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

Pest Risk Analysis for

Zizania latifolia (Griseb.) Hance ex F.Muell.

Zizania latifolia flowering on lake edge (DE) Courtesy S. Follak – EPPO Global Database (EPPO Code: ZIZLA)

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The risk assessment follows EPPO standard PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (available at http://archives.eppo.int/EPPOStandards/pra.htm), as recommended by the Panel on Phytosanitary Measures. The risk assessment uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php).

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Based on this PRA, *Zizania latifolia* was added to the EPPO A2 List of pests recommended for regulation as quarantine pests in 2024. Measures for plants for planting are recommended.

Pest Risk Analysis for *Zizania latifolia*

PRA area: EPPO region
Prepared by: Expert Working Group (EWG) on *Zizania latifolia*
Date: 12-15 February 2024. Further reviewed and amended by EPPO core members and Panel on Invasive Alien Plants (see below).

Composition of the Expert Working Group (EWG)

BRANQUART Etienne (Mr)	Service Public de Wallonie Agriculture, Ressources Naturelles et Environnement, Belgium
CHAMPION Paul (Mr)	National Institute of Water and Atmospheric Research, New Zealand
CHAPMAN Daniel (Mr)	University of Stirling, United Kingdom
FOLLAK Swen (Mr)	Austrian Agency for Health and Food Safety (AGES), Institute for Sustainable Plant Production, Austria
FROHLICH Danielle (Ms)	c/o SWCA Environmental Consultants, United States
KULAKOVA Yuliana (Ms)	All-Russian Plant Quarantine Center, Russian Federation
VAN VALKENBURG Johan (Mr)	Netherlands Food and Consumer Product Safety Authority, Netherlands
EPPO	
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The first draft of the PRA was prepared by Mr Swen Follak (AT).

Ratings of likelihoods and levels of uncertainties were made during the meeting. These ratings are based on evidence provided in the PRA and on discussions in the group. Each EWG member provided a rating and a level of uncertainty anonymously and proposals were then discussed together in order to reach a final decision. Such a procedure is known as the Delphi technique (Schrader *et al*., 2010).

Following the EWG, the PRA was further reviewed by the EPPO Core Members for PRA (Dmitrii Musolin, Alan MacLeod, Camille Picard).

The PRA, in particular the section on risk management, was reviewed and amended by the EPPO Panel on Invasive Alien Plants on 2024-05. EPPO Working Party on Phytosanitary Regulation and Council agreed that *Zizania latifolia* should be added to the A2 List of pests recommended for regulation as quarantine pests in 2024.

CONTENTS

Summary of the Express Pest Risk Analysis for *Zizania latifolia*

PRA area: EPPO region (Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, The Republic of North Macedonia, Malta, Moldova, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Türkiye, Ukraine, United Kingdom, Uzbekistan).

Describe the endangered area: The EWG considered that areas highly suitable for establishment are the Pannonian, Continental, Black Sea, Anatolian, Steppic, Mediterranean, Boreal and Atlantic biogeographical regions. *Zizania latifolia* is restricted to fresh water and wetland habitats. River systems with large estuaries (deltas) such as Danube, Dnieper, Dniester, Ebro, Guadalquivir, Po, Rhone and the Volga are particularly suitable for spread. Low-lying agricultural land and associated drainage systems are included in the endangered area.

Main conclusions: *Zizania latifolia* is already established in Belarus, Belgium, France, Lithuania, Russia, and Ukraine. In addition, there are a smaller number of persistent planted populations from Estonia, Germany, Ireland, Switzerland and the United Kingdom. The overall likelihood of further entry of *Z. latifolia* into the EPPO region is moderate with a moderate uncertainty. The likelihood of establishment outdoors is very high with low uncertainty. Habitats are widespread within the EPPO region and further establishment is likely in regions where habitats and climatic conditions are conducive for growth. Likelihood of establishment in protected conditions is very low with moderate uncertainty. The potential for spread within the EPPO region is high with a moderate uncertainty. *Z. latifolia* can spread naturally via plant fragments in waterways, and via human assisted spread (e.g. horticulture trade, fragmentation due to management practices). The magnitude of impact in the current area of distribution (excluding the EPPO region) is very high with a moderate uncertainty. *Z. latifolia* has negative impacts on biodiversity and ecosystem services. Persistent populations can act as ecosystem transformers, favouring wetlands draining, eutrophication and sedimentation. The plant has also been shown to have socio-economic impacts on low-lying agricultural land and associated drainage systems. The EWG considered that the potential impact in the EPPO region is high with a high uncertainty. Similar types of impacts are expected though the high rating reflects the potential impacts on biodiversity and ecosystem services in the EPPO region. A high uncertainty reflects the limited amount of scientific evidence on the negative impacts and the perceived early stage of the invasion in the EPPO region. Based on high likelihood of spread (moderate uncertainty) from existing established populations in the EPPO region, and high impact (high uncertainty) the overall risk appears correct.

Phytosanitary risk for the *endangered area* (*Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document*)	High X	Moderate ☐	Low ☐
Level of uncertainty of assessment	High ☐	Moderate X	Low ☐

Other recommendations:

- Monitor the rate of spread of *Z. latifolia* from existing populations in the EPPO region.
- Conduct dedicated surveys of *Z. latifolia* in the EPPO region.
- Carry out scientific studies on the impact of *Z. latifolia* in the EPPO region.
- Set up surveillance, early detection and rapid action, especially in water courses downstream from established populations of Z. *latifolia* in the EPPO region.
- Promote awareness raising of *Z. latifolia* in the EPPO region.

EPPO Pest Risk Analysis:

***Zizania latifolia* (**Griseb.) Hance ex F. Muell.

Prepared by: EPPO Expert Working Group
Date: 2024-02-12/15

Stage 1. Initiation

Reason for performing the PRA:

This PRA was conducted to determine the likelihood and extent of entry into the EPPO region along with establishment and spread of *Z. latifolia* and the magnitude of its potential impacts within the EPPO region. *Z. latifolia* is a perennial rhizomatous helophyte with a risk to biodiversity and agriculture. The species has many weedy traits that makes it highly competitive in wetland habitats. It grows rapidly, has a high biomass accumulation, and reproduces vegetatively from an extensive root system. The species was introduced into the EPPO region as an ornamental plant for ponds in gardens and parks, and it has been planted to provide habitat for wildlife in managed waterbodies. At present, established populations are known from EPPO countries from the margins of water bodies and river systems. The EPPO Panel on Invasive Alien Plants added *Z. latifolia* to the EPPO Alert list in 2022 (EPPO, 2023). *Z. latifolia* has the potential for spread further within the EPPO region.

PRA area:
EPPO region: (Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, The Republic of North Macedonia, Malta, Moldova, Montenegro, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Türkiye, Ukraine, United Kingdom, Uzbekistan).

(see https://www.eppo.int/ABOUT_EPPO/eppo_members)

Stage 2. Pest risk assessment

1. Taxonomy

Kingdom: Plantae, Division: *Spermatophyta*, Sub-Division: *Angiospermae*, Class: *Monocotyledoneae*, Order: *Poales*, Family: *Poaceae*, Genus: *Zizania*, Species: *Zizania latifolia* (Griseb.) Hance ex F. Muell., Proc. Acclim. Soc. Victoria 1: 419 (1872).

EPPO code: ZIZLA (EPPO, 2024)

Synonyms (in chronological order):
Hydropyrum latifolium Griseb. in C.F.von Ledebour, Fl. Ross. 4: 466 (1853)
Zizania dahurica Turcz. ex Steud. in Syn. Pl. Glumac. 1: 4 (1853)
Zizania aquatica var. *latifolia* (Griseb.) Kom. in Trudy Imp. S.-Peterburgsk. Bot. Sada 20: 261 (1901)
Zizania mezii Prodoehl in Bot. Arch. 1: 245 (1922)
Zizania caduciflora Hand.-Mazz. in Symb. Sin. 7: 1278 (1936), nom. superfl.
Zizania latifolia (Griseb.) Turcz. ex Stapf Bull. Misc. Inform. Kew 1909: 385 (1909).

This list of synonyms and names is based on Plants of the World Online (http://apps.kew.org/wcsp/) and World Flora Online (http://www.worldfloraonline.org/).

Common names:
Chinese: gū (菰), jiaobai (茭白), English: Manchurian wild rice, French: riz sauvage de Manchourie, German: Mandschurischer Wasserreis, Japanese: makomo (マコモ) Portuguese: arroz-da-índia, bambu-acuático, Russian: цицания широколистная, Ukrainian: цицанія широколиста

Plant type: Perennial rhizomatous helophyte

Related species in the EPPO region:

The *Zizania* genus (wild rice) includes four known species: *Zizania aquatica* L., *Z. latifolia*, *Zizania palustris* L., *Zizania texana* Hitch. (POWO, 2024). Only *Z. latifolia* is invasive in the EPPO region.

Zizania latifolia is native to east Asia including the Russian Far East (POWO, 2024). In addition to *Z. latifolia*, two other species can be found in the EPPO region:

Zizania aquatica: is an annual species native from Central and E. Canada to N. Central and E. USA. It has been introduced to the EPPO region (See Table 1). In Hungary, *Z. aquatica* is commercially produced as a cereal (https://indianrizs.hu/).

Zizania palustris: The native range of this annual species is Canada to USA. It has been introduced to the EPPO region (Central European Russia, North Caucasus).

2. Pest overview

2.1 Introduction

Zizania latifolia is a perennial wetland, riparian and rhizomatous helophyte. It is a pioneer species with a high morphological plasticity and is tolerant to submergence. The species is utilised as an aquatic vegetable and medicinal plant with a long history of use in China and the east Asian region (Wu et al., 2023). The vegetable is imported into the EPPO region from China (pers. comm. J. van Valkenburg, 2024). It has ecological and economic value in nature (provides forage and shelter, purifies water etc.) (Wu et al., 2023).

In addition to the wild form of the species, *Z. latifolia* is domesticated as the special form of a plant-fungus complex, i.e., the host *Z. latifolia* and the endophytic fungus *Ustilago esculenta*. Once *Z. latifolia* is infected by *U. esculenta*, it hypertrophies the base of *Z. latifolia* stems favouring edible use. It also loses the ability to undergo sexual reproduction via seeds because the fungus hinders the development of the flower primordium. A single domestication event occurred in the lower reaches of the Yangtze River (China) at the Tang Dynasty (approximately 1,400 years ago), then this vegetable was cultivated and bred. Thus, the breeding of new accessions can only rely on the natural somatic mutants in tillers or rhizomes (Xie et al., 2023).

Zhao et al. (2019) found significant genetic divergence between wild and cultivated *Z. latifolia* in China. The extent of genetic differentiation between wild and cultivated plants was greater than the differentiation among wild populations. The vegetable cultivars of *Z. latifolia* have been shown to escape to natural habitats in China (Zhao et al., 2019). Escaped cultivated *Z. latifolia* can be found along the shores of ponds or streams near cropping fields spreading by clonal propagation via underground rhizomes and detached shoots.

No evidence has been found that *Z. latifolia* is cultivated as a vegetable in the EPPO region.

2.2 Description

The following description is primarily based on the Flora of China (2006):
Wild populations of *Zizania latifolia* produces underground as well as surface stems (rhizomes) that form multiple tillers and enable vegetative propagation.

Culms erect, 1–2.5 (4) m tall, rooting at lower nodes. Leaf sheaths thickened, leaf blades broadly linear, 50–90 cm long and 1.5–3.5 cm wide. Ligule triangular, 10–15 mm long. Inflorescences are panicles branching out multiple times either upwards or sideways, 30–50 cm long and 10–15 cm wide, lower branches with male spikelets, upper branches with female spikelets. Male spikelet 8–15 mm long; lemma elliptic-oblong, margin ciliate, awn 2–8 mm. Female spikelet 15–25 mm, lemma linear, awn 15–30 mm. Fruits are caryopses, approximately 10 mm. The seeds of *Z. latifolia* are sparsely arranged on the ear and mature at different times, after which they fall off easily.

Images of *Z. latifolia* can be found in Appendix 2 and can also be retrieved from the EPPO Global Database (EPPO, 2024).

There is the potential for misidentification of between the *Zizania* species. Guides for the identification of the species should be consulted.

2.3 Life cycle

In its native range, phenological observations indicated that the growing season begins in March/April. In China (Yangtze flood plain), phenological observations support the division of the life history of *Z. latifolia* into five periods (Yang et al., 2020): the rhizome bud period (February–March), a period of early growth (April–May), a rapid growth period (June–August), a flowering and fruiting period (September–October), and a dormant period (November–January). Plant height and biomass accumulation in autumn is generally negatively correlated with submergence depth in the early part of the growing season (until April). Self-thinning is considered an element of intra-specific competition for resources (Yang et al., 2020). In Japan (near Tokyo), Asaeda & Siong (2008) showed that shoot density markedly increased after emergence of shoots at the end of March until May (up to 800 shoots m^{-2}). Then, shoot density reduces due to self-thinning by more than 70% by the end of July and thereafter, stabilizing with nearly constant density. Shoot height gradually increased up to 250 cm by late July, then maintained constant height thereafter.

Zizania latifolia has phenotypic plasticity in morphology and shifts in reproductive strategy and biomass allocation enables it to survive flooding events (Wang et al., 2014). It shows high growth rates and shoot height (up to 4 m in height) with increasing flooding depth, as the species can develop faster stem elongation as a response to increasing water depth (Li et al., 2018). Its capacity to form uprooted floating mats in wetlands also improves its resilience to inundated conditions (Hong et al., 2018; Wen et al., 2023). The species can respond to water level fluctuation up to 5 m (Yang et al., 2020). The optimal water depth is 5 to 40 cm (Kwon et al., 2006; Li et al., 2018).

Zizania latifolia plants are comprised of rhizomes, stolons, culms, and adventitious roots from each of the stems, and leaves of the culms (Yang et al., 2014). It reproduces from seed and asexually by clonal expansion of rhizomes and vegetative fragmentation.

In the introduced range, in New Zealand, all known populations of *Z. latifolia* are evergreen (pers. comm. P. Champion, 2024), whereas it is reported as deciduous in parts of its native range.

Seed

In the native range, *Z. latifolia* was reported to produce recalcitrant (desiccation-sensitive) seeds, and the water content of seeds is a critical factor in germination (Jin et al., 2005). There is a reference to seeds losing viability when dried after four weeks (Kew, 1909), however, the EWG found no supporting information to substantiate this. Seeds germinate at 0.5 cm or greater sediment depth (Zhao et al., 2018).

In New Zealand, freshly collected seed had an estimated viability of ~70% (James pers. comm. in Champion 2020). However, seed does not seem to play an important role in the life cycle of the species, at least in the introduced range. In New Zealand, seedlings are not reported in the natural environment (pers. comm. P. Champion, 2024). Seed production may be very limited or absent in the introduced range as observed in Lithuania (Liatukas & Stukonis, 2009) or in Belgium (Verloove, 2011).

Rhizome

New plants can form from rhizomes which contain numerous viable buds. There is no information on the minimum size of a rhizome needed to form a plant. Tang et al. (2022) showed a final sprouting percentage from 70 % at a flooding depth of 0 cm compared to 52 % at 30 cm. Yang et al. (2020) observed much higher figures: sprouting was unaffected by submergence to a depth of 40 cm.

Growth and biomass

Z. latifolia has high growth rates and produces a large amount of biomass. In a constructed wetland treatment system, the species produced above-ground biomass of 3.8 kg m^{-2} and a total biomass of 7.4 kg m^{-2}. Tsuchiya et al. (1993) reported above-ground and total biomasses of 1.6 and 2.4 kg m^{-2}, respectively, in a natural stand (Japan). In another study, shoot biomass peaked at 2.1 kg m^{-2} in 2002 and 1,74 kg/m^{-2} in 2003 at the end of August under natural conditions in Japan (Asaeda & Siong, 2008).

In the introduced range, in New Zealand, Champion & Hofstra (2010) reported an above-ground biomass of 2.99 kg m^{-2} and below-ground biomass of 8.00 kg m^{-2} in a field population (February/March), with similar biomass estimates obtained from plants cultivated in 60 L pots. Tanner (1996) reported a total biomass of 7.4 kg m^{-2} in a constructed wetland.

2.4 Environmental requirements

Natural populations of *Z. latifolia* are distributed over a wide latitudinal range (20° to 55° N) and also over a wide climatic range (GBIF, 2023).

The main limiting factors for *Z. latifolia* are (pers. comm. Y. Kulakova, 2023):
- low water temperatures,
- frequent fluctuations in the water level (especially at seedling stage),
- lack of standing water,
- flooding high water.

Temperature:

The data available from China indicate that growth of *Z. latifolia* starts when average air temperatures are greater 5 °C and that the strongest growth is at temperatures from 18 to 28 °C.

It has been reported that the overwintering axillary buds are released from dormancy when the average air temperature exceeds 5 °C (Ye et al., 2017). Ye et al. (2017) recognized that stem enlargement and plant growth are inhibited below 10 °C. Yan et al. (2013) showed that tillers mainly emerged when the average air temperature approached 18 °C, however tillering was suppressed when average temperature was over 28 °C (Zhang, 1991 cited in Yan et al., 2013). For example, in China (Hangzhou), the growth period of cultivated *Z. latifolia* lasts from early February to December. Here, the species is exposed to low temperatures and wide diurnal temperature ranges (9.6 to 25 °C [mean temperature]) (Yan et al., 2013).

Zizania latifolia can withstand cold winter temperatures. In the EPPO region, the species occurs in countries with hard frost, such as Lithuania (e.g., Kėdainiai district), Estonia (Lake Endla), and Russia (Rybinsk). The area of the Rybinski reservoir appears to mark the northern limit of occurrence of the plant in the EPPO region. Here, the species does not escape from places where it is cultivated and remains confined to (sheltered) places of intentional introduction (Maltseva & Bobrov 2017).

Moisture:
Zizania latifolia requires waterlogged soil conditions for germination and growth.

Salinity:
Zizania latifolia is tolerant to brackish water (Tang et al., 2022) as it can grow in mild salinized wetlands (salinity less than 15 mmol/L) (Tang et al., 2022). It is intolerant of high salinity, determining the downstream extent on the Northern Wairoa River (New Zealand) (Champion et al. 2001).

2.5 Habitats
In the native range, *Z. latifolia* grows in wetland habitats. It occurs on “the borders of lakes, in still-water bays, along slow-running” streams in Russia (Notov, 2009), grows in “ponds and riverbanks” in Japan (Ohwi, 1964) and in “shallow water of lake margins and swamps and as uprooted floating mats in deep waters, forming large patches” in China (Flora of China, 2006; Wen et al., 2023). In the Republic of Korea, the species occurs in the riparian zone of lowland rivers and in estuaries with sandbars (Seok et al., 2023).

In the introduced range, in New Zealand, the species occurs in wetlands, emergent and riparian areas of still and flowing water bodies, also invading wet pastures. In Hawaiʻi, this species was likely introduced by Chinese immigrants and cultivated as a vegetable (Wagner et al., 1999). As a consequence, it has been mainly found growing in taro (*Colocasia esculenta*) fields, persisting from previously cultivated individuals.

See section 7 for further details on habitats in the EPPO region.

2.6 Existing PRAs
In the USA, U.S. Fish & Wildlife Service prepared a risk assessment (U.S. Fish & Wildlife Service, 2021). The outcome was that *Z. latifolia* has the status of a “high risk” species.

In California (USA), *Z. latifolia* has an overall score of high (14 out of 15) with a moderate uncertainty based on the lack of data from the USA (Kelch, 2018). The conclusion of the assessment was that *Z. latifolia* is a potential significant weed of both natural and wet crop lands and irrigation canals in California. It is also a carrier of the fungus (*U. esculenta*) that could attack and seriously reduce productivity of wild rice.

The University of Florida’s Institute of Food and Agricultural Sciences (UF/IFAS) prepared a risk assessment for the State of Florida. The outcome was that *Z. latifolia* has “high invasion risk” (University of Florida/IFAS/Center for Aquatic & Invasive Plants species, 2017).

The Hawaiʻi-Pacific Weed Risk Assessment determined that this species poses a high risk for becoming invasive in the Pacific region (Kelch, 2018).

In New Zealand, Champion & Clayton (2000) performed a risk assessment on non-native semi-aquatic plants. *Z. latifolia* had the third highest weed risk (score of 68 / theoretical maximum score of 100). Only *Phragmites australis* (75) and *Hydrilla verticillata* (74) rated higher. It is noted that those species are indigenous to the EPPO region but are major weeds in other parts of the world.

In Belgium, the environmental risk assessment was assessed as very high using the Harmonia+ risk assessment protocol and therefore included in the alert list of the LIFE RIPARIAS project (Branquart et al., 2022).

3. Is the pest a vector? **Yes** ☐ **No** **X**

Note: The domesticated lines of *Z. latifolia* are host of the smut fungus *Ustilago esculenta* Henn., which invades the plant and secretes a kind of auxin that stimulates the host cells to expand, forming a stem gall. The fungus is thought to pose a threat to the three species of North American wild rice (Terrell & Batra, 1982; U.S. Fish & Wildlife Service 2021; see 12.1 Impact on biodiversity).

4. Is a vector needed for pest entry or spread? **Yes** ☐ **No** **X**

5. Regulatory status of the pest

In New Zealand, *Z. latifolia* is a "Pest of concern to New Zealand" (Quarantine pest) (Ministry for Primary Industries, 2023). The species is an unwanted organism and notifiable organism under the Biosecurity Act 1993: propagation, spread, display and sale are prohibited. *Z. latifolia* is one of nine weed species managed by central government for national eradication under the National Interest Pest Response programme (https://www.mpi.govt.nz/biosecurity/exotic-pests-and-diseases-in-new-zealand/long-term-biosecurity-management-programmes/national-interest-pest-responses-programme/).

In Australia, *Z. latifolia* is on the National Priority List of Exotic Environmental Pests, Weeds and Diseases (Brooks et al. 2022). Thus, it is considered as a species of "significant environmental and social amenity risk to Australia" (https://www.agriculture.gov.au/biosecurity-trade/policy/environmental/priority-list). In Western Australia, *Z. latifolia* is a "Declared Pest, Prohibited - s12". Prohibited organisms are declared pests by virtue of section 22(1) and may only be imported and kept subject to permits (https://www.agric.wa.gov.au/organisms/128909).

6. Distribution

Asia

China (native)

Zizania latifolia has been domesticated and is cultivated in China as an aquatic vegetable (Guo et al., 2007). Natural populations of *Z. latifolia* are distributed in the east of China along a wide stretch of latitudinal zones (21 to 50° N). The species can be found in the river basins of the Heilongjiang, Liaohe, Huanghe and Yangtze Rivers (e.g., Zhang et al., 2016; Chen et al., 2017; Yang et al., 2020; Wagutu et al., 2022). At present, *Z. latifolia* is cultivated on more than 60,000 ha (Xie et al., 2023). The largest production areas are in the eastern coastal provinces Jiangsu and Zhejiang (Guo et al., 2007). It is also found throughout Asia where it is recorded as both native and introduced (see table 1).

Russia (native range)

The species is native to the East Siberia and the Far East (Komarov, 1934; Tzvelev, 1976; Afonin et al., 2008; Tzvelev & Probatova, 2019). In these areas, the species is distributed sporadically in the natural environment.

Oceania

New Zealand

Zizania latifolia is locally established in several regions of the North Island, namely in Northland, Auckland, Waikato, and Wellington (Freshwater Pests of New Zealand, 2020; New Zealand Plant Conservation Network, 2023). It was first introduced to Dargaville (Northland) and recorded as established in 1906 (Cheeseman, 1906). Later, it was described as abundant in Northland occupying "… 338 ha along 55 km of the Northern Wairoa River, its tributaries and associated drainage systems, with 16 outlier populations …" (Joynt & Newby, 1998).

North America

USA

The species is considered established in Hawai‘i on the islands of Kaua‘i, likely on O‘ahu, and Hawai‘i Island. In continental USA, the species has been rarely found so far. *Z. latifolia* has been intentionally introduced into the USA as an ornamental, namely to Maryland. It has been planted in shallow water in Snowden Pond in the 1920s at the Patuxent Wildlife Research Center (U.S. Fish & Wildlife Service, 2021). The species was illegally cultivated, e.g., in Modeste, California (Watson et al., 1991). *Z. latifolia* is not considered established in the natural environment in mainland USA.

<u>Canada</u>
One location has been detected in British Columbia in 2004 (https://search.museums.ualberta.ca/12-116227). It is locally abundant in shallow tidal water (just above sea level) along the edges of Widgeon Slough on Siwash Island.

EPPO Region
Zizania latifolia has been introduced as an aquatic ornamental (marketed as “bog plants”) since the turn of the 20th century. It was also introduced to the EPPO region from the 1930s onwards in water reservoirs in the EPPO region in countries of the former Soviet Union to provide habitat for biota in managed waterbodies (e.g., Dubyna et al., 2017).

At present, established populations occur in a few EPPO countries (see Table 3). Further populations may occur in the EPPO region but reports are missing.

The global distribution of *Zizania latifolia* is shown in Figure 1.

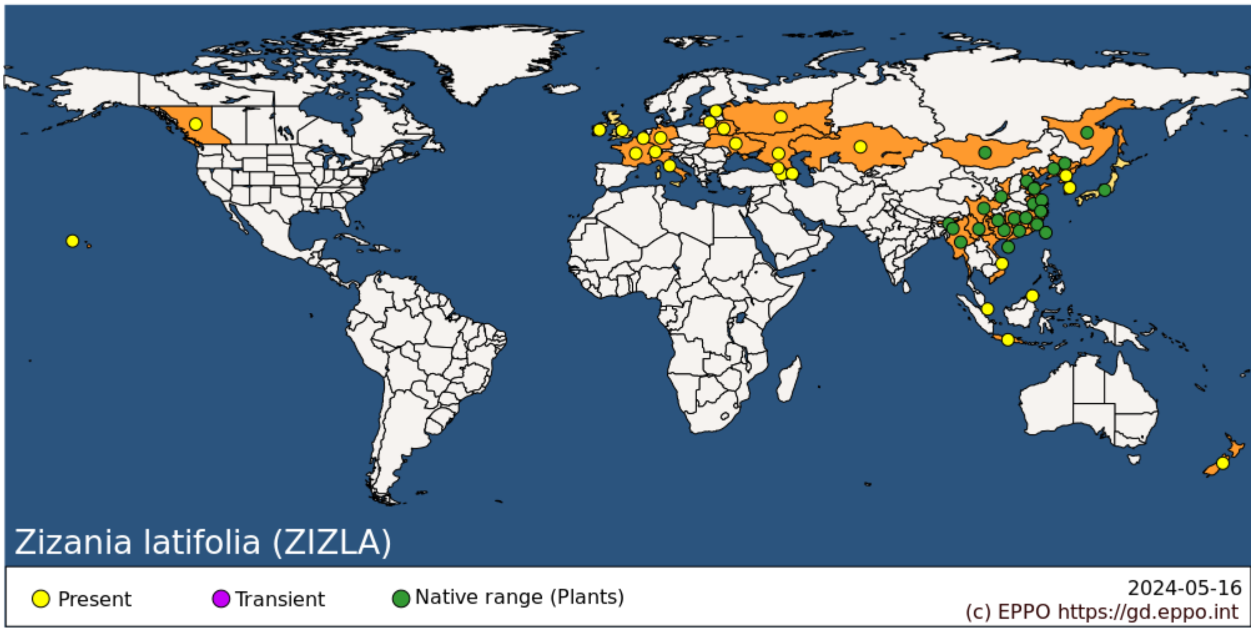

Figure 1: The global distribution of *Zizania latifolia* (EPPO, 2024). Green dots show the native range and yellow dots show the introduced range.

Table 1. Distribution and status of *Zizania latifolia*

Region	Distribution	Status	References and comments
North America			
Canada	British Columbia	Introduced	GBIF (2023), Herbarium specimen (https://search.museums.ualberta.ca/12-116227)
USA	Hawai'i	Introduced	Wagner et al., 1999
Asia			
	Armenia	Introduced	Lytvinskaya & Abdyeva (2021)
EPPO region			
	Azerbaijan	Introduced (status unclear)	Lytvinskaya & Abdyeva (2021)
	Belarus	Introduced (established)	Dubovik et al. (2021)
	Belgium	Introduced (established)	Verloove (2023)
	Estonia	Introduced (planted)	Kuusk et al. (2003), eElurikkus (2023)
	France	Introduced (established)	(pers. comm. G. Fried, 2024)
	Germany	Introduced (planted)	Amarell (2020)
	Georgia	Introduced (status unclear)	POWO (2024), Lytvinskaya & Abdyeva (2021)
	Ireland	Introduced (planted)	National Biodiversity Data Centre (2023)
	Italy	Introduced	Galasso et al., (2022)
	Kazakhstan	Introduced (status unclear)	POWO (2024)
	Lithuania	Introduced (established)	Liatukas & Stukonis (2009)
	Russia (Central Russia*, European Russia*, Southern Russia*, Russian Far East**)	Introduced, established* /Native**	Tzvelev (1976), Tzvelev & Probatova (2019), Vinogradova et al. (2018) ***Z. latifolia* is native to the Russian Far East and Eastern Siberia
	Switzerland	Introduced (status unclear)	GBIF (2023), Herbarium specimen (ZT-00079984 by United Herbaria Z+ZT / CC BY 4.0)
	Ukraine	Introduced (established)	Dubyna et al. (2017)
	United Kingdom	Introduced (planted)	BSBI Online Plant Atlas (2020)
Asia			

	China (Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hebei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Shaanxi, Shandong, Sichuan, Yunnan, Zhejiang)	Native	Flora of China (2006)
	India (Assam, Manipur)	Native	POWO (2024), Sahoo et al. (2018)
	Indonesia (Java)	Native	POWO (2023) Naturalis Biodiversity Center (2024)
	Japan (Hokkaido, Honshu, Shikoku, Kyushu, Okinawa)	Native	Ohwi (1965)
	Malaysia, Borneo	Introduced (established)	POWO (2024); Naturalis Biodiversity Center (2024)
	Mongolia (East Mongolia)	Native	Baasanmunkh et al. (2022)
	Myanmar	Native	Flora of China (2006)
	Democratic People's Republic of Korea	Native	POWO (2024)
	Republic of Korea	Native	POWO (2024), Cho & Kim (1994), Seok et al. (2023)
	Singapore	Native	Flora of Taiwan (2024)
	Taiwan	Native	Flora of Taiwan (2024)
	Vietnam	Introduced (established)	Naturalis Biodiversity Center (2024)
Oceania			
	New Zealand	Introduced (established)	Freshwater Pests of New Zealand (2020)

Specific details about the distribution in selected EPPO countries

Belarus
Zizania latifolia was reported in Belarus for the first time in 1966 (Dubovik et al., 2021). The species has established in the south of Belarus (Polesia) (Mialik, 2021).

Belgium
Zizania latifolia is sold and locally established in Belgium where it has been planted as a marsh plant along ponds and lakes (Verloove, 2023). It was first observed in 2009 on the margins of a pond near La Hulpe (https://waarnemingen.be/observation/44769819/), probably as a relic of former cultivation (ornamental use). There are few other observations thereafter, except one in 2010 in a city canal in Ghent, in Lummen (Laambeekvallei) and one in 2015, in a canal in Moerbeke since 2017 (Verloove, 2023). Recently, there have been numerous reports of the species throughout Belgium, probably as a result of the species being included in the alert list of the LIFE RIPARIAS project (https://alert.riparias.be/) and an extensive population was recorded in 2023 along the River Leie near Ghent (pers. comm. I. Jacobs, 2024).

Estonia
Zizania latifolia was planted in Lake Endla (central Estonia) between 1953 and 1955 (Kuusk et al., 2003). This population is still present in this area (eElurikkus, 2023).

France
First introduced in the botanical garden of Paris (Jardin des Plantes). In 1914 it was grown in the Allier (Thiollets, Gorbier-Peublanc, near Jaligny) on the banks of a lake. In 1919, it invaded all the surrounding of the lake, on 300m long and 3-4m wide. *Z. latifolia* has been first recorded in the wild in October 2016 in the Basque Country. The plant was found on the shore of the Aran river in the municipality of Urt (64-

Pyrénées-Atlantiques) where it has flowered and is considered as naturalized. Two other locations of the plant have recently been found elsewhere in France, each time in ponds where *Z. latifolia* was deliberately planted and where it has become invasive (covering all the ponds): firstly in north-east France (in Montferrand-le-Château (25-Doubs) recorded in September 2018) and secondly in the west of the Massif Central (on the Gourdon's pond (19-Corrèze) in August 2019). (G. Fried, pers. com., 2024).

<u>Germany</u>
Zizania latifolia was detected for the first time in Germany in Freiburg in Breisgau in 2018 on the shore of the lake Opfinger (Amarell, 2020). It is not known how this population was first introduced into the area. In 2023, the species covered at least 200 m of shoreline (pers. obs. S. Follak, 2023).

<u>Lithuania</u>
Zizania latifolia was recorded in the Dotnuvėlė stream near Akademija pond in the city of Akademija in 2006 (Liatukas & Stukonis, 2009). A detailed investigation showed that *Z. latifolia* formed monospecific stands and covered an area of approximately 2500 m^2.

<u>Russia (introduced range)</u>
Zizania latifolia was first introduced in 1934 into the European part of Russia to provide habitat for biota in managed waterbodies (Morozova, 2014; Maltseva & Bobrov, 2017). The introduction of *Z. latifolia* into the Rybinsk Reservoir started in the late 1950s and in the Middle Volga region in 1957.

At present, *Z. latifolia* can be found along a wide stretch of latitudinal zones (45 to 60° N) (Figure 2). The species can be found in nine regions (oblasts) according to Vinogradova et al. (2018): Bryansk, Vladimir, Kaluga, Kostroma, Moscow, Yaroslavl, Krasnodar, Astrakhan and Volgograd. Starodubtseva et al. (2017) published a record of the species also in the Voronezh oblast region in a protected area (State federal level nature sanctuary Voronezhsky). *Z. latifolia* occurs e.g., in water reservoirs along the Volga River (Maltseva & Bobrov, 2017) and in lakes, such as the Lakes Velikoe, Parovoe and Vashutinskoye (Belyakov & Garin, 2018; Belyakov et al., 2020). *Z. latifolia* is recorded in the Astrakhan State Biosphere Reserve (Afanasiev & Laktionov, 2008).

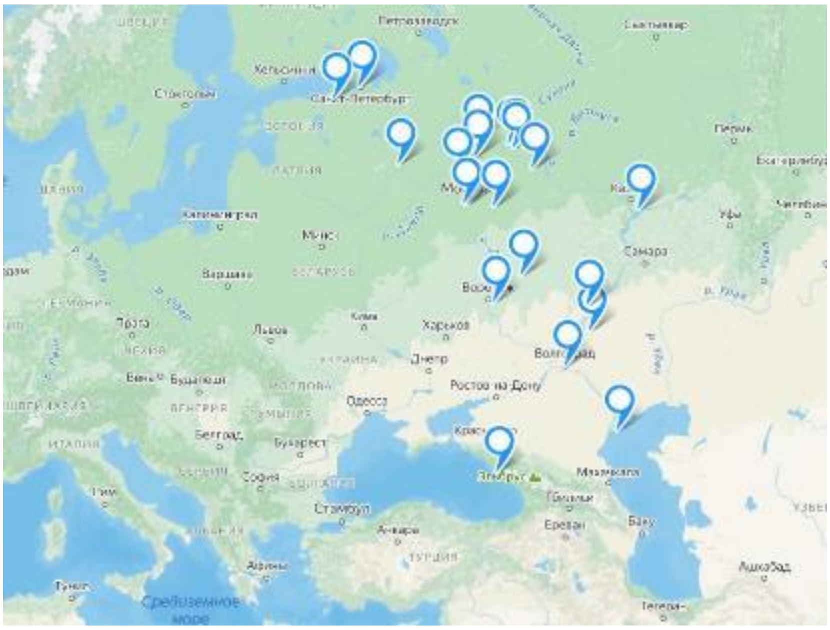

Figure 2. Distribution of *Zizania latifolia* in Russia (introduced range). The map was compiled based on observations, uploaded on the https://www.plantarium.ru and recent references (Y. Kulakova)

<u>Ukraine</u>
Zizania latifolia was intentionally introduced both as a food source and for phytomeliorative purposes in the 1950s (Dubyna et al., 2017; Zub & Prokopuk, 2020). At present, the species is established and occurs in shallow water of large rivers (Dnipro, Dniester, Bug, Sluch), in artificial reservoirs, floodplain lakes and coastal zones (Dubyna et al., 2017; Zub & Prokopuk, 2020; Grokhovska et al., 2021; Dvoretskiy, 2021; Zhukov et al., 2022). *Z. latifolia* was recorded in the territory of the Kanevsky Nature Reserve (Pashkevych & Burda, 2017).

United Kingdom

Zizania latifolia was first cultivated in 1899 and was first recorded in the natural environment from Nuneham Park (Oxfordshire) in 1916. The species has been found around a few ponds in southern England since 1947 (Hollings & Hollings, 2006; BSBI Online Plant Atlas, 2020).

7. Habitats and where they occur in the PRA area

(Habitat classification based on EUNIS habitat types, Version from 2021: https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1)

Table 2. Habitats for *Zizania latifolia*.

Habitat (main)	**Classification**	**Status of habitat**	**Is the pest present in the habitat in the PRA area (Yes/No)**	**Comments (e.g., *major/minor habitats* in the PRA area)**	**Reference**
T: Forests	T11: Temperate *Salix* and *Populus* riparian forest	Protected in part	No	Minor	Champion et al. (2001)
Q: Wetlands	Q5: Helophyte beds Q6: Periodically exposed shores	Protected in part	Yes	Major	Maltseva & Bobrov (2017); Dvoretskiy (2021)
R: Grasslands and lands dominated by forbs, mosses, or lichens	R3: Seasonally wet and wet grasslands (e.g. natural habitat)	Protected in part	No	Major	Lytvinskaya & Abdyeva (2021)
V: Vegetated man-made habitats	V2: Cultivated areas of gardens and parks; V3: Artificial grasslands and herb dominated habitats; V212: Botanical gardens; V23: Recently abandoned garden areas; V14: Inundated or inundatable croplands, including rice fields	Not protected	Yes	Major	V2, V23, V3: Hollings & Hollings (2006); Maltseva & Bobrov (2017); Verloove (2023); Arnold (1959); Northland Regional Council (2023), pers. comm. P. Champion 2024
Transportation networks	Drainage networks, roadside ditches [no EUNIS classification]	Not protected	Yes	Moderate	Arnold (1959), Shaw & Allen (2003)

Suitable habitats occur for the establishment of *Z. latifolia* in the PRA area.

Within the EPPO region, the species has been largely recorded in wetland habitats.

The species has been found in garden and fishery ponds (Hollings & Hollings, 2006; Maltseva & Bobrov, 2017; Verloove, 2023), in shallow water of water reservoirs and water bodies of large rivers (e.g. Dnipro, Dniester, Ukraine; Volga, Russia) and small rivers (Dotnuvėlė, Lithuania) and lakes and coastal zones (estuaries) (Liatukas & Stukonis, 2009; Maltseva & Bobrov, 2017; Belyakov et al., 2020; Zub & Prokopuk, 2020; Dvoretskiy, 2021). *Z. latifolia* is also found in tributaries of the Leie River near Ghent, as well as in canals elsewhere in Belgium.

Zizania latifolia (together with its congener *Zizania palustris*) was recorded in "wet meadows and swampy biotopes" (Lytvinskaya & Abdyeva, 2021).

Outside of the EPPO region (excluding native range):

In New Zealand, it grows in riparian areas next to rivers, lakes, and drains, in swamps and on low-lying farmland (Ministry for Primary Industries, 2022) as well as in roadside ditches (Shaw & Allen, 2003). *Z. latifolia* can also infest damp paddocks and pastures (Arnold, 1959; Northland Regional Council, 2023). See also images on habitats invade in New Zealand: https://www.weedbusters.org.nz/what-are-weeds/weed-list/manchurian-rice-grass/).

In New Zealand, *Z. latifolia* can invade lowland cropping habitats, especially sweet potato (kumara) (pers. comm. P. Champion, 2024). In Hawai'i, taro fields are also habitat for *Z. latifolia* (pers. comm. D. Frohlich, 2024).

8. Pathways for entry

The following pathways for entry of *Z. latifolia* are discussed in this PRA. Pathways in bold are studied in section 8.1; other pathways were considered as a very low likelihood of entry and are detailed in section 8.2:

- **Plants for planting**
- Scientific purposes
- Contaminant of ship/boat ballast
- Contaminant of used machinery and equipment
- Natural spread
- Animal feed

8.1 Pathways studied

All the pathways are considered from areas where the pest has been reported to be present, into the EPPO region. Examples of prohibition or inspection are given only for some EPPO countries (in this express PRA the regulations of all EPPO countries was not fully analysed). Similarly, the current phytosanitary requirements of EPPO countries in place on the different pathways are not detailed in this PRA (although some were taken into account when looking at management options). EPPO countries would have to check whether their current requirements are appropriate to prevent the introduction of the pest.

Table 3. Pathway plants for planting

Pathway	**Plants for planting**
Coverage (short description why it is considered a pathway)	This pathway covers the entry of *Z. latifolia* into the EPPO region via plants for planting (seeds, rhizomes, live plant). The pathway includes *Z. latifolia* plants for planting carried by travellers and in the internet trade. Ornamental use: *Z. latifolia* is used as a garden ornamental for landscaping in parks, ponds and lakesides in the EPPO region. Improving wildlife habitats: *Z.latifolia* has been planted in natural areas in Russia and Ukraine to enrich the habitat for wildlife in water reservoirs (Maltseva & Bobrov, 2017; Dubyna et al., 2017). There is also evidence that it is grown as a cover for wild water birds in the United Kingdom (Liatukas & Stukonis [2009] citing Fern [1997]) and Belgium (pers. comm. E. Branquart, 2024). Phytomeliorative/phytoremediation purposes: *Z. latifolia* is known for its ability to intercept pollutants and purify water bodies (Tanner, 1996; Chen et al., 2017; Zhang et al., 2023) making it a potential candidate for phytoremediation. It has been introduced to Ukraine for phytomeliorative purposes (Zub & Prokopuk, 2020) but the extent of cultivation is unclear. Erosion control: In China, the species is used for dyke consolidation and coastline stabilization (Chen et al., 2017; Wu et al., 2023) but its effectiveness for erosion control is uncertain. In New Zealand, attempts to use *Z. latifolia* for erosion control had negative consequences (Williams & Champion, 2008) and it is not promoted for this purpose in the EPPO region. Paludiculture: While *Z. latifolia* has been proposed for paludiculture on restored peatlands (“wet agriculture and forestry on peatlands”) (Abel & Kallweit, 2022), information on its use for this purpose is not known. Biofuel production: The prospects of using *Z. latifolia* for bioethanol production have been explored in India (Sahoo et al., 2018) but commercial use in the EPPO region has not been reported and is unlikely. Crop vegetable: *Z. latifolia* is not grown commercially as a vegetable in the EPPO region, though in other regions (e.g. Asia) it is a desirable food specialty and different cultivars exist (Guo et al., 2007; Xie et al., 2023). However, these cultivars are not named. There is the possibility that the species can be purchased to be cultivated in private gardens for own consumption.

Pathway	**Plants for planting**
Pathway prohibited in the PRA area?	The import of *Z. latifolia* plants for planting is not prohibited in the EPPO region.
Pathway subject to a plant health inspection at import?	Yes, partly in some EPPO countries. All consignments of plants for planting other than seeds are subject to a phytosanitary certificate at import in the EU and consignments may be subjected to inspection.
Pest already intercepted?	*Z. latifolia* is available from nurseries and online stores throughout the EPPO region, e.g.: - Nurseries: https://www.garten-toegel.at/shop/de/zizania-latifolia-wasserreis.html (whole plants for gardeners) - Online store Amazon: https://www.amazon.de/s?k=Zizania+latifolia&__mk_de_DE=%C3%85M%C3%85%C5%BD%C3%95%C3%91&ref=nb_sb_noss (seeds).
Most likely stages associated with the pathway	The plant itself is the pest. **Seeds**: seeds can be purchased from online suppliers and sent via mail order in packets. This type of plant material is associated with the pathway. **Live plants**: live plants can be purchased from online suppliers. Live plants will be most likely propagated and traded within the EPPO region, although live plants may be imported into the EPPO region. **Rhizomes**: may also be imported.
Important factors for association with the pathway	Plants for planting will be packaged and maintained to ensure their survival during transportation along the pathway. Seeds sent via mail order have the potential to be delivered to any country in the EPPO region. *Z. latifolia* may enter a country as a misidentified species. *Z. latifolia* was produced, mislabelled and sold by a Belgian grower under the name *Zizania aquatica* up to 2023.
Survival during transport and storage	It is likely that live plants will survive transport and storage as the plant (or seed) is the commodity itself. Provided they are cared for, live plants should be able to survive the period of transport and storage. Seed must be kept moist for it to retain viability.
Trade	There is no evidence that *Z. latifolia* is imported as an ornamental species based on information from a single EPPO country, although that country is a major horticultural trader (e.g. import data on ornamental plants from the Netherlands, 2024), except as a vegetable product from China (not viable plant). Trade of *Z. latifolia* occurs within the EPPO region though there is no specific data on the amounts.

Pathway	Plants for planting
Will the volume of movement along the pathway support entry?	There is a low volume of movement along the pathway, in particular for entry into the EPPO region. There is little information on volumes of movement within the EPPO region. The species is not a very popular species in horticulture in the EPPO region. However, the volume of movement from one EPPO country to another can support entry into areas where the pest does not occur. Most of the live plants will be propagated and traded within the EPPO region as it was the case in Belgian aquatic plant nurseries up to recently.
Will the frequency of movement along the pathway support entry?	There is a low frequency of movement along the pathway, in particular for entry into the EPPO region. There is little information on frequency of movement within the EPPO region. The species is not a very popular species in horticulture in the EPPO region. However, the frequency of movement from one EPPO country to another can support entry into areas where the pest does not occur. *Z. latifolia* can propagate vegetatively and even with a low volume of trade, one individual is enough to establish and spread. Most live plants will be propagated and traded within the EPPO region as it was the case in Belgian aquatic plant nurseries up to recently.
Transfer to a suitable habitat	*Z. latifolia* requires aquatic and wet habitats for growth and is likely to be deliberately planted into such habitats. As the commodity is intended for planting in a habitat that will support its growth, including natural habitats, transfer is almost certain.
Likelihood of entry and uncertainty	**Moderate likelihood of entry with a moderate uncertainty.** The moderate uncertainty is based on: lack of information on the trade of the species within the EPPO region / there are a number of end uses of the species but its extent of its utilisation in the EPPO region is unknown. Seed, plants and/or rhizomes may be exchanged between users without any documentation.

8.2 Pathways with a very low likelihood of entry

- **Scientific purposes**
  Zizania latifolia (wild) populations are important genetic resources. Traits of *Z. latifolia* are used for rice breeding owing to its close relationship to rice (*Oryza sativa* L.) (Chen et al., 2006; Guo et al., 2015). There may be other areas of research, for example biofuels. There is no evidence that *Z. latifolia* is imported for scientific purposes in the EPPO region. The EWG considered this pathway has a moderate uncertainty (different types of research could utilise the species).

- **Contaminant of ship/boat ballast**
  The species was most likely introduced to New Zealand around the early 20th century in the solid ballast carried by ships, which was discarded on the banks of the Northern Wairoa River (Arnold 1937). Today, water ballast is used instead of solid ballast. This pathway is considered largely historical. The EWG consider this pathway has a low uncertainty (historical pathway).

- **Contaminant of used machinery and equipment**
  Used machinery and equipment: Seed and rhizome material of *Z. latifolia* may become a contaminant of machinery and equipment. However, there is probably very little movement of used machinery from the countries where the pest occurs into the EPPO region and if there is, it is probable that such equipment would undergo phytosanitary procedures such as decontamination (e.g. in the EU, machinery and vehicles imported from third countries other than Switzerland and which have been operated for agricultural or forestry purposes should be cleaned and free from soil and plant debris (Regulation (EU) 2019/2072)). Agricultural machinery will likely be used in suitable habitats. The propagules of *Z. latifolia* are not likely to survive on this pathway (seed) or they are likely to be detected during inspection (rhizomes). This pathway is covered by an International Standard for Phytosanitary Measures (ISPM 41) (IPPC, 2017). The EWG considered this pathway has a moderate uncertainty (uncertainty in the level of cleaning / levels of inspection / viability of the propagules).

- **Natural spread**
  Taking into consideration the current area of distribution (see section 6), it is not possible that *Z. latifolia* can naturally spread from outside of the PRA into the PRA area (excluding the far eastern part of Russia). However, there is the potential of existing populations in the EPPO region spreading to areas where it is currently absent (see section 11). The EWG consider this pathway has a low uncertainty.

- **Animal feed**
  There are historic references that *Z. latifolia* was used as an animal feed in France (Boite, 1887). The EWG consider that this pathway is nowadays is very unlikely and it is not considered further.

Overall rating of the likelihood of entry combining the assessments from the individual pathways considered:

The EWG conclude that the overall rating for entry of *Z. latifolia* into the EPPO region is moderate with a moderate uncertainty, based on the worst-case scenario (import of plants for planting).

<table>
<tr><td>Rating overall</td><td>Very low ☐</td><td>Low ☐</td><td>Moderate X</td><td>High ☐</td><td>Very high ☐</td></tr>
<tr><td colspan="3">Rating of uncertainty</td><td>Low ☐</td><td>Moderate X</td><td>High ☐</td></tr>
</table>

9. Likelihood of establishment outdoors in the PRA area

Zizania latifolia is already established in Belarus, Belgium, France, Lithuania, Russia, and Ukraine. In addition, there are a smaller number of persistent planted populations from Estonia, Germany, Ireland, Switzerland and the United Kingdom.

Habitats which are suitable for *Z. latifolia* are detailed in section 7. These habitats are widespread within the EPPO region and further establishment is likely in regions where habitats and climatic conditions are conducive for establishment.

9.1 In the natural environment

Zizania latifolia has already established in the natural environment in wetland habitats within the EPPO region (see section 7). It can be assumed that clonal species, such as *Z. latifolia*, can make use of immediate growth and regeneration from rhizome fragments and thus, are predicted to establish and compete with other plants quite effectively.

In some areas in the EPPO region, there is extensive establishment along river banks (for example near Ghent, Belgium). In natural environments, there is the potential for establishment via clonal expansion in riparian forests and wet grasslands adjacent to wetland areas.

Deliberate introductions into the natural wetland environments (e.g., for hunting purposes and wildlife habitat enhancement) would facilitate the establishment of new populations.

9.2 In the managed environment

Zizania latifolia is established in water reservoirs, canals, drainage ditches in the EPPO region (Notov, 2009; Belyakov & Garin, 2018). In addition, it can establish in managed wetland habitats (e.g., fishing ponds/lakes). It is recorded as established in parks (e.g., Moscow) (pers. comm. Y. Kulakova, 2023).

In managed environments, there is the potential for establishment via clonal expansion into wet low-lying pastures (Randall, 2017) used for cattle production and inundated or inundatable croplands, including rice fields.

Establishment is likely in managed environments such as allotments and gardens where the plant is cultivated as a crop plant, and the condtions (enough water logged soil or ponds) are present.

9.3 Other factors affecting establishment

Natural enemies
Specific natural enemies are not known to occur on *Z. latifolia* within the EPPO region. Generalist natural enemies may potentially attack the plant, but these are unlikely to cause enough damage to influence establishment.

In Japan, there is evidence that water birds selectively forage on the rhizomes of the species leading to the expansion of *Z. latifolia* from rhizome fragments (Watanabe et al., 2008; Ohkawara & Tajiri, 2023).

Climate conditions

A species distribution model was developed for this PRA (see Appendix 1) and predicts a large climatically suitable area spanning most lowland parts of Europe. Existence of known populations distributed from Ireland and southwest France in the west to St. Petersburg in the north and central Russia in the east supports this wide range of potential establishment in the EPPO region. Within this climatically suitable region, the species may establish if introduced to suitable wetland habitats.

However, the modelling suggests that northern Britain, Scandinavia, northern Russia, and high mountain areas remain mostly unsuitable due to low summer temperatures. In addition, the model suggests that low water table depths may prevent establishment in more arid parts of Iberia, North Africa and the Middle East and southern Russia to central Asia.

Predictions of the model for 2041-2070, under the moderate SSP1-2.6 climate change scenario and the more extreme SSP3-7.0 scenario suggest that warmer summer temperatures may allow establishment further northwards. Slight reductions in suitability are predicted for more arid areas (e.g., Mediterranean and Steppic areas) though this may be under-estimated in the model because it does not represent any drying out of current wetlands.

These results are reflected in the suitability of different European Biogeographical Regions. Regions highly suitable for establishment in the current climate include the Pannonian, Continental, Black Sea, Anatolian, Steppic, Mediterranean, Boreal and Atlantic. By 2041-2070, overall modelled suitability increases in all of these except for declines in the Mediterranean and to a lesser extent in the Steppic and Pannonian (Appendix 2: Figure 9). Suitability also notably increases in Alpine areas.

Soil conditions
Zizania latifolia requires waterlogged soil conditions and tolerates a wide range of substrates (e.g. wet soils that range from pH 5-8). Li et al. (2018) found that the substrate texture (sandy loam, clay loam, and silt) had no effect on rhizome sprouting in *Z. latifolia*. Kwon et al. (2006) stated that the optimal soil textures were loam, silt loam and sandy loam, while it appears frequently in soil with a high silt content.

The EWG considered that the rating of the likelihood of establishment is very high; the species is already established in the EPPO region and further establishment is likely. There are habitats available in climatically suitable areas.

Rating of the likelihood of establishment outdoors in the PRA area	Very low ☐	Low ☐	Moderate ☐	High ☐	Very high X
Rating of uncertainty			Low X	Moderate ☐	High ☐

10. Likelihood of establishment in protected conditions the PRA area

Protected conditions, such as in greenhouses or polytunnels used to grow aquatic ornamentals, can provide a suitable habitat for *Z. latifolia*.

No evidence was found of the accidental presence of *Z. latifolia* under protected conditions in the EPPO region.

It is unlikely that *Z. latifolia* will be introduced into protected conditions as a contaminant and if it was, individuals would be removed.

The EWG considered that the likelihood of *Z. latifolia* establishing in protected conditions in the EPPO region is very low with a moderate uncertainty.

Rating of the likelihood of establishment in protected conditions	Very low X	Low ☐	Moderate ☐	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate X	High

11. Spread in the PRA area

Natural spread
The species spreads naturally via seeds, rhizomes, and floating mats.

In New Zealand, a high rate of spread following introduction has been documented. Cheeseman (1906) reported this species as "copiously naturalised by the Northern Wairoa River between Te Kopuru and Dargaville and increasing fast". Approximately 15 km of riverbank would have been invaded. Arnold (1937) described an extensive belt of 25 miles (40 km) along the Northern Wairoa River which had increased to 30 miles (48 km) with an area from Ruawai to Pukehuia being colonised (Arnold, 1959). Joynt and Newby (1998) estimated the extent to be 55 km of the Northern Wairoa River, 44 km of tributaries and large areas of drains and low-lying pasture, with a total area of 338 ha. There has been little or no increase in the infested area on the Northern Wairoa River since the instigation of the NIPR programme in 2008 (pers. comm. P. Champion, 2024). More recently, over 200 outlier sites were identified in western Northland, away from the Northern Wairoa and associated waterbody infestations (Joynt 2009).

Seeds: In its native range, seed of *Z. latifolia* is mainly dispersed by water flow (Zhao et al., 2018).

Zizania latifolia flowers in the PRA area, however information on the production of fertile seeds is limited. In Lithuania, the species was flowering, but seed production has not been reported in 2006 to 2008 (Liatukas & Stukonis, 2000). Likewise, in Belgium flowering has been observed but no seed was set (pers. comm. I. Jacob, 2024). In Germany, the species was flowering, too (Amarell, 2020, pers. obs. S. Follak, 2023), and, in Russia (Nizhny Novgorod oblast), the observed population formed "blossoms and bears fruits" (Belyakov & Garin, 2018). Reports on the quantity of seed production are not available. In France (Basque country), *Z. latifolia* was also observed flowering but there is no information available on viable seed production

Seedlings are not known in the introduced range, e.g. in New Zealand despite viable seeds being produced (pers. comm. P. Champion, 2024).

Plant fragmentation: The species can actively disperse in water bodies with the water flow by rhizome fragments. Belyakov & Garin (2018) noticed that establishment of the species on new areas of the shorelines of the Pustyn system lakes occurs mostly due to fragmentation of plants and its transportation via high water levels. Moreover, Liatukas & Stukonis (2009) concluded that rhizome fragments were responsible for the spread along the shoreline of the Akademija pond and downstream of the river Dotnuvėlė almost 50 and 200 m away (seed formation was not observed). Such small satellite populations downstream are spreading rapidly. It occupied an area from about 0.25 m^2 in 2006 to about 3 m^2 in 2007 (Liatukas & Stukonis, 2009).

Clumps of *Z. latifolia* could uproot (under progressing water levels) and form floating mats allowing it to colonize new areas in the water body and downstream (Wen et al., 2023).

Waterfowl feeding on rhizomes can act to fragment the plant and facilitating dispersal, and additionally increase rhizome production (Watanabe et al., 2008, Ohkawara & Tajiri, 2023). Wagutu et al. (2022) stated that *Z. latifolia* seeds are edible for waterfowl and migratory birds, which could lead to seed dispersal (in China). The role of birds in the dispersal of the species in the EPPO region is not known.

Human assisted spread

Rhizome fragments of *Z. latifolia* can be dispersed from infested water bodies, water channels/drains and roadside ditches by contaminated soil attached to farm and drainage machinery or excavators during landscaping activities or drain cleaning.

Water level regulation can promote the expansion of the population size in wetland habitats in the EPPO region as seen in China (Jia et al., 2017). A high spread potential has been demonstrated in Chinese lakes. Zhang et al. (2016) showed that the distribution area of *Z. latifolia* linearly increased from 1981 to 2009 in the Wuchang Lake, and the annual average growth rate was about 1.8 km^2/year. In 2009, the plant covered about 53% of the whole lake. Likewise, Jia et al. (2017) showed a gradual loss of open water in Lower Wuchang Lake due to the encroachment from *Z. latifolia* from varying cover from 9.68 km^2 [1992] to a maximum of 49.17 km^2 [2001]. In the East Taihu Lake, the species has covered 35.5 km^2 of formerly open water (Li, 1996).

The use of the species in horticulture and as a crop plant in gardens and allotments can act to spread the species within the EPPO region over large distances. The plant is available via e-Commerce in the EPPO region (see section 8.1). Plants may also be dumped as garden waste and if deposited in a suitable waterlogged habitat, plants could become established. There is evidence that *Z. latifolia* is planted in the natural environment to promote wildlife habitats, which can promote spread.

The potential for spread is likely to increase with further establishment in the EPPO region (see section 9).

The EWG considered the rating of magnitude of spread to be high, based on water dispersal of rhizomes, floating mats and potentially seed, knowledge of spread capacity in other introduced regions. Uncertainty reflects the lack of documented information of the spread rate in the EPPO region, lack of information on the role of seed in spread.

Rating of the magnitude of spread	Very low ☐	Low ☐	Moderate ☐	High X	Very high ☐
Rating of uncertainty			Low ☐	Moderate X	High ☐

12. Impact in the current area of distribution (excluding the PRA area)

Zizania latifolia builds persistent monospecific stands in invaded natural habitats and changes the composition of the flora and is considered an ecosystem engineer.

12.1 Impacts on biodiversity

In China, in its native range, Zhang et al. (2016) reported that due to the overgrowth of *Z. latifolia*, the submerged and emergent macrophytes (*Vallisneria natans*, *Hydrilla verticillata*, *Phragmites australis*, *Typha angustifolia*) previously present had nearly disappeared in Wuchang Lake. Wen et al. (2023) showed that the emergent community in the Lake Erhai (Yunnan Province) had changed from a *P. australis*, *Typha orientalis* and *Acorus calamu*s dominant community to a *Z. latifolia* monodominant community over the past decades.

The problems with the species in these lakes are mainly due to water regulation measures (i.e., dam construction for flood control) that have led to more favorable conditions for *Z. latifolia* (low water levels during the plant's early growth phase and more stable water levels during the year). Also plant development is known to be strongly enhanced by excessive nutrient inputs and water eutrophication (Kangmin, 1999; Yu et al., 2019). In these types of lakes, *Z. latifolia* is likely the dominant species due to its greater morphological plasticity and flooding tolerance compared with other common emergent macrophytes (Li et al., 2018; Wen et al., 2023). However, studies also indicated that the area occupied by the species in lakes is subject to fluctuations due to other human activities (e.g., wetland degradation, increasing pollution, aquaculture), sometimes leading to a constant decline of *Z. latifolia* (e.g., Fang et al., 2006; Zhao et al., 2013).

In Japan, *Z. latifolia* is frequently associated with common reed (*Phragmites australis*) occupying deeper water than that species (Yamasaki & Tang 1981, Yamasaki 1984, Asaeda & Siong 2007). Similar shallow water habitats where this species forms monocultures at the deepest extent of emergent vegetation are found throughout its native range (Asaeda & Siong 2007) and the plant is often regarded as invasive. Uchida & Tazaki (2005) considered *Z. latifolia* to be more competitive than *P. australis*.

In New Zealand, Champion et al. (2001) concluded that *Z. latifolia* displaces short-stature vegetation (essentially all non-woody species) and envelops taller individual indigenous plants (e.g., within *Dacrycarpus dacrydioides* swamp forest those plants would be unable to produce progeny within the dense stand of *Z. latifolia*. Over time a monoculture of *Z. latifolia* would result. Impacts on fauna were less extreme, fish and macroinvertebrate diversity were similar in invaded and non-invaded water bodies, although diversity was low, typical of lowland streams within an agricultural catchment.

In the USA, *Z. latifolia* is considered a reservoir for pests like *Ustilago esculenta*, which can potentially be transmitted to and threaten native *Zizania* species (e.g. Terrel & Batra, 1982, Watson et al., 1991).

12.2 Impact on ecosystem services

Zizania latifolia has an impact on ecosystem services within the current area of distribution (Table 4).
Table 4. *Zizania latifolia* - impacts on ecosystem services

Ecosystem service	**Does the pest impact on this Ecosystem service?** Yes/No	**Short description of impact**	**Reference**
Provisioning	Yes negatively	The species can reduce the productivity of low-lying pastures and cropping areas. Can have negative impacts on paddocks and can affect fishery.	William & Champion (2008), Jia et al. (2017)
Regulating	Yes negatively	The species can impede water flow and increase the chance of flooding by blocking drains and water channels.	William & Champion (2008), Jia et al. (2017)
Supporting	Yes negatively	Eutrophication, as a result of human activities, increases plant growth of *Z. latifolia*. Plant material causes deterioration of water quality in lakes. It alters nutrient cycling in wetlands. It increases soil organic matter, total carbon, total nitrogen, total sulphate, available nitrogen, and the C/N ratio in the rhizosphere soil and favours the development of bacterial and algal blooms.	Kangmin (1999), Li (1997), Yu et al (2019), Zhou et al. (2020), Ma et al (2023)
Cultural	Yes negatively	Dense growth could restrict access to the waterbody for recreation activities and fishing. This may impede the use of the lake for recreation activities in the long-term.	Hollings & Hollings (2006)

The overgrowth of *Z. latifolia* reduces the area of open water through the invasion of the invasive plant and deposition of dead plant material in the lakebed. This also consumes large amounts of oxygen and releases nutrients because of residue decomposition. Kangmin (1999) reported from China, that during the hot seasons in the 1980s, large amounts of wilted *Z. latifolia* sank and decomposed, consuming dissolved oxygen, and releasing H_2S. This resulted in mass fish kills (Lake Taihu, China). Moreover, Li (1997) stated that the species leads to terrestrialization and water pollution in this lake. The decaying plant material causes serious secondary-pollution to the lake water, forming so called "yellow water". Yu et al. (2019) and Ma et al. (2023) also reported that *Z. latifolia* development in Chinese lakes causes the accumulation of organic matter in water that can result in the release of malodorous compounds and has a negative impact on water quality.

12.3 Socio-economic impact

Information on socio-economic impacts is mainly available from China and New Zealand. Most of the studies are observational rather than scientific investigations. The economic consequences associated with the occurrence of *Z. latifolia* is considered important for agriculture, water construction, and fisheries:

- It damages drainage systems and affects the water balance regime;
- It negatively impacts agricultural land (pastures and crop land);
- It affects the (local) fishing industry.

The species can impede water flow and increase the chance of flooding by blocking drains and water channels (Williams & Champion, 2008). It has been observed that *Z. latifolia* negatively impacts agricultural land in New Zealand (Arnold, 1959; Champion & Hofstra, 2010). The persistence of the species has changed farming practices. Some areas of sweet potato farming have been overtaken by *Z. latifolia*. Most affected are pastures near rivers. Here, the species spreads up the water courses and drains, blocks floodgates outlets and destroys stop banks (i.e., earth banks designed to contain the power of rivers and streams). Spreading rhizomes penetrate the stop banks (levees) and opens them up, subsequently the area becomes saturated and slumps. The species encroaches rapidly into the swampy conditions created. Thus, the species leads to degeneration of pastureland (Arnold, 1959; William & Champion, 2008). In the Republic of Korea, *Z. latifolia* is reported as a weed in no-tillage rice production (Im et al., 2015).

The plant can colonize large areas of lakes and severely interfere with fishing due to blocking access to the open water. This has been observed in different Chinese lakes (e.g., Li, 1996; Jia et al., 2017). *Z. latifolia* had covered 35.5 km^2 of formerly open water in the Taihu Lake (Li, 1996). Jia et al. (2017) also showed a gradual loss of open water in Lower Wuchang Lake due to the encroachment from *Z. latifolia* (varying cover from 9.68 km^2 [1992] to a maximum of 49.17 km^2 [2001]). This consequently led to financial losses from major reductions in fishing income (exact data is not available).

The EWG considered the magnitude of impact in the current area of distribution is very high. This is based on well documented evidence of persistent populations which can act as ecosystem transformers, favouring wetlands draining, eutrophication and sedimentation. The persistence of the species has changed farming practices. It can alter the chemical composition of an areas. A moderate uncertainty relates to the lack of documented economic evidence.

Rating of magnitude of impact in current area of distribution	Very low ☐	Low ☐	Moderate ☐	High ☐	Very high X
Rating of uncertainty			Low ☐	Moderate X	High ☐

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution?
No. Impacts can be similar but with lower magnitude and there will be a higher uncertainty.

13.1 Current and potential impacts on biodiversity in the PRA area

There are reports on *Z. latifolia* negatively affecting biodiversity within the EPPO region. Observational and scientific investigations are available.

In Russia, *Z. latifolia* has spread in the Volga Delta (Astrakhan oblast) in the last decades, displacing other aquatic species (Afanasiev & Laktionov, 2008). While *Z. latifolia* has not spread to the adjacent places in the northern riverhead of the Volga River (the Rybinsk Reservoir), it can dominate aquatic plant communities in southern regions (for example, Krasnodar territory, Samara oblast, etc.) and strongly compete with other species (*Butomus umbellatus*, *Phragmites australis*, *Sparganium erectum*, *Typha angustifolia*, *T. latifolia*) (Matveev & Zotov, 1973; Matveev & Solovyova, 1997; Maltseva & Bobrov, 2017).

It has already been reported from nature conservation sites, e.g., Kanevsky nature reserve (Ukraine), Voronezh State nature biosphere reserve (Rusia) (Pashkevych & Burda, 2017; Starodubtseva et al., 2017).

In Lithuania, the population of *Z. latifolia* has expanded and forms mono-dominant stands. Liatukas & Stukonis (2009) stated that "… [t]his new species was aggressive in out-competing other species, as the largest patches of *Z. latifolia* had only very few small spots [patches] of other species".

In Ukraine, scientific investigation showed that *Z. latifolia* forms a specific coenoses (association *Zizanietum* Akhtiamov 1987), which is very poor in other species. The proportion of cover of *Z. latifolia* varies from 85 to 100 % (plants height ranges from 150 to 250 cm) (Dvoretskiy, 2021). In the Dniester Delta area, *Z. latifolia* can cause the disappearance of many other species, including those of wide ecological amplitude, particularly *Phragmites australis* (Dvoretskiy, 2021). *Z. latifolia* has significantly expanded in the coastal part of the islands of the Dnieper Delta in recent years. *Z. latifolia* can change the structure of natural plant communities (Dubyna et al., 2017).

In western Europe, observations show that *Z. latifolia* can form persistent monospecific stands along water bodies (Hollings & Hollings, 2006). Thus, it is likely that similar effects on biodiversity described outside of the EPPO region will occur within the EPPO region, but there is no scientific evidence (EWG opinion).

If left unmanaged, this species would be expected to have similar impacts to that seen in other invaded regions. *Z. latifolia* has the potential to spread, establish and cause impacts to high conservation value wetlands (e.g. Ramsar sites). It also has the potential to cause impacts in water bodies throughout the EPPO region.

Z. latifolia has the potential to colonise rice production areas which are also hotspots for wetland biodiversity (e.g. Camargue, Ebro, Guadalquivir, etc.).

The use of herbicides close to the water body can be a potential impact for the EPPO region. Application of herbicides is often restricted near water (especially in the EU).

13.2 Current and potential impact on ecosystem services in the PRA area

There is currently no information on *Z. latifolia* negatively affecting regulating and supporting ecosystem services within the PRA area. However, there is anecdotal information on *Z. latifolia* affecting negatively cultural ecosystem services. Hollings and Hollings (2006) stated that *Z. latifolia* "… [advanced] by aggressive rhizomes, both into the bank and underwater and preventing access for the anglers" in a pond in England. This impact can also occur throughout the EPPO region where populations of the plant can form persistent mono-specific stands.

Potential impacts on regulating, supporting provisioning ecosystem services will be similar to those detailed in section 12.2. However, the magnitude of these impacts may vary depending on the local situation.

Impacts on provisioning ecosystem services are dealt with in section 12.3 'Socio-economic impacts'.

13.3 Current and potential socio-economic impact in the PRA area

The potential economic impact of *Z. latifolia* in the EPPO region could be significant if the species spreads and establishes in further areas.

Zizania latifolia may have the potential to colonise wet pastureland and low-lying crop land where it grows from nearby river sites. In Belgium, it has been observed to invade the margins of periodically flooded pastures (pers. comm. J. van Valkenburg, 2024).

Zizania latifolia may have the potential to colonise rice (*Oryza sativa*) production areas which can act to interfere with rice production by interfering with water flow and infest field margins and encroach into the fields.

Zizania latifolia can grow in irrigation ditches and reduce water delivery and access which will have negative socio-economic impacts.

The EWG considered the magnitude of impact in the PRA area is high. A high rating is given based on the observed impact in the PRA area, in particular the impact on biodiversity and ecosystem services. The EWG consider that socio-economic impacts will be lower, but it is not possible to give a rating for this as it is not a typical agricultural weed, and there is little information on the current socio-economic impact in the PRA area. A high rating of uncertainty is given due to a limited amount of scientific evidence on the negative impacts and the perceived early stage of the invasion in the EPPO region.

Rating of the magnitude of impact in the area of potential establishment	Very low ☐	Low ☐	Moderate ☐	High X	Very high ☐
Rating of uncertainty			Low ☐	Moderate ☐	High X

14. Identification of the endangered area

The EWG considered that areas highly suitable for establishment are the Pannonian, Continental, Black Sea, Anatolian, Steppic, Mediterranean, Boreal and Atlantic biogeographical regions. It is restricted to fresh water and wetland habitats. River systems with large estuaries (deltas) such as Danube, Dnieper, Dniester, Ebro, Guadalquivir, Po, Rhone, Volga, are particularly suitable. Low-lying agricultural land and associated drainage systems are included in the endangered area.

15. Overall assessment of risk

Zizania latifolia is already established in Belarus, Belgium, France, Lithuania, Russia, and Ukraine. In addition, there are a smaller number of persistent planted populations from Estonia, Germany, Ireland, Switzerland and the United Kingdom. The overall likelihood of further entry of *Z. latifolia* into the EPPO region is moderate with a moderate uncertainty. The likelihood of establishment outdoors is very high with low uncertainty. Habitats are widespread within the EPPO region and further establishment is likely in regions where habitats and climatic conditions are conducive for growth. Likelihood of establishment in protected conditions is very low with moderate uncertainty. The potential for spread within the EPPO region is high with a moderate uncertainty. *Z. latifolia* can spread naturally via plant fragments in waterways, and via human assisted spread (e.g. horticulture trade, fragmentation due to management practices). The magnitude of impact in the current area of distribution (excluding the EPPO region) is very high with a moderate uncertainty. *Z. latifolia* has negative impacts on biodiversity and ecosystem services. Persistent populations can act as ecosystem transformers, favouring wetlands draining, eutrophication and sedimentation. The plant has also been shown to have socio-economic impacts on low-lying agricultural land and associated drainage systems. The EWG considered that the potential impact in the EPPO region is high with a high uncertainty. Similar types of impacts are expected though the high rating reflects the potential impacts on biodiversity and ecosystem services in the EPPO region. A high uncertainty reflects the limited amount of scientific evidence on the negative impacts and the perceived early stage of the invasion in the EPPO region. Based on high likelihood of spread (moderate uncertainty) from existing established populations in the EPPO region, and high impact (high uncertainty) the overall risk appears correct.

Section	Likelihood	Uncertainty
Entry		
Plants for planting	Moderate	Moderate
Establishment outdoors in the PRA area	Very high	Low
Establishment in protected conditions in the PRA area	Very low	Moderate
Spread	High	Moderate
Impact in the current area of distribution	Very high	Moderate
Potential impact in the PRA area	High	High

Stage 3. Pest risk management

16. Phytosanitary measures

The results of the risk assessment show that *Z. latifolia* has a high phytosanitary risk to the endangered area with a moderate uncertainty.

Recommendations by the EWG are the following:

- ***Zizania latifolia* should be recommended for regulation as a quarantine pest,**
- ***Ziania latifolia* should be banned for sale in the EPPO region.**

16.1 Measures on individual pathways to prevent entry

Possible pathways *(in order of importance)*	Measures identified
Plants for planting	Prohibition of import of *Zizania latifolia* into the EPPO region

16.2 Eradication and containment

National measures
Early detection is important to identify new occurrences of the species. *Z. latifolia* should be monitored and eradicated, contained or controlled where it occurs in the area of potential establishment in the EPPO region. In addition, public awareness campaigns to prevent spread from existing populations in countries at high risk are necessary (e.g., Belgium: https://www.riparias.be/en/631/download).

Management of *Zizania latifolia*

Eradication
Eradication measures provided in this section should be promoted where feasible with a planned strategy to include surveillance, containment (see following paragraph), treatment and follow-up measures to assess the success of such actions. Regional cooperation is essential to promote phytosanitary measures and information exchange in identification and management methods. NPPOs should facilitate collaboration with all sectors to enable early identification including education measures to promote citizen science and linking with universities, land managers and government departments.

In New Zealand, successful eradication of small to medium (~ 100 ha in area) populations has been achieved using the grass-specific herbicide haloxyfop-P methyl with a large reduction in abundance at all treated sites (pers. comm. P. Champion, 2024). Under current regulations no herbicides can be used within the habitats occupied by this species in the EU.

Eradication is possible for *Z. latifolia* in case of early detection of small populations including digging up or uprooting individual plants, for further options see the section containment.

Containment
NPPOs should provide land managers and stakeholders with identification guides including information on preventive measures and control techniques (e.g., Belgium: https://www.riparias.be/en/631/download).

Control of the species is difficult, because of the large annual accumulation of biomass, its extensive underground root/rhizome system, and its ability to grow from small rhizome fragments and the inaccessibility of most populations. The following control options are proposed under the conditions in Asia (China) and New Zealand.

Water level regulation: Raising water levels in spring (March–May) during the species' germination period could be successful in reducing the area colonised within lakes (Zhang et al., 2016; Jia et al., 2017).

***Reducing shoot biomass*:** Chandra & Tanaka (2006) identified two key seasons when cutting and removal of *Z. latifolia* shoots could be effective: (1) during the period when substantial self-thinning of shoots occurs (June–July) and (2) when the plant is mature before senescence (September–October). This is a labour intensive and costly measure but provides additional means of controlling biomass accumulation (Jia et al., 2017).

Excavation: Mechanical diggers can be used to remove the plant from ditches, drainage channels and riverbanks, but there is a high risk of transferring rhizome fragments to new sites (https://www.weedbusters.org.nz/what-are-weeds/weed-list/manchurian-rice-grass).

Herbicides**:** The number of effective herbicides is rather limited, and their use is restricted, because many chemicals can affect waterways and the species within. In pastures, it is recommended to spray the graminicide haloxyfop-P-methyl (https://www.weedbusters.org.nz/what-are-weeds/weed-list/manchurian-rice-grass/). Rhizomes persist for years and can recover after spraying so ongoing control is important.

17. Uncertainty

The EWG used the categories of main sources of uncertainties (under development) discussed by the Panel on Phytosanitary Measures in October 2023:

- *Key uncertainties*: likely to significantly affect the overall conclusions (including overall risk and overall uncertainty) of the PRA (i.e., the determination of whether the pest has the characteristics of a quarantine pest, and the pathways that should be managed);
- *Other main uncertainties*: not likely to affect the overall conclusions of the PRA but likely to impact conclusions of individual part(s) of the risk assessment or risk management.

Key uncertainties	Other main uncertainties
	Lack of information on dispersal
	Uncertainty in the current distribution
	Lack of data on impact in the EPPO region
	Lack of information on trade data for plants for planting

18. Remarks

The EWG recommends:

- Monitor the rate of spread of *Z. latifolia* from existing populations in the EPPO region.
- Conduct dedicated surveys of *Z. latifolia* in the EPPO region.
- Carry out scientific studies on the impact of *Z. latifolia* in the EPPO region.
- Set up surveillance, early detection and rapid action, especially in water courses downstream from established populations of *Z. latifolia* in the EPPO region.
- Promote awareness raising of *Z. latifolia* in the EPPO region.

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Appendix 1 Climatic suitability modelling for *Zizania latifolia*

Aim

To project the climatic suitability for potential establishment of *Zizania latifolia* in Europe and the Mediterranean region, under current and predicted future climatic conditions.

Data for modelling

Species occurrence data were primarily obtained from the Global Biodiversity Information Facility (GBIF). GBIF occurrence records were obtained for both the accepted species (GBIF, 2024a) and a doubtful one (GBIF, 2024b), since combining both gave better coverage of the distribution (e.g. New Zealand was poorly represented by the accepted species). Additional occurrence records were obtained from Atlas of Living Australia, Integrated Digitized Biocollections (iDigBio), Plantarum.ru, agroatlas.ru, Ukrainian Biodiversity Information Network, Botanical Society of Britain and Ireland and other reliable records of established populations provided by the Expert Working Group performing the risk assessment.

The records were scrutinised to remove any considered of dubious quality (e.g. known transient or cultivated occurrence, imprecise or bad coordinates, no date older than 1970, co-located with herbaria or botanic gardens, country or province centroids), including use of R package CoordinateCleaner to remove dubious records (Zizka et al., 2019). Records were also removed if lacking coverage of one or more model predictor layers.

Records from China, South Korea, Japan, India and far eastern Russia were considered to represent the native range, based on information in the PRA and Plants of the World Online.

The records were converted to binary grid representing "any occurrence" or "not recorded" at a 0.125 x 0.125 degree resolution for modelling (approximately 8 x 13 km in central Europe) (Figure 1a). As such, any problems with duplicated records from different data sources are removed at this stage. This resulted in 485 grid cells containing valid records of *Z. latifolia* (Figure 1a), which is considered a sufficient number for distribution modelling.

Predictor variables were selected based on the life history and habitat requirements of *Z. latifolia* and likely limiting factors for establishment in Europe. Predictors included climate from 1981 to 2010 from the Chelsa database V2.1 (Karger et al., 2017), and measures of the availability of the wetland habitats preferred by *Z. latifolia*. Several wetland variables were used as all suitable global datasets will miss very small wetland areas in which *Z. latifolia* can establish.

- Mean temperature of the warmest quarter (bio10 °C), as a measure of growing season thermal regime. As detailed in the PRA, optimal temperatures for growth occur between 18 and 28 °C and growth may be inhibited below 10 °C and above 28 °C.
- Mean minimum temperature of the coldest month (bio6 °C). As detailed in the PRA *Z. latifolia* is tolerant of cold winter temperatures, but as a perennial species occurring in water there is presumably some limit to this tolerance. Conversely, lack of winter chilling may impede seed germination, as seeds require a long period of cold dormancy (Horne & Kahn, 2000).
- Percentage area with high water table (log(x+1 transformed), derived from the Plymouth Marine Lab's global 1 km resolution map of water table depth (https://wci.earth2observe.eu/thredds/catalog/usc/water-table-depth/catalog.html). From this source, the percentage of each grid cell with water table above 50 cm depth was calculated. This was intended to represent the availability of low-lying wetland areas.
- Percentage cover of inland freshwater wetlands (log(x+1) transformed) derived from the GWL_FCS30 global 30 m wetland map (Liangyun Liu, 2022). The map includes permanent water, swamp, marsh and flooded flat habitats.
- Surface water permanence (months) derived from the Global Surface Water Explorer 10 m map (Pekel et al., 2016) and representing the mean number of months for which surface water is present in areas with any presence of surface water.
- Length of large rivers (km, log(x+1) transformed) derived from the hydroRIVERS dataset containing all global rivers that have a catchment area of at least 10 km² or an average river flow of at least 0.1 m³/sec (Lehner & Grill, 2013).

- Perimeter length of large lakes (km, log(x+1) transformed) derived from the hydroLAKES dataset containing all global lakes with a surface area of at least 10 ha (Messager et al., 2016).
- Flow accumulation (km^2, log(x+1) transformed) derived from the hydroSHEDS dataset (Lehner et al., 2008) and representing the accumulated upstream area.

To estimate the effect of climate change on the potential distribution, equivalent modelled future climate variables (bio6 and bio10) for 2041-2070 were obtained for two IPCC Coupled Model Intercomparison Project 6 (CMIP6) scenarios or Shared Socioeconomic Pathways (SSPs) (Meinshausen et al., 2020):

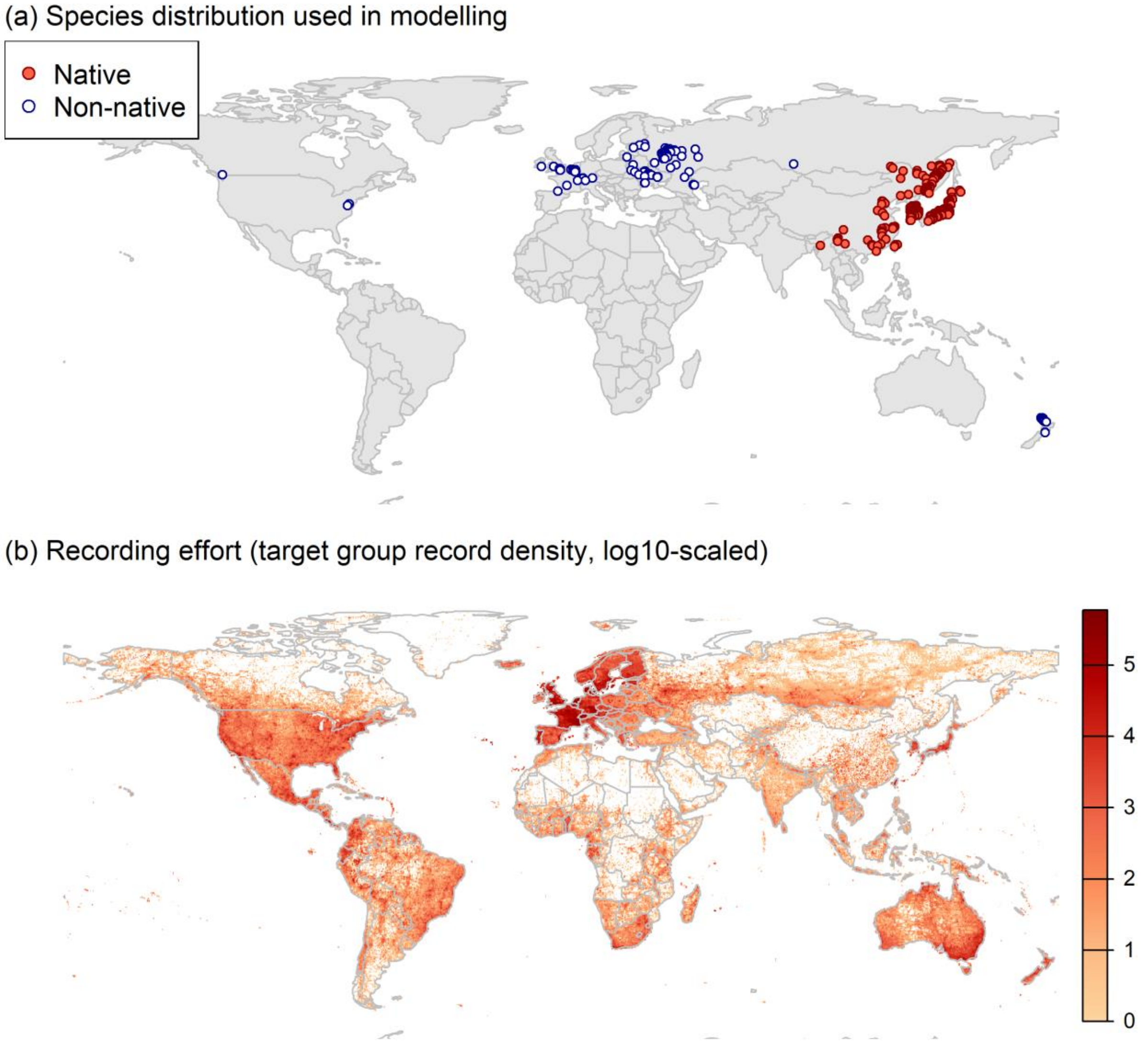
- SSP1-2.6 is an optimistic low-emissions scenario in which atmospheric CO_2 concentration peaks below 450 ppm in the mid-21st century and then falls slightly. The estimated warming by around 2050 is 1.7 °C.
- SSP3-7.0 is a high emissions scenario for a world that fails to act to limit warming. Atmospheric CO_2 concentrations rise to approximately 850 ppm by 2100. The estimated warming by around 2050 is 2.1 °C.

For both SSPs, the climate variables for modelling were obtained as averages of outputs of five Global Climate Models (NOAA's GFDL-ESM4, UK Met Office's UKESM1-0-LL, Max Planck Institute's MPI-ESM1-2-HR, Institut Pierre Simon Laplace's IPSL-CM6A-LR, and Meteorological Research Institute's MRI-ESM2-0), downscaled and calibrated against the Chelsa baseline.

Unfortunately future scenarios for the variables representing wetland habitat availability are not available, but are likely to be affected by climate change due to higher temperatures and altered precipitation patterns. As such the future projections are made assuming the no change in wetland availability.

Finally, as a proxy for spatial recording effort bias in the area of current occupancy by the species, the recording density of vascular plants (phylum Tracheophyta) on GBIF was obtained (Figure 1b). Notably some parts of the native range had relatively high recording effort (Japan and South Korea), while other native areas had more patchy recording (China and far-east Russia) or almost non-existent recording (North Korea). Details on the use of this layer are in the next section.

Figure 1. (a) Occurrence records used for modelling *Zizania latifolia*, showing the native and non-native records. (b) A proxy for recording effort – the number of post-1970 vascular plant records held by the Global Biodiversity Information Facility, displayed on a log_{10} scale.



Species distribution model

The modelling methodology was a modification of standard presence-background (presence-only) ensemble distribution modelling intended to better represent emerging invasive non-native species at global scale (Chapman et al., 2019). This method attempts to account for dispersal constraints on non-equilibrium invasive species' global distributions by excluding locations that may be environmentally suitable but where the species has not been able to disperse to.

To do this, background samples (pseudo-absences) were sampled from two distinct background regions:

- An **accessible background** includes places close to *Z. latifolia* populations, in which the species is likely to have had sufficient opportunity to disperse to (Barve et al., 2011). Based on potential for long-distance seed dispersal, the accessible background was defined as a 400 km buffer around the native range (minimum convex polygon bounding native occurrences) and a 15 km buffer around non-native occurrences (capturing a 4-cell neighbourhood of the non-native occurrences). Sampling was more restrictive from the invaded range to account for stronger dispersal constraint over a shorter residence time. In previous testing of the model approach alternative buffer radii did not substantively affect the model projections (Chapman et al., 2019).

- An **unsuitable background** includes places expected to be physiologically unsuitable for the species, so that absence will be irrespective of dispersal constraints. Little specific ecophysiological information was available so other than where stated extreme values of the predictors at the species occurrences were used to define unsuitability. Unsuitable areas were determined based on at least one of the following conditions:

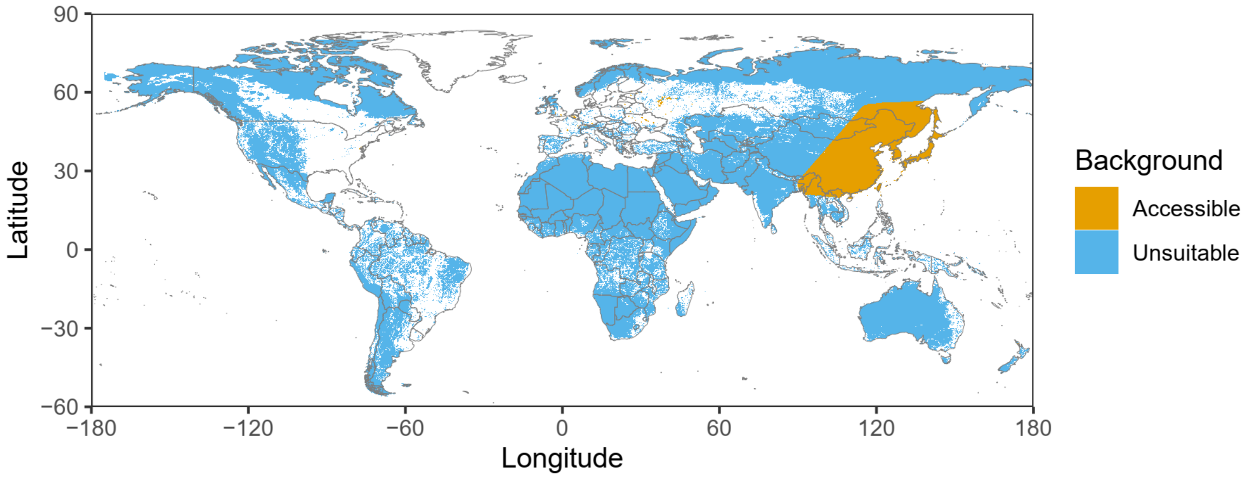
  - Mean temperature of the warmest quarter (bio10) > 29 °C (above the optimal temperature for growth of *Z. latifolia*);
  - Mean temperature of the warmest quarter (bio10) < 14 °C (representing the coldest occurrences and below the optimal growth temperature range for *Z. latifolia*);
  - Minimum temperature of the coldest month (bio6) < -30 °C (based on the coldest occurrences, presumed too cold for survival through winter);
  - Percentage with high water table < 1% (presumed lack of suitable habitat);
  - Wetlands cover = 0% (presumed lack of suitable habitat);
  - Water permanence = 0 (presumed lack of suitable habitat).

Of the 485 occurrences, 26 (5.3%) fell in the unsuitable background. This was mainly due to records in grid cells without any wetland or surface water presence in the global scale maps used for modelling (though very small water bodies may have been present).

For modelling, five random background samples were obtained as follows:

- From the **accessible background** 485 samples were drawn, which is the same number as the occurrences. Sampling was performed with realistic recording bias using the target group approach (S. J. Phillips et al., 2009) in which sampling was weighted by GBIF Tracheophyte recording density (Figure 1b). Taking the same number of background samples as occurrences ensured the background sample had the same level of bias as the data and balanced the presences and background points within the main environmental range of the samples.
- From the **unsuitable background** 2000 simple random samples were taken. Sampling was not adjusted for recording biases as we are confident of unsuitability in these regions. This also ensures the inclusion of areas unsuitable for nearly all plants (e.g. deserts or very high altitude and latitude locations) regardless of whether there has been recording there.

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



Using these data, a presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package v4.2-4 (Thuiller et al., 2023). Each dataset (presences and each individual background sample) was randomly split into 80% for model training and 20% for model evaluation. With each training dataset, the following statistical algorithms were fitted with the default BIOMOD2 settings (except where specified) and rescaled using logistic regression:

- **GLM:** Generalised linear model with linear and quadratic terms for each predictor,
- **GBM:** Generalised boosting model,
- **GAM:** Generalised additive model with four degrees of freedom per predictor,
- **MARS:** Multivariate adaptive regression splines,
- **ANN:** Artificial neural network,
- **RF:** Random forest,
- **Maxnet:** Maximum Entropy (Maxent) in the maxnet R package (S. Phillips, 2021),
- **XGBOOST:** eXtreme Gradient Boosting Training.

Prevalence weights were applied to give equal overall importance to the occurrences and the background. Normalised variable importance was assessed and variable response functions were produced using BIOMOD2's default procedure. Model predictive performance was assessed by calculating the True Skill Statistic (TSS, i.e., sensitivity + specificity - 1) and Area Under the Receiver-Operator Curve (AUC, i.e., probability a background point has a lower suitability than an occurrence point) for model predictions on the evaluation data reserved from model fitting.

An ensemble model was created by rejecting poorly performing algorithms and then averaging the predictions of the remaining algorithms, weighted by TSS. To exclude poorly performing algorithms from the ensemble, TSS values were converted into modified z-scores based on their difference to the median TSS across all algorithms, normalised by the median absolute deviation (Iglewicz & Hoaglin, 1993). Poorly performing algorithms with unusually low TSS ($z < -1$) were rejected.

Global model projections of the ensemble model were made for the current climate and for the two climate change scenarios. 'Clamping' was used to avoid model extrapolation beyond the ranges of the input variables.

The ensemble predictions were partitioned into suitable and unsuitable regions using a threshold that ensured a required sensitivity of 0.95 (i.e., predicting 95% of occurrence locations as suitable).This was done so that the there was high confidence that the areas highlighted as suitable are likely to potentially contain the occurrence records (Freeman & Moisen, 2008).

Limiting factor maps were produced following Elith et al. (2010). Limiting factors for each grid cell were estimated as the variable giving the greatest increase in suitability when it was changed to a presumed near-optimal value (median value in the occurrence grid cells).

Results and Discussion

The ensemble model suggested that suitability for *Z. latifolia* at the global scale and resolution of the model was strongly limited by both climate and availability of wetland habitats (Table 1). The strongest limiting factors were summer mean temperature (bio10), proportion of land with a high water table and

winter minimum temperature (bio6). Both climate variables exhibited a unimodal response curve showing preference for warm summers and cold winters. There was a clear positive effect of high water tables, reflecting the species requirement to root in waterlogged soil. In addition, there was also relatively strong positive effects of surface water permanence and wetland habitat cover (Table 1, Figure 3).
Global projection of the ensemble model in current climatic conditions selected a 95% sensitivity suitability threshold of 0.43, producing the map in Figure 4. The native region in Asia appeared well delineated, based on comparison to the occurrence records and the Flora of China list of Chinese provinces for the species (http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_id=135329). Limiting factor analysis (Figure 6a) showed that the model defined the southern edge of the native range mainly based on high winter temperature (bio6). The northern range margin was mostly determined by low summer temperature (bio10) and the western range margin by a combination of low summer temperature and low water table.
Beyond the native region, there were suitable areas projected for the currently invaded area in New Zealand (Figure 4). Large areas of suitable climate were also projected for relatively uninvaded regions such as in USA and Canada, eastern Australia and temperate parts of South America and South Africa, which suggests a potential for further expansion should the species be introduced there more widely.
In the EPPO region, the model predicts a large suitable area spanning most lowland parts of the region in Europe (Figure 5). Existence of established populations distributed from Ireland and southwest France in the west to central Russia in the east supports this wide range of potential establishment in the EPPO region. Nevertheless, the model suggests that northern Britain, Scandinavia, northern Russia and high mountain areas remain mostly unsuitable (Figure 5), which in the model is primarily due to low summer temperatures (Figure 6b). In addition, the model suggests that low water table depths may prevent establishment in more arid parts of Iberia, North Africa and the Middle East and southern Russia to central Asia (Figure 5, 6b).
Predictions of the model for 2041-2070, under both the moderate SSP1-2.6 and more extreme SSP3-7.0 climate change scenarios (Figures 7 and 8) suggests a potential for northwards expansion of the suitable region, driven by warmer summers. There is also a modest reduction in suitability in the southern parts of the EPPO region, presumably driven by warmer temperatures. Note that these projections assume no change in the availability of wetland habitats or the water table.
These results are reflected in the suitability of different European Biogeographical Regions (Bundesamt fur Naturschutz (BfN), 2003) (Figure 9). Regions highly suitable for establishment in the current climate include the Pannonian, Continental, Black Sea, Anatolian, Steppic, Mediterranean, Boreal and Atlantic. By 2041-2070, overall modelled suitability increases in all of these except for declines in the Mediterranean and to a lesser extent in the Steppic and Pannonian (Figure 9). Suitability also notably increases in Alpine areas.

Table 2 provides a similar breakdown by EPPO member state, identifying many countries with substantial suitable areas, and projected suitability increases for northern countries and decreases for more arid countries.

Caveats and uncertainties

Modelling the potential distributions of range-expanding species is always difficult and uncertain. In this case study, uncertainty arises because:

- While the model appears to delimit the broad climatically suitable region for the species well, it may not adequately capture the importance of wetland habitats in determining where it actually invades within this region. This is because the global scale layers used as indicators of wetland habitats miss many small waterbodies, rivers and wet areas.

- Further, the connectivity between wetland areas may be key for spreading the species and realising its potential distribution, as is suggested by the invasion pattern along major river corridors, e.g. in Russia and Ukraine.

- Large parts of the native range yielded relatively few records (China) which may have impeded the model in characterising suitable locations.

- *Zizania latifolia* is also widely cultivated in its native range and so some of the native records used in modelling may not represent truly established populations.

- There was not time to test the sensitivity of the modelling to all methodological choices (e.g. sizes of accessible background, definition of unsuitable background, use of target group bias correction, choice of suitability threshold).

Table 1. Summary of the cross-validation predictive performance (AUC) and variable importances (%) of the fitted model algorithms and the ensemble of the best performing algorithms. Importance values are the averages from models fitted to five different background samples of the data, normalised to sum to 100%.

Algorithm	AUC	TSS	In the ensemble	Variable importance							
				Mean temperature of warmest quarter (bio10)	Minimum temperature of coldest month (bio6)	Percentage with high water table	Wetlands cover	Surface water permanence	Lake shore length	River length	Flow accumulation
MAXNET	0.9410	0.7768	yes	43.9	16.8	28.2	4.2	6.1	0.2	0.5	0.2
GAM	0.9356	0.7634	yes	50.5	9.5	31.7	2.0	4.5	0.2	1.2	0.4
MARS	0.9332	0.7460	yes	47.3	13.2	32.6	3.7	2.2	0.2	0.7	0.1
GBM	0.9386	0.7366	yes	39.0	14.7	37.3	7.8	0.6	0.0	0.5	0.0
GLM	0.9360	0.7360	yes	53.9	7.5	31.5	1.8	2.8	0.4	1.2	0.8
ANN	0.8838	0.7076	yes	30.3	19.6	32.7	2.3	11.8	0.7	0.9	1.6
RF	0.9228	0.5816	no	39.7	12.5	27.7	9.7	4.3	1.8	2.1	2.3
XGBOOST	0.9168	0.5480	no	36.8	15.5	25.9	8.8	5.2	1.5	3.7	2.7
Ensemble	0.9394	0.7836	-	46.9	11.9	34.5	2.6	3.3	0.1	0.4	0.3

Figure 3. Partial response plots from the individual algorithms (coloured lines) and ensemble model (thick black lines), ordered from most to least important. In each plot, other model variables are held at their median value in the training data. Variable codes: bio10 = mean temperature of warmest quarter (°C); high_water_table = % with high water table (log(x+1)); bio6 = mean minimum temperature of the coldest month (°C); water_permanence = mean number of months for which surface water is present (months); wetlands = % with wetland land cover (log(x+1)); river_length = length of large rivers (km, log(x+1)); flow_accumulation = accumulated upstream area (km2, log(x+1)); lake_shore length = perimeter length of large lakes (km, log(x+1)).

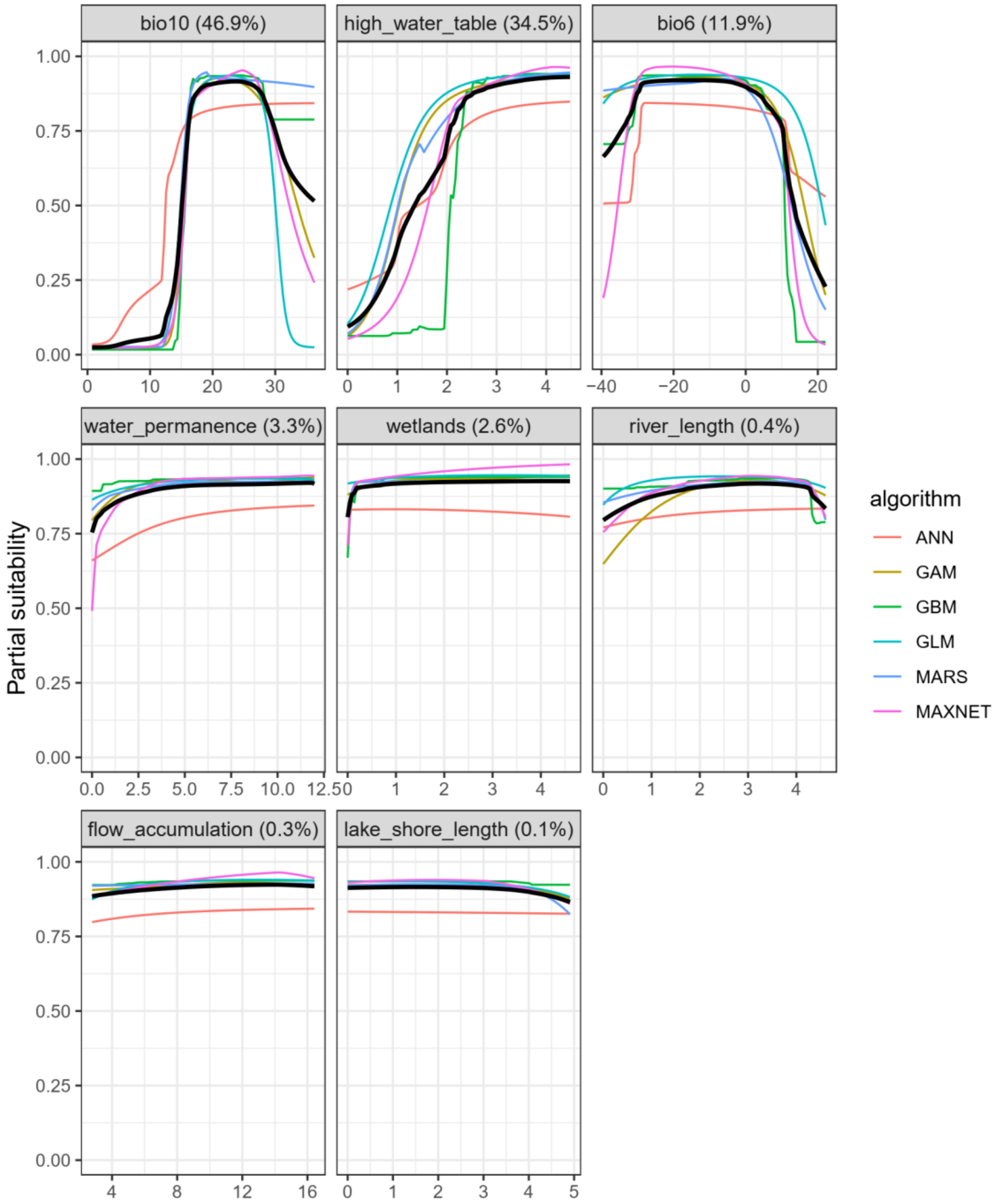


Figure 4. (a) Projected global suitability for *Zizania latifolia* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.25 x 0.25 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Red shading indicates suitability, according to the selected threshold. (b) Uncertainty in the suitability projections, expressed as the standard deviation of projections from different algorithms in the ensemble model.

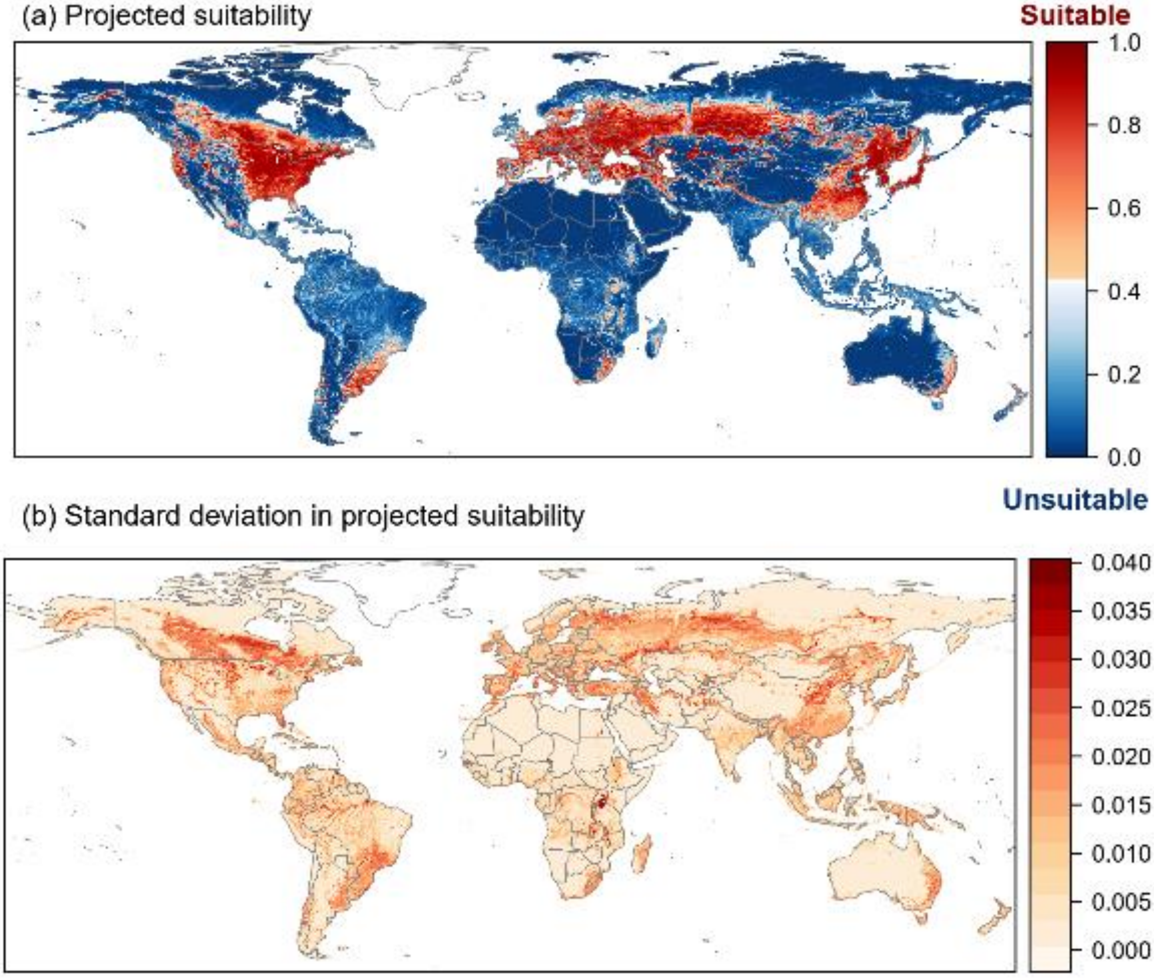


Figure 5. Projected current suitability for *Zizania latifolia* establishment in Europe and the Mediterranean region, modelled based on effects of temperature and wetland habitat availability.

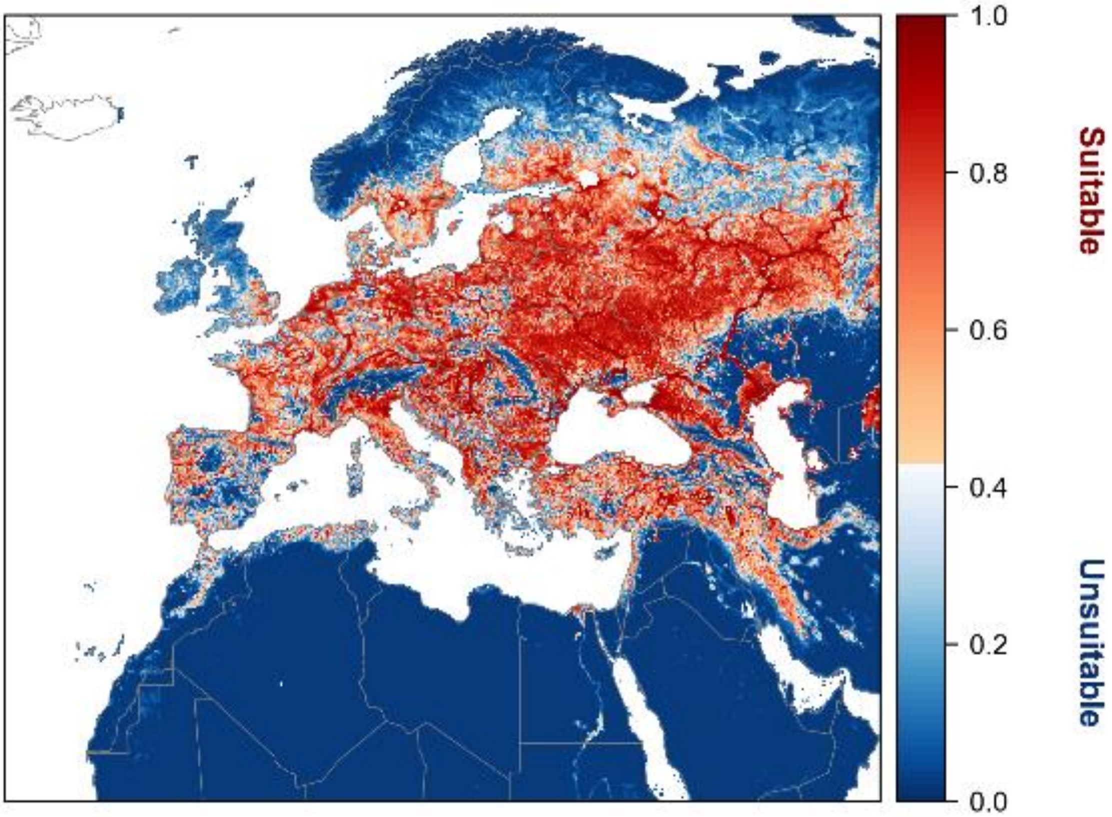
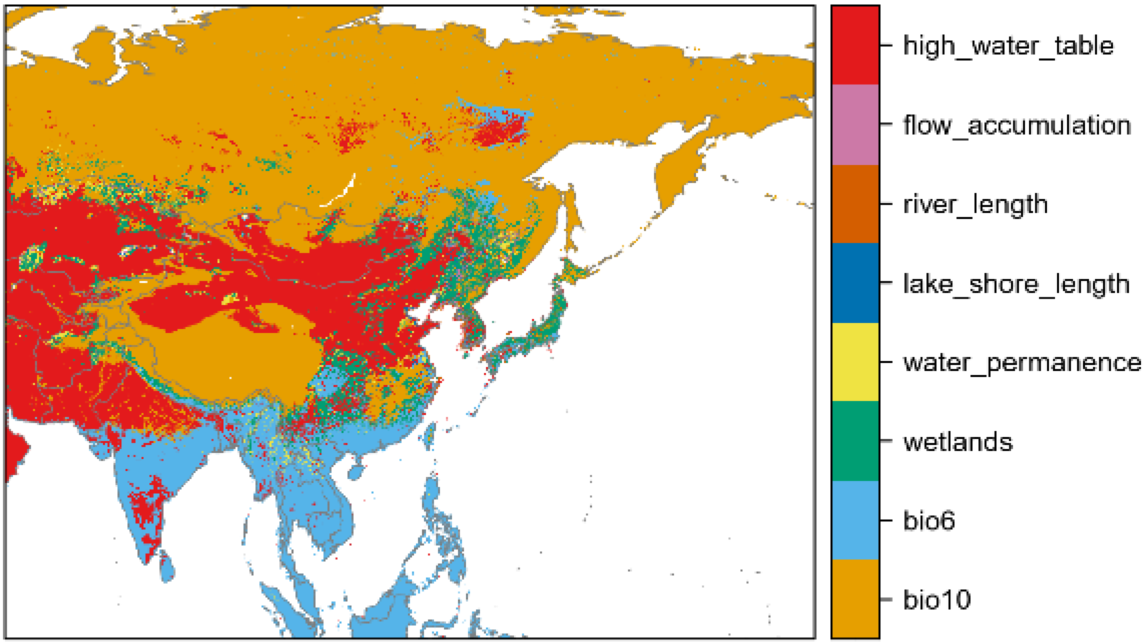


Figure 6. Limiting factor maps projected by the model for *Zizania latifolia* in (a) its native region and (b) Europe and the Mediterranean region, under the current climate and land use. Colours show the variable most strongly limiting suitability in the model, either because the values are too low or too high. Variable codes: high_water_table = % with high water table (log(x+1)); flow_accumulation = accumulated upstream area (km^2, log(x+1)); river_length = length of large rivers (km, log(x+1)); lake_shore length = perimeter length of large lakes (km, log(x+1)); water_permanence = mean number of months for which surface water is present (months); wetlands = % with wetland land cover (log(x+1)); bio6 = mean minimum temperature of the coldest month (°C); bio10 = mean temperature of warmest quarter (°C).

(a)



(b)

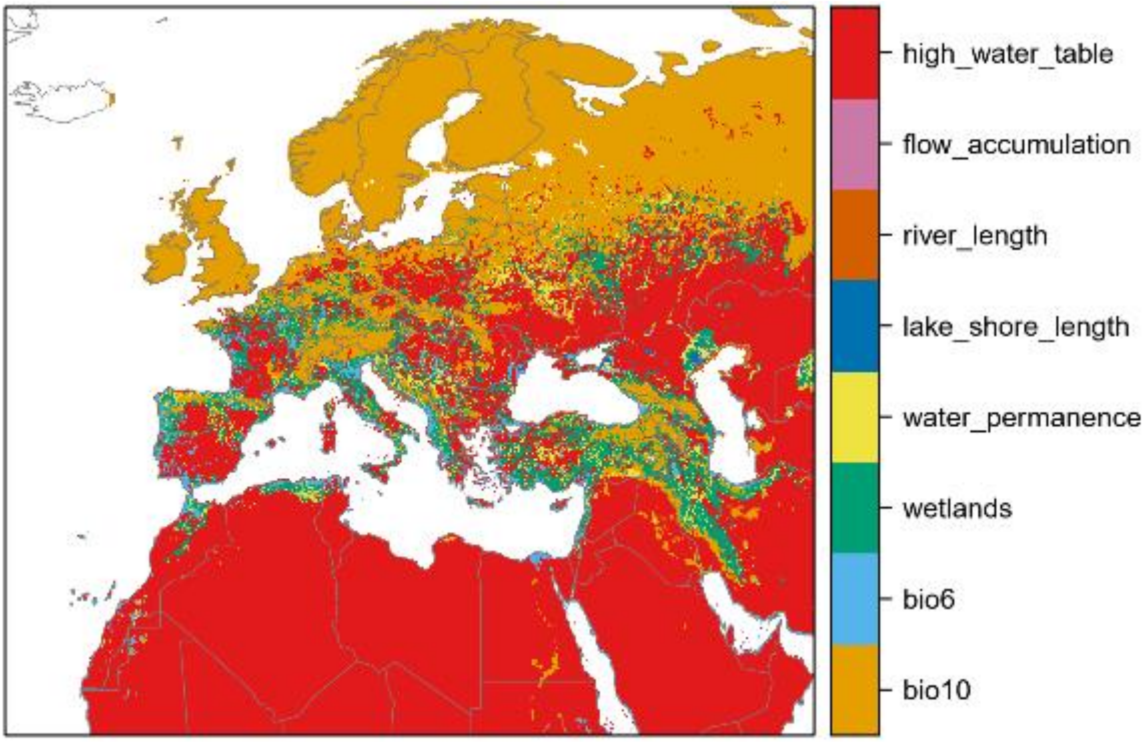


Figure 7. Projected suitability for *Zizania latifolia* establishment in Europe and the Mediterranean region for 2041-2070 under climate change scenario SSP1-2.6, based on changes in climate but not wetland availability.

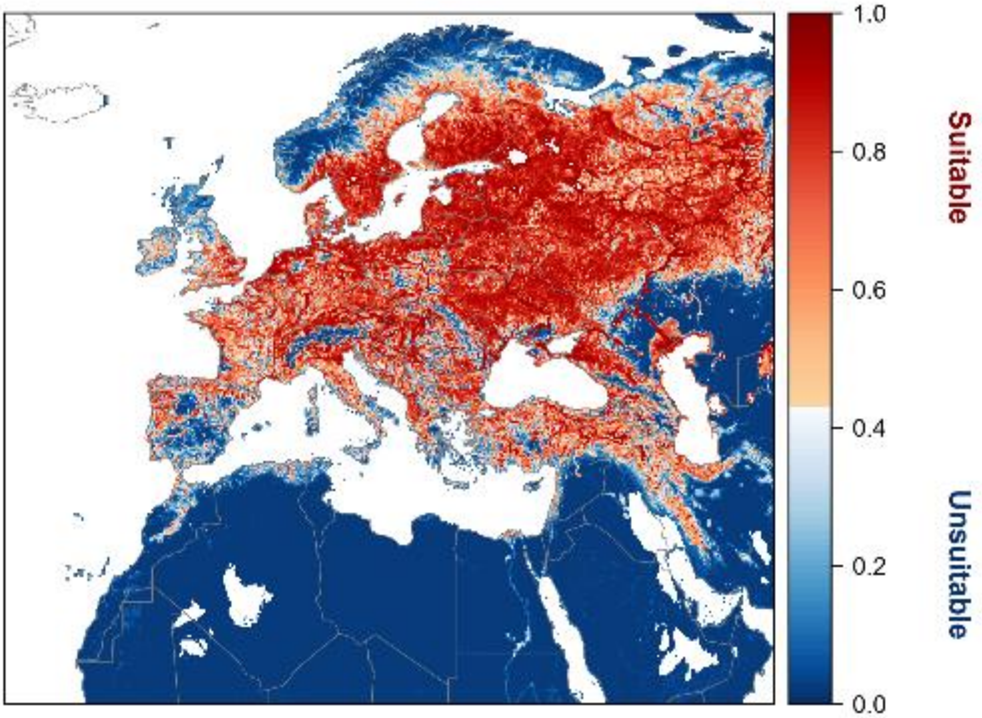


Figure 8. Projected suitability for *Zizania latifolia* establishment in Europe and the Mediterranean region for 2041-2070 under climate change scenario SSP3-7.0, based on changes in climate but not wetland availability.

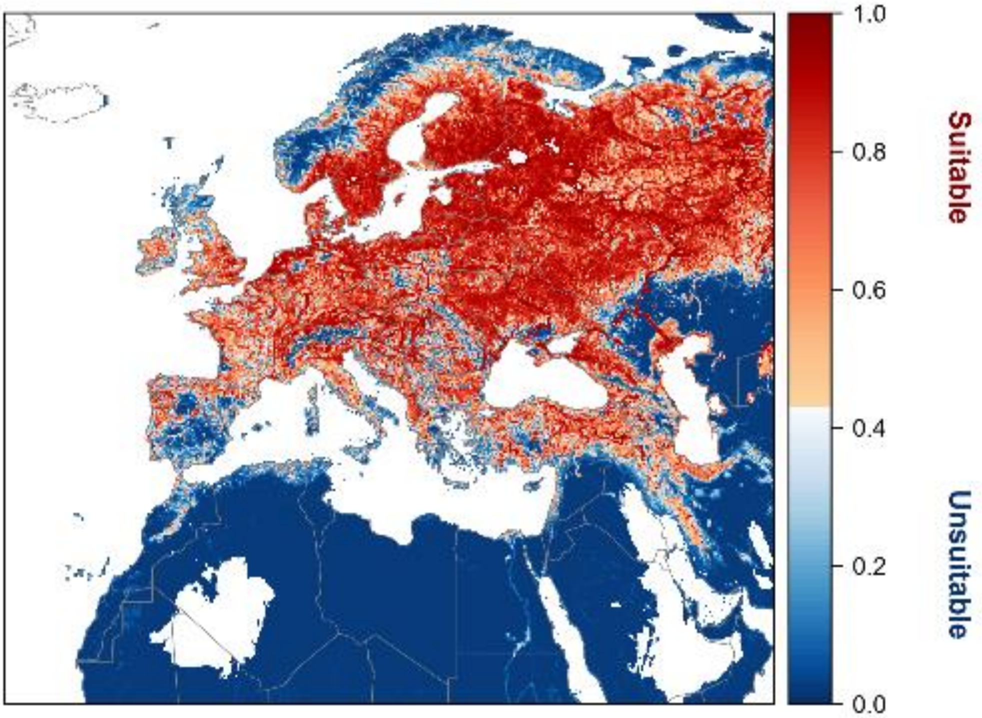
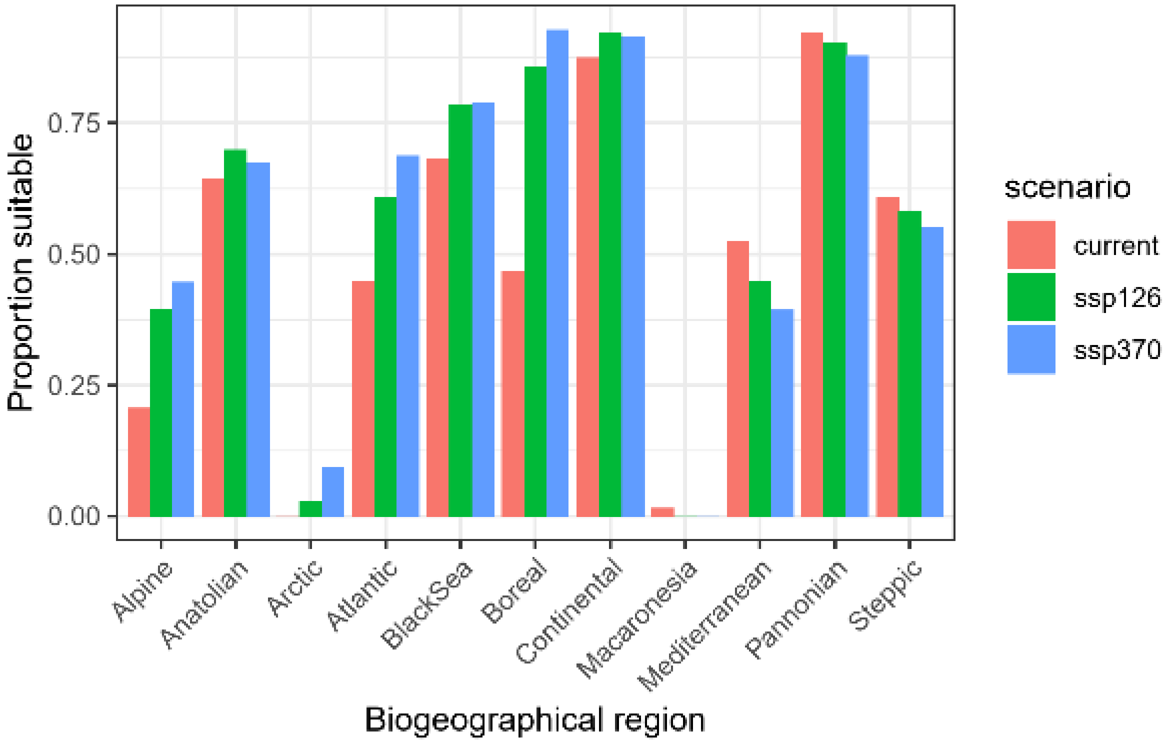


Figure 9. Variation in projected suitability among Biogeographical regions of Europe (Bundesamt fur Naturschutz (BfN), 2003). Bar plots show the proportion of grid cells in each region classified as suitable in the current climate (1981-2010) and projected climate for 2041-2070 under scenarios SSP1-2.6 and SSP3-7.0. The coverage of each region is shown in the map below.


Proportion suitable
0.00
0.25
0.50
0.75
Alpine
Anatolian
Arctic
Atlantic
BlackSea
Boreal
Continental
Macaronesia
Mediterranean
Pannonian
Steppic
Biogeographical region
scenario
current
ssp126
ssp370

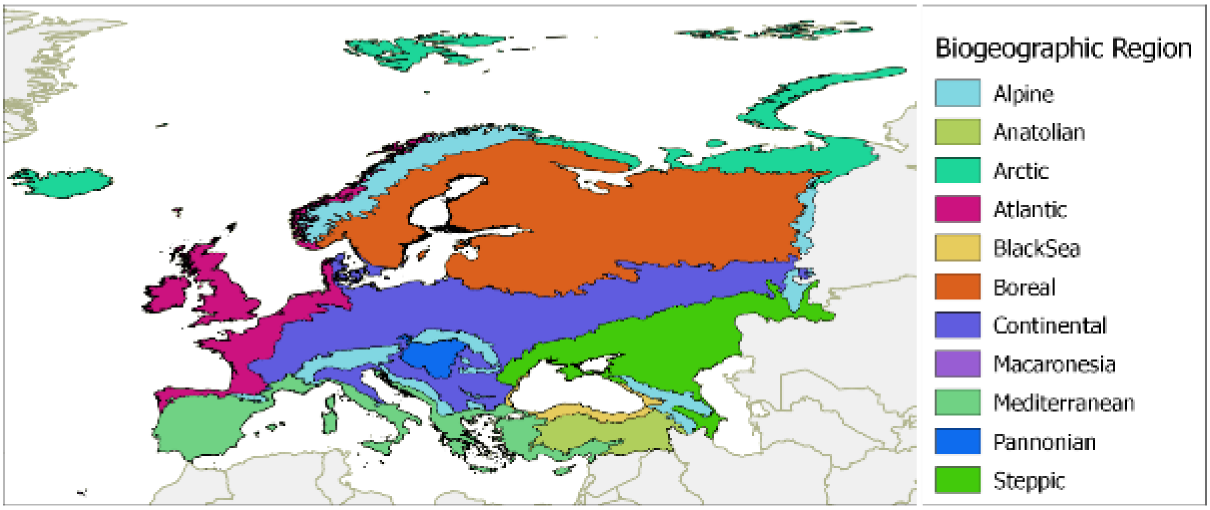

Biogeographic Region
Alpine
Anatolian
Arctic
Atlantic
BlackSea
Boreal
Continental
Macaronesia
Mediterranean
Pannonian
Steppic

Table 2. Projected suitability (in per cents, %) among EPPO member countries, sorted from high to low in the current climate. Values are the per cent (%) of grid cells in each country classified as suitable in the current climate (1981-2010) and projected climate for 2041-2070 under scenarios SSP1-2.6 and SSP3-7.0.

EPPO country (ISO3)	Current	SSP1-2.6	SSP3-7.0
MDA	100%	99%	99%
LTU	99%	100%	100%
LVA	97%	100%	100%
BLR	97%	98%	98%
ALB	96%	100%	99%
NLD	92%	97%	97%
EST	91%	99%	99%
HUN	91%	89%	86%
UKR	91%	90%	89%
HRV	88%	87%	83%
CZE	83%	97%	98%
BGR	81%	84%	83%
DEU	79%	93%	93%
SVN	77%	86%	87%
BEL	76%	97%	97%
POL	76%	84%	82%
FRA	71%	79%	79%
BIH	69%	83%	80%
TUR	68%	69%	65%
SRB	69%	70%	66%
MKD	66%	67%	57%
PRT	66%	60%	55%
SVK	66%	84%	85%
DNK	61%	92%	95%
ROU	64%	67%	65%
ITA	60%	57%	53%

EPPO country (ISO3)	Current	SSP1-2.6	SSP3-7.0
GEO	58%	71%	76%
MNE	56%	93%	96%
AZE	49%	43%	37%
GRC	48%	39%	31%
AUT	46%	65%	71%
LUX	45%	91%	93%
CHE	40%	55%	61%
ESP	33%	31%	28%
FIN	31%	77%	87%
SWE	28%	62%	75%
RUS	28%	47%	52%
KAZ	27%	28%	28%
GBR	18%	47%	61%
CYP	17%	6%	3%
ISR	15%	7%	5%
UZB	13%	11%	11%
KGZ	12%	18%	21%
NOR	6%	13%	19%
MAR	5%	3%	3%
TUN	5%	2%	1%
IRL	1%	30%	61%
DZA	1%	1%	0%
JOR	1%	0%	0%
JEY	0%	14%	43%
GGY	0%	0%	0%
MLT	0%	0%	0%

Appendix 2 Images of *Zizania latifolia*

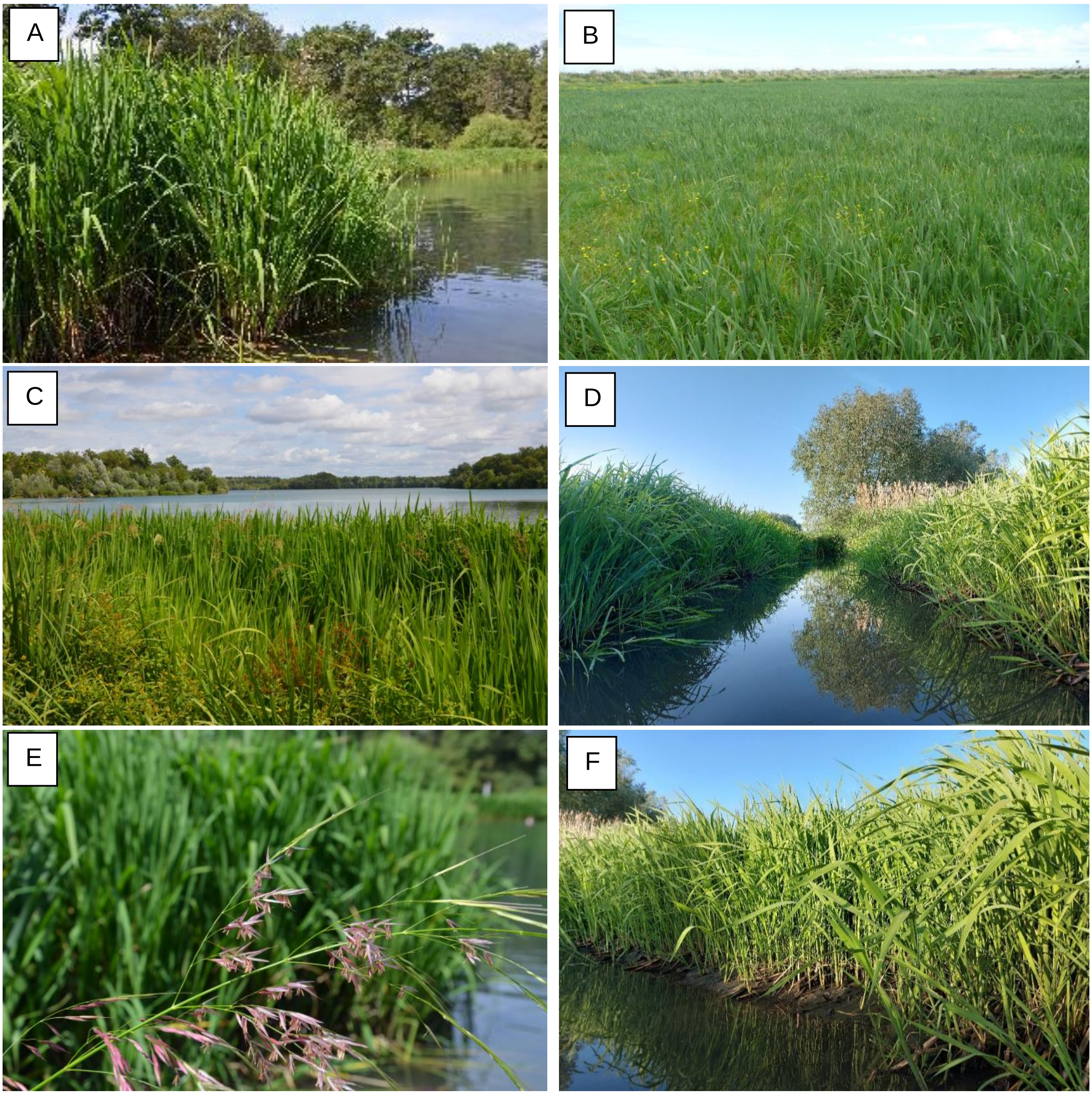


Figure 1: A: *Zizania latifolia* covers the shoreline of a small lake in Germany (Courtesy: Swen Follak), B: invading pasture land in New Zealand (Courtesy: Paul Champion), C: invading lake side in Germany (Courtesy: Swen Follak), D: river invasion in Belgium (Courtesy: Indra Jacobs), E: *Zizania latifolia* flowering in Germany (Courtesy: Swen Follak), F: river invasions in Belgium (Courtesy: Indra Jacobs).