europe has several atypical aquatic thermal habitats and this may expand impacts into areas that would otherwise be considered climatically unsuitable by coarse environmental modelling. For example, *G. spilanthoides* occurs in the Hungarian thermal canals where the presence of the plant is probably related to planting for harvesting at a later date. If these waters are connected to more typical waters they may act as a permanent source of propagules (this has been shown for *Pistia stratiotes*, Hussner *et al*., 2014).
The highest impacts will be seen in the countries and biogeographical regions detailed in the endangered area (see section 14).

In the PRA area, *G. spilanthoides* has the potential to impact on native plant species due to its invasive smothering behaviour. The invasion of alien invasive plants can increase competition for space with native aquatic plants and affects most threatened aquatic plant species (Bilz et al., 2011).

Potential red list species and species from the Habitat Directive which may be impacted on both under current climate and future climate include *Isoetes malinverniana* (Critically Endangered, Italy), *Elatine brochonii* (Vulnerable, France and Spain), *Anagallis crassifolia* and *Marsilea strigosa* (Vulnerable, France, Italy and the Iberian Peninsula), *Pilularia minuta* (Endangered), *Damasonium polyspermum* and *Ipomoea sagittata* (Vulnerable).

13.01. Negative environmental impacts with respect to biodiversity and ecosystem patterns and processes

Rating of magnitude of impact on biodiversity in the PRA area	*Low* ☐	*Moderate*	*High* **X**
Rating of uncertainty	*Low* ☐	*Moderate*	*High* **X**

13.02. Negative impact the pest may have on categories of ecosystem services

Rating of magnitude of impact on ecosystem services in the PRA area	*Low* ☐	*Moderate* **X**	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate*	*High* **X**

13.03 Socio-economic impact of the species

Rating of magnitude of socio-economic impact in the PRA area	*Low* ☐	*Moderate* **X**	*High*
Rating of uncertainty	*Low* ☐	*Moderate*	*High* **X**

14. Identification of the endangered area

The endangered area includes countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria. The endangered area includes the Mediterranean and Continental biogeographic regions.

Gymnocoronis spilanthoides is frost tolerant and grows in slow moving rivers (including tidally influenced areas), reservoirs, irrigation channels, ponds, lakes, canals and ditches. It often establishes on the water body margins or in shallow water, where it can form floating mats that smother the water body (CRC, 2003). It also grows in marshes and swamps, especially where nutrient enriched (CRC, 2003). The Expert Working Group considers that although the native range of *G. spilanthoides* is essentially tropical, it can survive and be problematic in much cooler environments outside of its native range (for example in Italy). Although *G. spilanthoides* has a tropical to subtropical native range (South America), it has proved to be extremely hardy in naturalised populations of other regions, tolerates frosts of up to -5°C and can survive as a submerged plant under ice (Paul Champion, Personal Observation, 2016).. Consequently, *G. spilanthoides* is likely to have a much greater potential range within the EPPO region than the modelling predicts (EWG opinion).

Based on the current distribution modelling of the species, there is potential for establishment in the southern EPPO countries. The highest potential for establishment is in the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria. To a lesser extent, there is the potential for establishment in the Atlantic zones of Portugal, Spain and France and small areas of the Black Sea (Georgia) (see Appendix 1). All water bodies not enclosed in ice for prolonged periods during the winter months, including thermally abnormal waters in other EPPO countries could provide potential habitats for *G. spilanthoides*. Habitats within the endangered area include slow moving rivers, canals, irrigation and drainage systems, lakes and reservoirs which are widespread within the EPPO region. Impact is likely to be greatest in the warmer parts of its range based on the findings of Burnett (2008).

15. Climate change

Climate change

By the 2070s, under climate change scenario RCP8.5, projected suitability for G. spilanthoides increases substantially. Many of the regions currently projected to be marginally suitable move towards high suitability, while the region of marginal suitability extends in western Europe as far north as Ireland. Therefore, the model suggests climate change could facilitate expansion of the invaded range of the species in Europe (to include the Alpine, Atlantic, Continental, and Mediterranean biogeographical regions and Albania, Bosnia and Herzegovina, Croatia, France, Greece, Italy Ireland, United Kingdom, Spain, Belgium, Netherlands, Germany, Slovenia, Montenegro), even though conditions in northern Europe are unlikely to become optimal.

15.01. Define which climate projection you are using from 2050 to 2100*

Climate projection RCP8.5 (2070)

Note: RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst-case scenario for reasonably anticipated climate change.

15.02 Which component of climate change do you think is most relevant for this organism?

Temperature **(yes)**	Precipitation **(no)**	$C0_2$ levels **(no)**
Sea level rise **(no)**	Salinity **(no)**	Nitrogen deposition **(no)**
Acidification **(no)**	Land use change **(no)**	Other (please specify)

Are the **introduction pathways** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
No, introduction to the EPPO region via the ornamental plant trade is unlikely to change as a result of climatic change. Indeed, there may be a geographical change in where the species may be grown (i.e. more consumers in northern European countries), but this will not change the introduction pathways themselves. All European biogeographical regions will have the same likelihood of entry and uncertainty scores. The overall rating for introduction pathways will not change for any of the pathways. Plants for planting (High score /low uncertainty) Contamination of machinery (Low score /low uncertainty) Contamination of leisure equipment (Low score /low uncertainty)	EWG opinion
Is the **risk of establishment** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Warmer temperatures will increase the growth and likelihood of establishment into a greater area of suitable habitats in the EPPO region. Risk and uncertainty will remain the same (see Appendix 1, Fig. 6). Likelihood of establishment in the natural environment: High score/low uncertainty Likelihood of establishment in the managed environment: High score/low uncertainty	Burnett (2008)
Is the **risk of spread** likely to change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Risk of spread may increase as more outdoor cultivated populations are grown and disposed of. Naturalised populations are likely to expand more rapidly leading to higher likelihood of spread. The risk is currently rated as moderate with moderate uncertainty and the risk will increase (high) with greater certainty (high) as more habitat becomes suitable under the modelled climate change scenario (see Appendix 1, Fig. 6).	EWG opinion
Will **impacts** change due to climate change? **(If yes, provide a new risk and uncertainty score)**	**Reference**
Warmer temperatures will increase the predicted impacts and also affect a greater area and increase the number of habitats suitable for the growth of the species in the EPPO region. With climate change impacts are likely to be greater for ecosystem services and socio-economic impacts (currently rated at moderate with high uncertainty) will increase to a high magnitude score and uncertainty will remain high.	Burnett (2008)

16. Overall assessment of risk

The results of this PRA show that *G. spilanthoides* poses a high risk to the endangered area (the countries bordering the Adriatic Sea (Albania, Bosnia and Herzegovina, Croatia, Greece, Italy and Montenegro) and the Eastern Mediterranean (Turkey) as well as parts of Morocco and Algeria) with a high uncertainty. The overall likelihood of *G. spilanthoides* entering into the EPPO region is high. The plant is both imported in and grown in the EPPO region and is sold as an aquarium and ornamental pond plant.

It is a relatively recent introduction to the plant trade, however, at present the species is only reported occurring outside of cultivation in the thermal waters of Lake Héviz and canals near Keszthely (Hungary) and occurrences in north-western Italy (Lombardia region).

While the species has aggressively invaded some areas outside of its native range there are however, some discrepancies. It is unusual that it is not reported as naturalised or escaping from commercial propagation sites in South East Asia nor is it reported as naturalised in its predicted range in North America despite the availability of the species in trade there.

Pathways for entry:

Plants for planting

Likelihood of entry	Low	Moderate	High x
Likelihood of uncertainty	Low x	Moderate	High

Contaminated machinery, leisure equipment

Likelihood of entry	Low x	Moderate	High
Likelihood of uncertainty	Low x	Moderate	High

Likelihood of establishment in the natural environment in the PRA area

Rating of the likelihood of establishment in the natural environment	Low	Moderate	High x
Rating of uncertainty	Low x	Moderate	High

Likelihood of establishment in managed environment in the PRA area

Rating of the likelihood of establishment in the managed environment	Low	Moderate	High x
Rating of uncertainty	Low x	Moderate	High

Spread in the PRA area

Rating of the magnitude of spread	Low	Moderate X	High
Rating of uncertainty	Low	Moderate X	High

Impacts
Impacts on biodiversity and the environment

Rating of the magnitude of impact in the current area of distribution	Low	Moderate	High X
Rating of uncertainty	Low	Moderate	High X

Impacts on ecosystem services

Rating of the magnitude of impact in the current area of distribution	Low	Moderate X	High
Rating of uncertainty	Low	Moderate	High X

Socio-economic impacts

Rating of the magnitude of impact in the current area of distribution	Low	Moderate X	High
Rating of uncertainty	Low	Moderate	High X

Impacts in the PRA area

Will impacts be largely the same as in the current area of distribution? **Yes**

17. Uncertainty

An overall high uncertainty rating has been given due to the lack of ecological studies. While the species has aggressively invaded some areas there are some discrepancies. This species has failed to establish in climatically suitable habitats in the USA and South East Asia despite its presence in the trade. Currently the species is indicating invasive tendencies (e.g., form a monoculture within a water body) in the few modified habitats in the PRA area. Based on the high costs of control for similar aquatic emergent weeds (*Hydrocotyle ranunculoides*), the early pre-emptive actions proposed would provide high benefit.

Uncertainty should also be considered in the context of species distribution modelling (SDM). Here records for *G. spilanthoides* and synonyms were retrieved from GBIF and other online sources, and were also digitised from occurrences that were either mapped or clearly georeferenced in published sources. This may mean that the realised climatic niche of *G. spilanthoides* is under-characterised. The expert working group consider that due to the early stage of establishment, with few naturalised records, the modelling is likely to give an underestimate of the potential range.

Additional uncertainty with regard to the modelling includes:

The sample size of 185 grid cells with occurrences is quite low and adds uncertainty to the modelling.

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.
- Levels of Tracheophyte recording may not be a consistent indicator of the recording of aquatic plants. There is a suggestion that aquatic plants may be disproportionately under-recorded in tropical regions (Jonathan Newman, *pers. comm*), which could have been responsible for an under-prediction of suitability in tropical regions.
- Air temperatures were used in the model, while water temperatures may be more appropriate for an aquatic plant. In some cases air and water temperatures can markedly diverge, for example warming associated with industrial outflows. Wherever the water temperature is warm enough, the species is likely to be able to persist, regardless of the model's estimate of suitability.
- Water chemistry and quality may have a large effect on the ability of the species to persist but were not used in the model, except by incorporation of soil pH. Factors such as nutrient concentration are likely to be important modifiers of habitat suitability.
- The climate change scenario used is the most extreme of the four RCPs. However, it is also the most consistent with recent emissions trends and could be seen as worst case scenario for informing risk assessment.

18. Remarks

Inform EPPO or IPPC or EU

- Inform NPPOs that surveys are needed to confirm the distribution of the plant, in particular in the area where the plant is present; and on the priority to eradicate the species from the invaded area. In addition, surveys should be conducted within the EPPO region to confirm if the plant is only grown in aquaria and not in outdoor ponds.

Inform industry, other stakeholders

- Encourage industry to assist with public education campaigns associated with the risk of aquatic non-native plants.

Specify if surveys are recommended to confirm the pest status

- Surveys should be conducted to confirm the current distribution and status of the species within the endangered area and this information should be shared within the PRA area.

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Annex 1: Projection of climatic suitability for *Gymnocoronis spilanthoides* establishment

Aim
To project the suitability for potential establishment of *Gymnocoronis spilanthoides* in the EPPO region, under current and predicted future climatic conditions.

Data for modelling
Climate data were taken from 'Bioclim' variables contained within the WorldClim database (Hijmans *et al.*, 2005) originally at 5 arcminute resolution (0.083 x 0.083 degrees of longitude/latitude) but bilinearly interpolated to a 0.1 x 0.1 degree grid for use in the model. Based on the biology of the focal species, the following climate variables were used in the modelling:

- Mean temperature of the warmest quarter (Bio10 °C) reflecting the growing season thermal regime. CABI ISC suggests that *G. spilanthoides* requires warmest month temperatures of at least 15 °C.
- Mean minimum temperature of the coldest month (Bio6 °C) reflecting exposure to frost. *Gymnocoronis spilanthoides* has some frost tolerance but as a tropical or sub-tropical species severe frosts may be limiting.
- Mean annual precipitation (Bio12 ln+1 transformed mm). Although the species is aquatic and will therefore have limited direct dependence on precipitation, sufficient precipitation for the presence of wetland habitat may be required.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate conditions for the 2070s under the Representative Concentration Pathway (RCP) 8.5 were also obtained. This assumes an increase in atmospheric CO_2 concentrations to approximately 850 ppm by the 2070s. Climate models suggest this would result in an increase in global mean temperatures of 3.7 °C by the end of the 21st century. The above variables were obtained as averages of outputs of eight Global Climate Models (BCC-CSM1-1, CCSM4, GISS-E2-R, HadGEM2-AO, IPSL-CM5A-LR, MIROC-ESM, MRI-CGCM3, NorESM1-M), downscaled and calibrated against the WorldClim baseline (see http://www.worldclim.org/cmip5_5m). RCP8.5 is the most extreme of the RCP scenarios, and may therefore represent the worst case scenario for reasonably anticipated climate change.

In the models we also included two measures of habitat availability:

- Cover of inland waterbodies was estimated from the Global Inland Water database (Feng *et al.*, 2016). The original database is a remote sensed estimate at a 30 x 30 m resolution of the presence of inland surface water bodies, including fresh and saline lakes, rivers, and reservoirs. For the PRA, this was supplied as a 0.1 x 0.1 degree raster indicating the proportion of the constituent 30 x 30 m grid cells classified as inland waters.
- Density of permanent rivers was estimated from VMAP0 (United States National Imagery Mapping Agency, 1997). River vectors were rasterised at 0.02 x 0.02 degree resolution. Then, we calculated the proportion of these grid cells containing rivers within each of the 0.1 x 0.1 degree cells used in the model.

The final variable used in the model was soil pH. Water pH has an important effect on *G. spilanthoides* growth, with pHs from 5.5 – 8 reported as tolerated (CABI, 2015). GIS layers for water pH are not available, so instead we used the SoilGrids soil pH layers (Hengl *et al.*, 2014). For the PRA, estimated soil pH in H_20 at depths of 0, 5, 15, 30, 60, 100 and 200 cm was supplied as 0.002083 x 0.002083 degree rasters. These were aggregated to the mean soil pH across all depths on a 0.1 x 0.1 degree raster.
Species occurrences were obtained from the Global Biodiversity Information Facility (www.gbif.org), supplemented with data from the literature and the Expert Working Group. Occurrence records with insufficient spatial precision, potential errors or that were outside of the

coverage of the predictor layers (e.g. small island or coastal occurrences) were excluded. The remaining records were gridded at a 0.1 x 0.1 degree resolution (Figure 1).

Examination of these records by the Expert Working Group indicated a small number were either examples of casual occurrences introduced to climatically unsuitable regions (for example, where severe winter frosts are known to kill all individuals) or records of persistent populations known to occupy climatically anomalous micro-habitats such as thermal streams or warmed industrial outflows. Specifically these represented records from Stockholm botanic garden and a thermally anomalous lake in Hungary. Both were removed from the occurrence data as they will impede the model's ability to characterise climatic suitability.

In total, there were 185 grid cells with recorded occurrence of *G. spilanthoides* available for the modelling (Figure 1).

Figure 1. Occurrence records obtained for *Gymnocoronis spilanthoides* used in the model, after exclusion of casual and thermally-anomalous records.

Species distribution model

A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v3.3-7 (Thuiller *et al.*, 2014, Thuiller *et al.*, 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental conditions (often termed 'pseudo-absences') in order to characterise and project suitability for occurrence. This approach has been developed for distributions that are in equilibrium with the environment. Because invasive species' distributions are not at equilibrium and subject to dispersal constraints at a global scale, we took care to minimise the inclusion of locations suitable for the species but where it has not been able to disperse to. Therefore the background sampling region included:

- The native continent of *G. spilanthoides*, South America, for which the species is likely to have had sufficient time to cross all biogeographical barriers; AND
- A relatively small 50 km buffer around all non-native occurrences, encompassing regions likely to have had high propagule pressure for introduction by humans and/or dispersal of the species; AND
- Regions where we have an *a priori* expectation of high unsuitability for the species (see Fig. 2). The following rules were applied to define the region expected to be highly unsuitable for *G. spilanthoides*:
    - Mean minimum temperature of the coldest month (Bio6) < -5 °C. As documented in the main text, *G. spilanthoides* can tolerate frost down to -5 °C by surviving as a submerged aquatic. We assume exposure to colder temperatures will prevent species occurrence. The coldest location with a presence in our dataset has Bio6 = -3.1 °C.

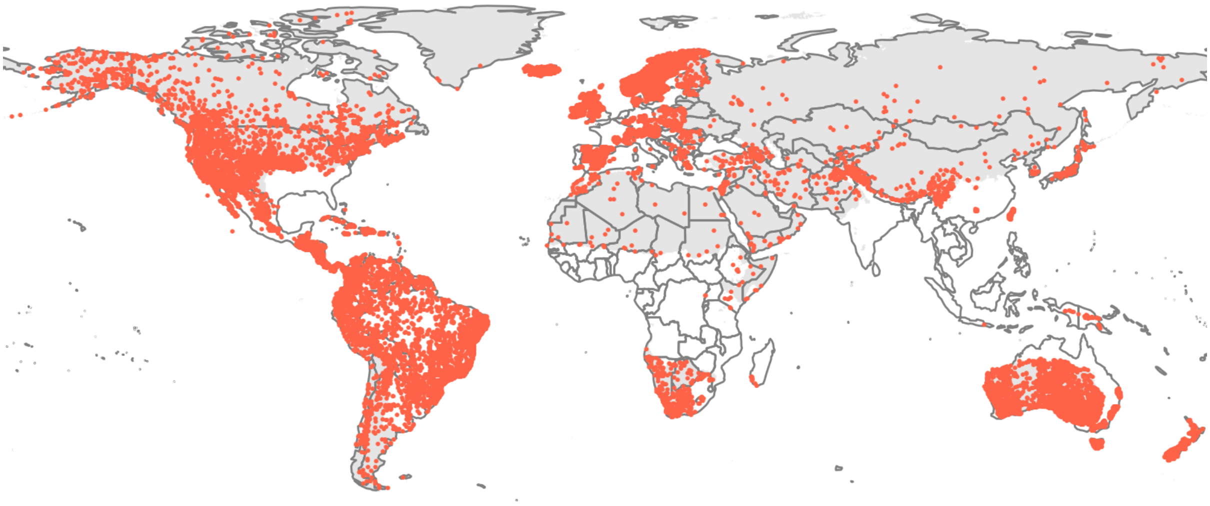
Weather records for nearby locations at the coldest place in Australia where *G. spilanthoides* exists (Lake Nagambie) shows mean minimum of 3.2 °C with a record low of -5.6 °C (A. Petroeschevsky, personal comment).

- Mean temperature of the warmest quarter (Bio10) < 15 °C. CABI (2015) suggests 15 °C is the minimum tolerated limit for the warmest month. In our database the coldest presence has Bio10 = 16.0 °C.
- Annual precipitation (Bio12) < 500 mm, consistent with reported minimum requirements in USDA APHIS (2012). Weather records for nearby locations at the driest place in Australia where *G. spilanthoides* exists (Lake Nagambie) shows an average annual precipitation of 546 mm (A. Petroeschevsky, personal comment).
- Soil pH > 8. CABI (2015) suggests that *G. spilanthoides* tolerates water pHs between 5.5 and 8. Furthermore, soils and water where *G. spilanthoides* occurs in Australia tend to be acidic (A. Petroeschevsky, personal comment). The range of soil pHs for our occurrence data are 4.4 to 7.4, while the soil pH GIS data has a minimum value of 4. Therefore, we assumed that limitation by high pH could affect the distribution.

Within this sampling region there will be substantial spatial biases in recording effort, which may interfere with the characterisation of habitat suitability. Specifically, areas with a large amount of recording effort will appear more suitable than those without much recording, regardless of the underlying suitability for occurrence. Therefore, a measure of vascular plant recording effort was made by querying the Global Biodiversity Information Facility application programming interface (API) for the number of phylum Tracheophyta records in each 0.1 x 0.1 degree grid cell. The sampling of background grid cells was then weighted in proportion to the Tracheophyte recording density. Assuming Tracheophyte recording density is proportional to recording effort for the focal species, this is an appropriate null model for the species' occurrence.

To sample as much of the background environment as possible, without overloading the models with too many pseudo-absences, five background samples of 10,000 randomly chosen grid cells were obtained (Figure 2).

Figure 2. Randomly selected background grid cells used in the modelling of *Gymnocoronis spilanthoides*, mapped as red points. Points are sampled from the native continent (South America), a small buffer around non-native occurrences and from areas expected to be highly unsuitable for the species (grey background region), and weighted by a proxy for plant recording effort.



Each dataset (i.e. combination of the presences and the individual background samples) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, ten statistical algorithms were fitted with the default BIOMOD2 settings (Thuiller *et al.*, 2014, Thuiller *et al.*, 2009), except where specified below:

- Generalised linear model (GLM)
- Generalised boosting model (GBM)
- Generalised additive model (GAM) with a maximum of four degrees of freedom per smoothing spline.
- Classification tree algorithm (CTA)
- Artificial neural network (ANN)
- Flexible discriminant analysis (FDA)
- Multivariate adaptive regression splines (MARS)
- Random forest (RF)
- MaxEnt
- Maximum entropy multinomial logistic regression (MEMLR)

Since the background sample was much larger than the number of occurrences, prevalence fitting weights were applied to give equal overall importance to the occurrences and the background. Variable importances were assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the Area Under the Receiver-Operator Curve (AUC) for model predictions on the evaluation data, that were reserved from model fitting. AUC can be interpreted as the probability that a randomly selected presence has a higher model-predicted suitability than a randomly selected absence. This information was used to combine the predictions of the different algorithms to produce ensemble projections of the model. For this, the three algorithms with the lowest AUC were first rejected and then predictions of the remaining seven algorithms were averaged, weighted by their AUC. Ensemble projections were made for each dataset and then averaged to give an overall suitability.

Results

The ensemble model had a better predictive ability (AUC) than any individual algorithm and suggested that suitability for *G. spilanthoides* was most strongly determined by the annual precipitation, mean temperature of the warmest quarter and the minimum temperature of the coldest month and soil pH (Table 1). From Fig. 3, the ensemble model estimated the optimum conditions for occurrence at approximately:

- Annual precipitation = 1364 mm (≥ 50% suitability with 788 to 4905 mm)
- Mean temperature of the warmest quarter = 27.6 °C (≥ 50% suitability with 17.8 to 35.9 °C)
- Minimum temperature of the coldest month = 7.7 °C (≥ 50% suitability with -3.6 to 15.9 °C)
- Soil pH = 6.9 (≥ 50% suitability across the full range of soil pH)

These optima and ranges of high suitability described above are conditional on the other predictors being at their median value in the data used in model fitting.

There was substantial variation among modelling algorithms in the partial response plots (Fig. 3). In part this will reflect their different treatment of interactions among variables. Since partial plots are made with other variables held at their median, there may be values of a particular variable at which this does not provide a realistic combination of variables to predict from. It also demonstrates the value of an ensemble modelling approach in averaging out the uncertainty between algorithms.

Global projection of the model (Fig. 4) indicates that the native and known invaded records all fell within regions predicted to have high suitability, while the model predicts potential for invasion of southeast USA, Mexico and central Africa as well as further invasive spread in Australia and east Asia.

In Europe and the Mediterranean region, the model predicts pockets of moderate suitability for *G. spilanthoides* including the one known location in northern Italy (Fig. 5). Other regions predicted to have marginal suitability include much of Portugal, the coast of the Bay of Biscay and parts of the coast of the Mediterranean, especially the east coast of the Adriatic.

By the 2070s, under climate change scenario RCP8.5, projected suitability for *G. spilanthoides* increases substantially (Fig. 6). Many of the the regions currently projected to be marginally suitable move towards high suitability, while the region of marginal suitability extends in western Europe as far north as Ireland. Therefore, the model suggests climate change could facilitate expansion of the invaded range of the species in Europe, even though conditions in northern Europe are unlikely to become optimal.

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

Algorithm	Predictive AUC	Variable importance					
		Minimum temperature of coldest month	**Mean temperature of warmest quarter**	**Annual precipitation**	**Inland water cover**	**River density**	**Soil pH**
GAM	0.9758	24.9%	36.2%	33.7%	2.0%	0.2%	2.9%
GBM	0.9740	20.1%	32.4%	39.0%	0.8%	0.0%	7.7%
MARS	0.9738	25.8%	28.8%	35.9%	2.0%	0.0%	7.5%
RF	0.9732	20.3%	23.8%	34.7%	2.6%	0.8%	17.8%
GLM	0.9702	21.5%	28.4%	40.3%	2.4%	0.2%	7.2%
MaxEnt	0.9526	20.6%	26.1%	35.2%	1.0%	0.4%	16.7%
ANN	0.9504	28.4%	31.2%	16.8%	5.0%	0.8%	17.8%
FDA	0.9504	21.3%	48.5%	23.3%	2.2%	0.0%	4.8%
CTA	0.9150	20.1%	30.4%	33.2%	2.9%	0.7%	12.7%
MEMLR	0.8190	2.0%	49.3%	7.4%	3.8%	7.2%	30.3%
Ensemble	0.9802	23.1%	29.6%	33.7%	2.3%	0.3%	11.0%

Figure 3. Partial response plots from the fitted models, ordered from most to least important. Thin coloured lines show responses from the seven algorithms, while the thick black line is their ensemble. In each plot, other model variables are held at their median value in the training data. Some of the divergence among algorithms is because of their different treatment of interactions among variables.

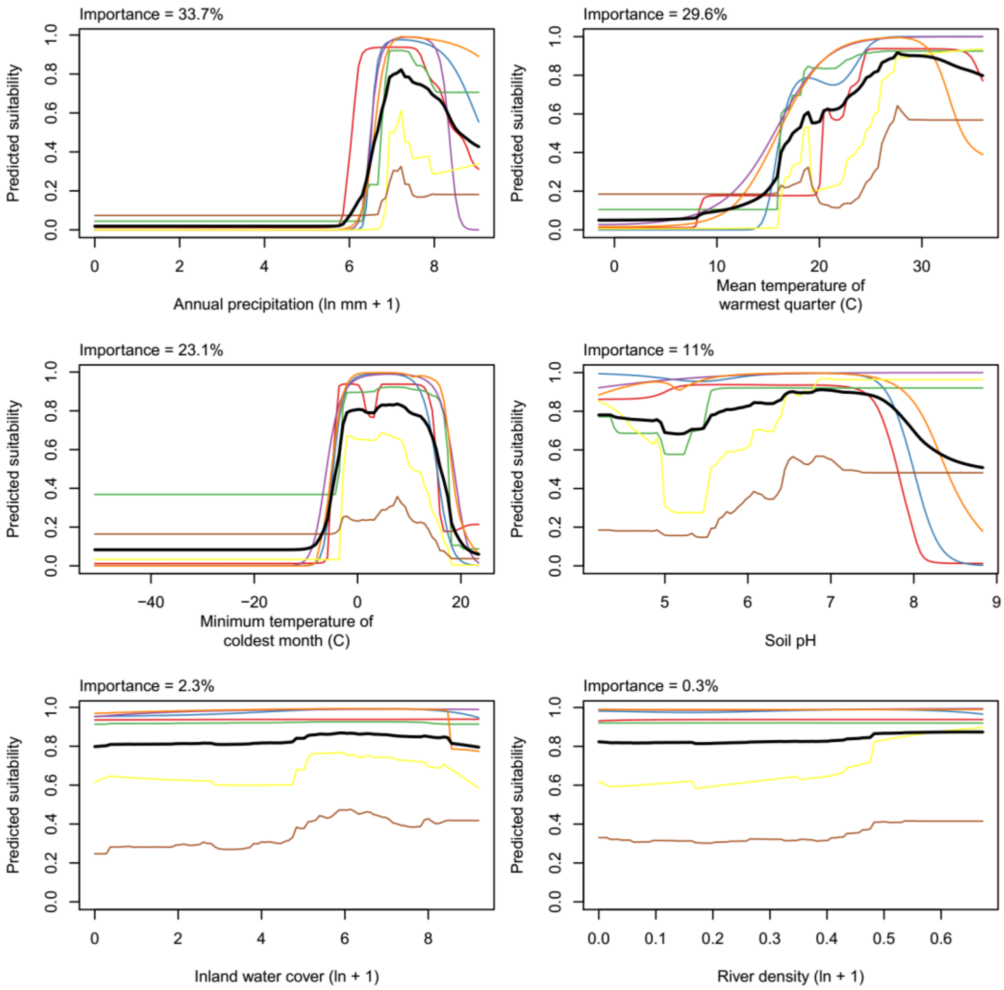


Figure 4. Projected global suitability for *Gymnocoronis spilanthoides* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.5 may be suitable for the species. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

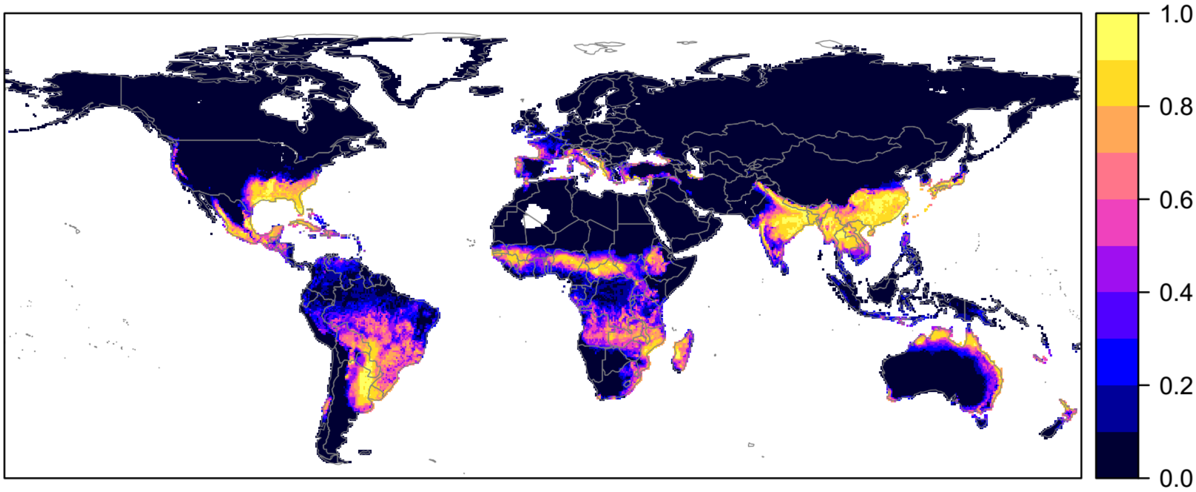


Figure 5. Projected current suitability for *Gymnocoronis spilanthoides* establishment in Europe and the Mediterranean region. For visualisation, the projected suitability has been smoothed with a Gaussian filter with standard deviation of 0.1 degrees longitude/latitude. The white areas have climatic conditions outside the range of the training data so were excluded from the projection.

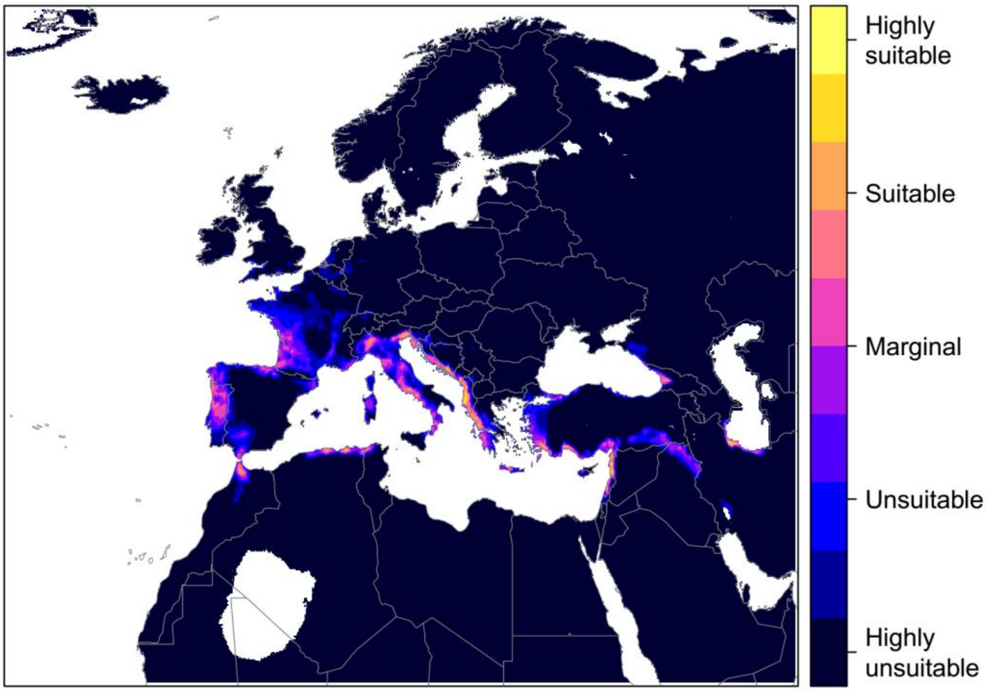
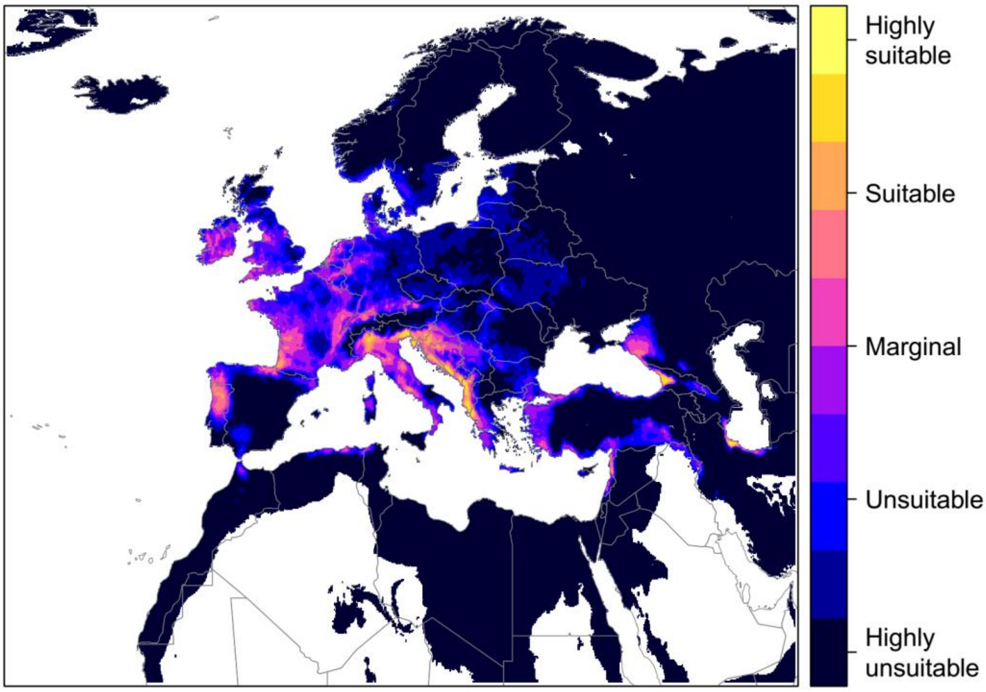


Figure 6. Projected suitability for *Gymnocoronis spilanthoides* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP8.5, equivalent to Fig. 5.



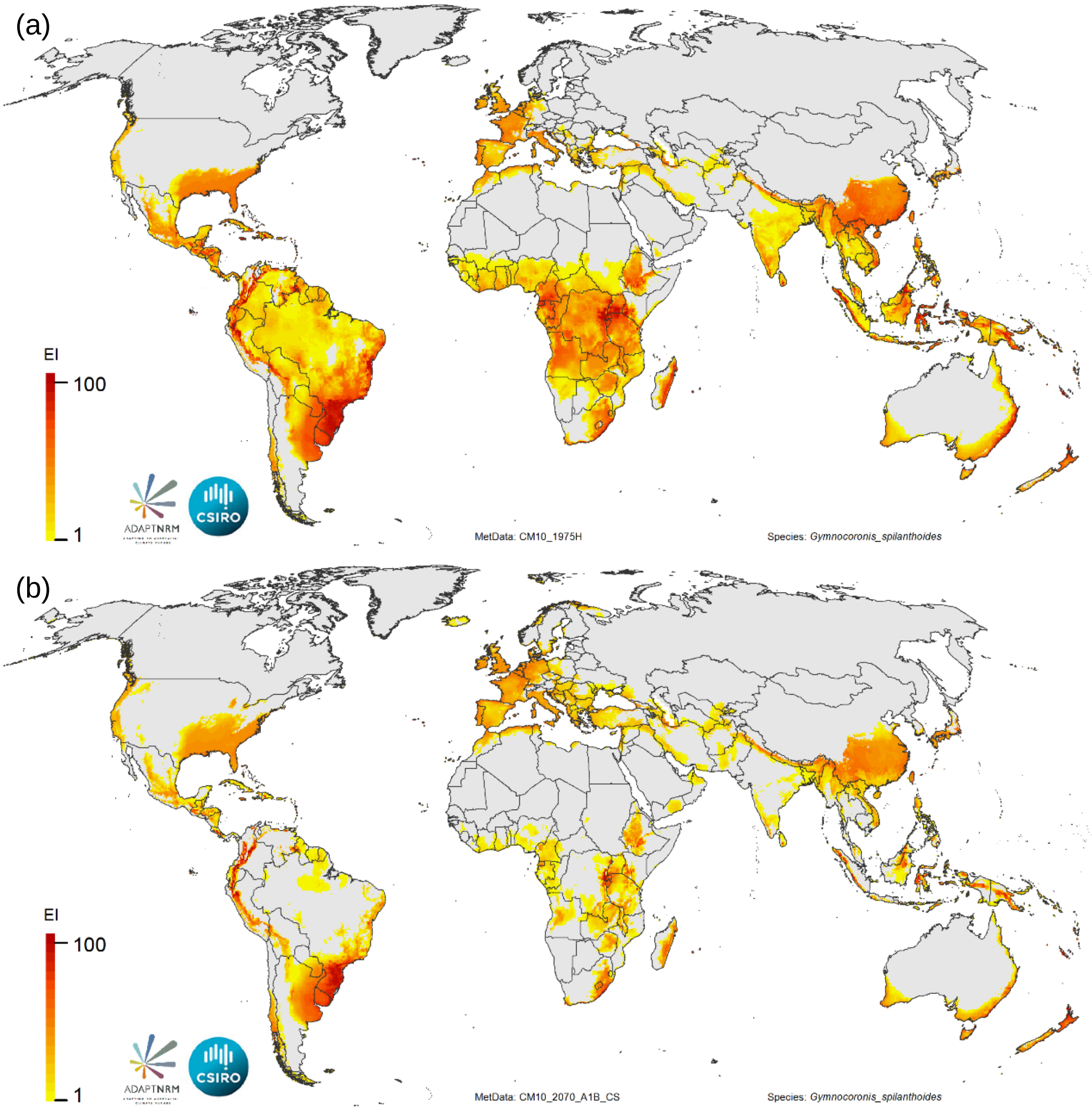
Comparison to an existing CLIMEX model

Figure 7 shows current and future CLIMEX Ecoclimatic Indices (EI) for *G. spilanthoides* produced by Scott and Ota (2014). Their model is driven by:

- Temperature (Limiting low temperature = 8 °C, Lower optimum = 15 °C, Upper optimum = 28 °C, Limiting high temperature = 31.5 °C),
- Soil moisture (Limiting low moisture = 0.22, Lower optimum = 0.33, Upper optimum = 1.4, Limiting high moisture = 2),
- Cold stress (Temperature Threshold = -1 °C, Temperature Rate = -0.01 $°C^{-1}$).

The CLIMEX EI is an estimate of relative climatic suitability. However, it will scale differently to our model in terms of which values of the EI indicate unsuitable, marginal or suitable conditions. Nevertheless, comparison of Fig. 7 and Fig. 5 suggests that CLIMEX may predict higher suitability in Europe in both current and future climates. We therefore highlight the uncertainty in the predictions made by different modelling approaches.

Figure 7. CLIMEX Ecoclimatic Index for *Gymnocoronis spilanthoides* for (a) the current day (average of 30 years centred at 1975) and (b) the 2070s under SRES climate change scenario A1B. The maps are reproduced from Scott and Ota (2014).



Caveats to the modelling
The sample size of 185 grid cells with occurrences is quite low and adds uncertainty to the modelling.

To remove spatial recording biases, the selection of the background sample was weighted by the density of Tracheophyte records on the Global Biodiversity Information Facility (GBIF). While this is preferable to not accounting for recording bias at all, a number of factors mean this may not be the perfect null model for species occurrence:

- The GBIF API query used to did not appear to give completely accurate results. For example, in a small number of cases, GBIF indicated no Tracheophyte records in grid cells in which it also yielded records of the focal species.
- We located additional data sources to GBIF, which may have been from regions without GBIF records.
- Levels of Tracheophyte recording may not be a consistent indicator of the recording of aquatic plants. There is a suggestion that aquatic plants may be disproportionately under-recorded in tropical regions (Jonathan Newman, *pers. comm*), which could have been responsible for an under-prediction of suitability in tropical regions.

Air temperatures were used in the model, while water temperatures may be more appropriate for an aquatic plant. In some cases air and water temperatures can markedly diverge, for example warming associated with industrial outflows. Wherever the water temperature is warm enough, the species is likely to be able to persist, regardless of the model's estimate of suitability.

Water chemistry and quality may have a large effect on the ability of the species to persist but were not used in the model, except by incorporation of soil pH. Factors such as nutrient concentration are likely to be important modifiers of habitat suitability.

The climate change scenario used is the most extreme of the four RCPs. However, it is also the most consistent with recent emissions trends and could be seen as worst case scenario for informing risk assessment.

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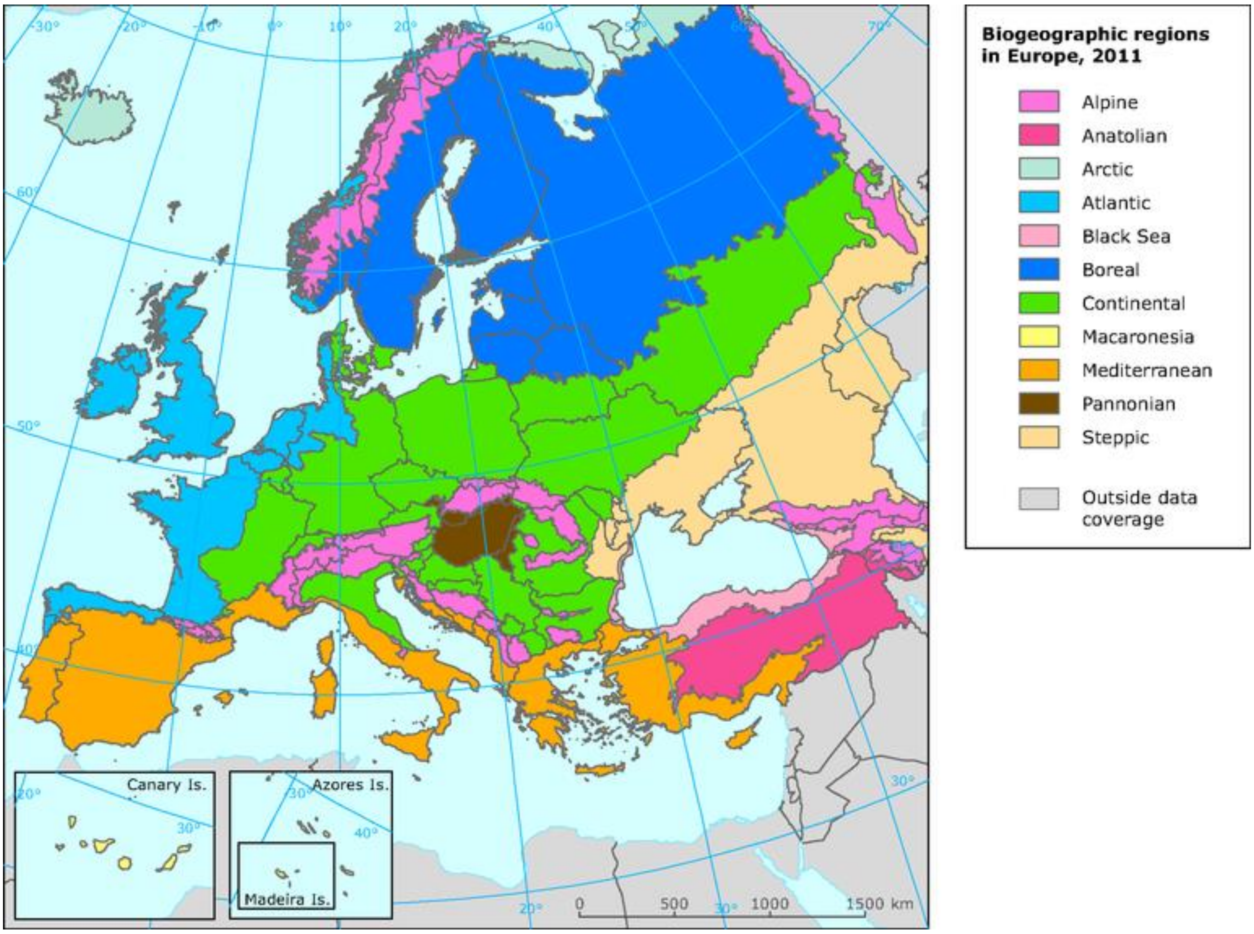
Appendix 2 Biogeographical regions in Europe



Appendix 3. Relevant illustrative pictures (for information)

Figure 1. *Gymnocoronis spilanthoides* covering a water body in New Zealand (P Mabin)

Figure 2 *Gymnocoronis spilanthoides* emerging from water body in New Zealand

Figure 3. *Gymnocoronis spilanthoides* invading marsh land in New Zealand

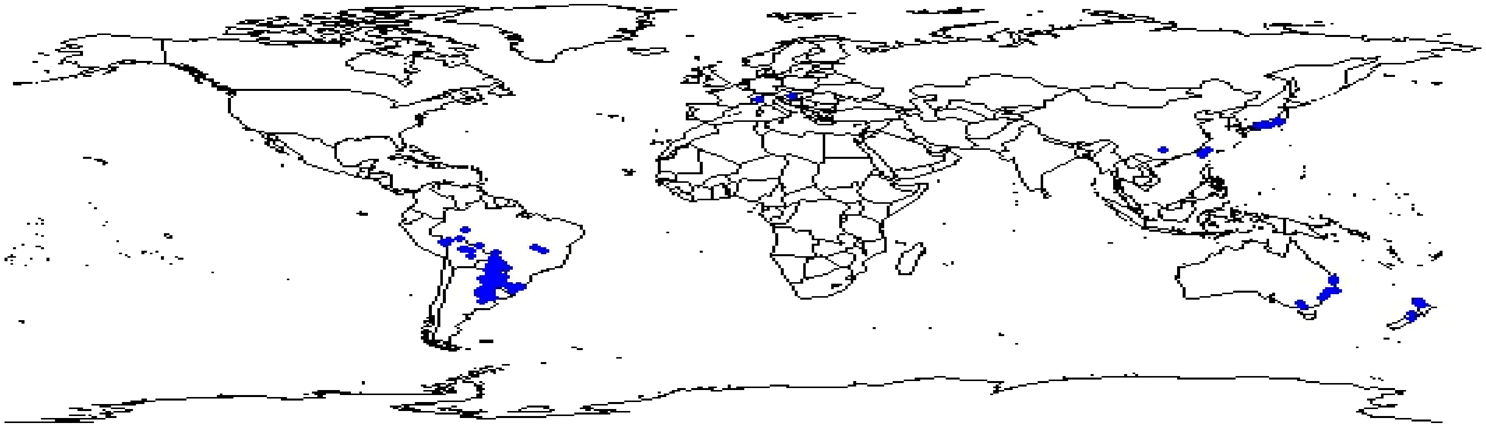
Figure 4 *Gymnocoronis spilanthoides* in Italy

Figure 5. Mat forming habit of *Gymnocoronis spilanthoides*

Figure 6. Young stem of *Gymnocoronis spilanthoides* (not yet hollow)

Figure 7. Flower of *Gymnocoronis spilanthoides*

Appendix 4. Distribution maps of Gymnocoronis spilanthoides[3]



[3] Note that these maps may contain records, e.g. herbarium records, that were not considered during the climate modelling stage

Figure 2. Gymnocoronis spilanthoides occurrence in South America

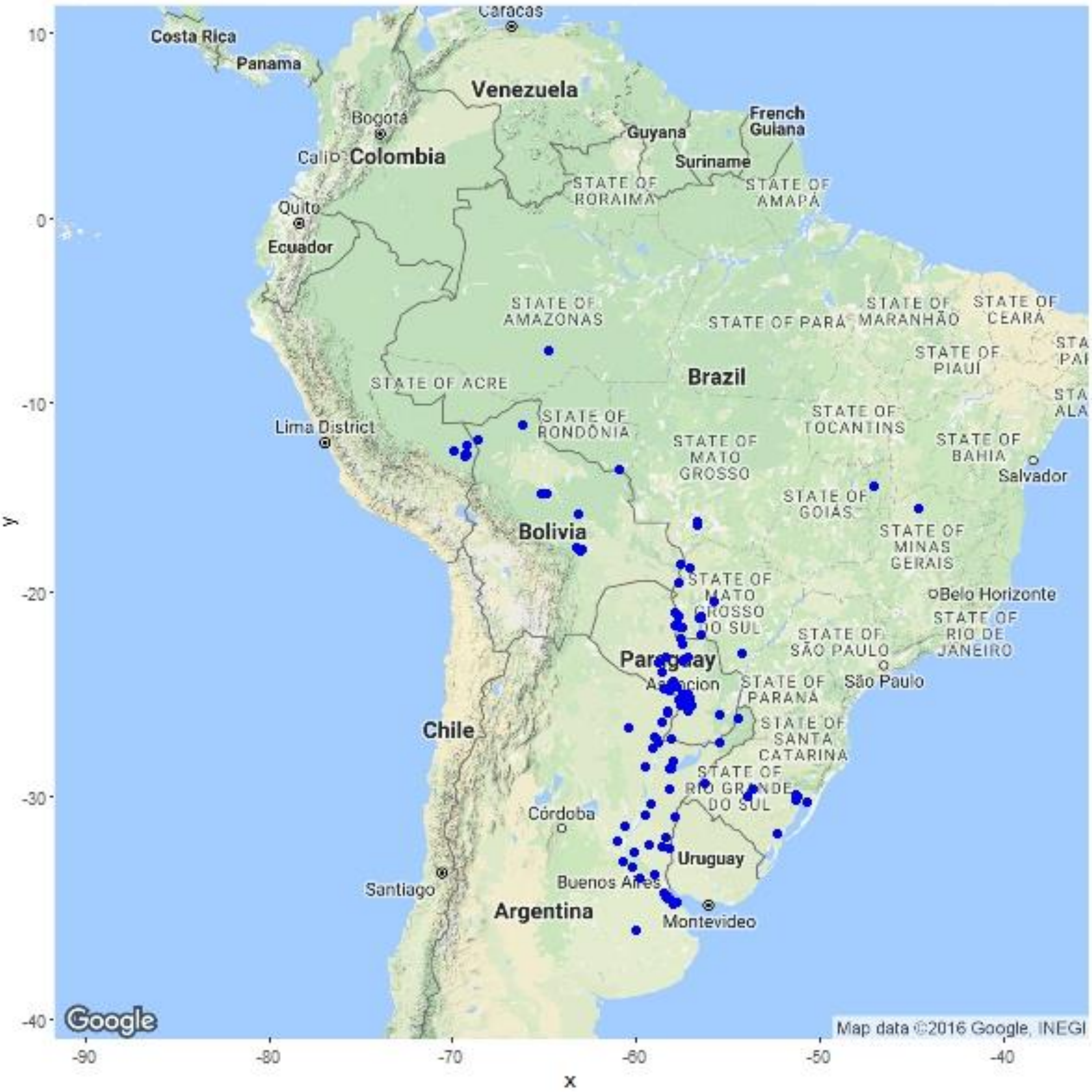


Figure 3. *Gymnocoronis spilanthoides* occurrence in Asia

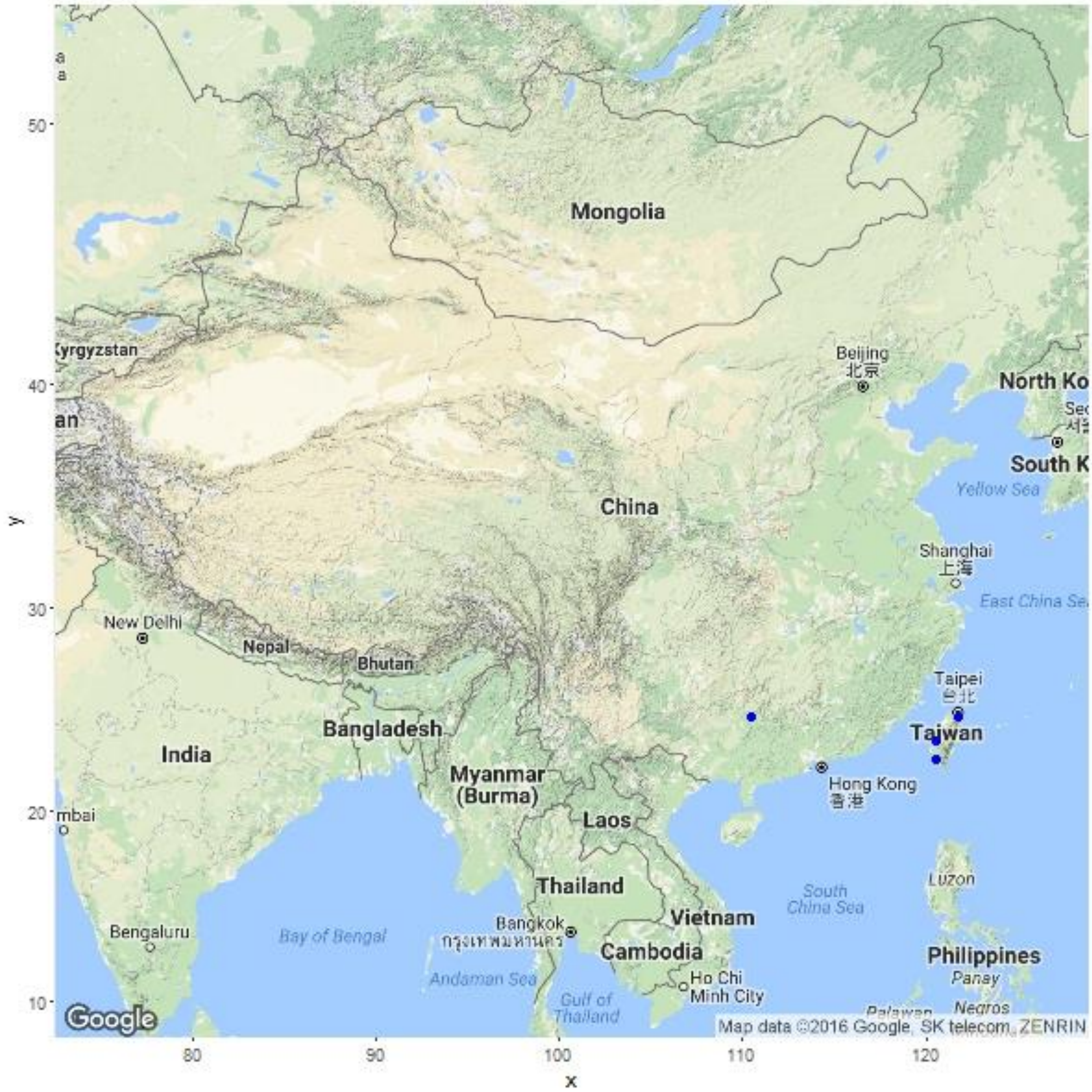


Figure 4. *Gymnocoronis spilanthoides* occurrence in Japan

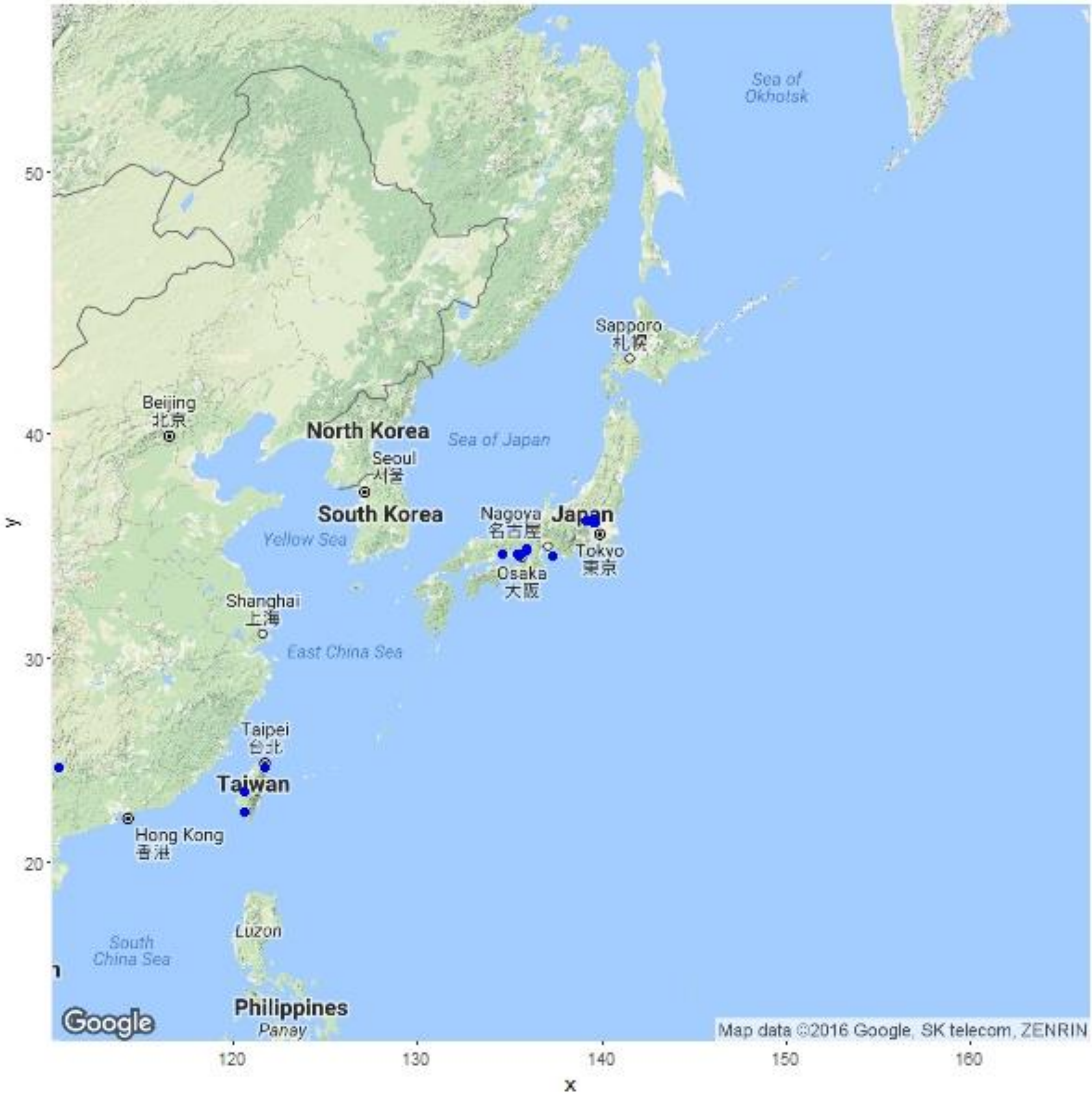


Figure 5. *Gymnocoronis spilanthoides* occurrence in Europe

Figure 6. *Gymnocoronis spilanthoides* occurrence in Australasia