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SCIENTIFIC OPINION

Scientific Opinion on the evaluation of the pest risk analysis on *Pomacea insularum*, the island apple snail, prepared by the Spanish Ministry of Environment and Rural and Marine Affairs [1]

EFSA Panel on Plant Health (PLH)[2, 3]

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ABSTRACT

The Panel considers the Spanish pest risk analysis (PRA) to be clear and to provide appropriate supporting evidence. However, (i) the environmental impact assessment is incomplete and (ii) the estimates for the potentially endangered area are too limited. The Panel points out that large areas of the European Union have climatic conditions, that are very similar to those of the areas of native distribution of *Pomacea* spp. snails, and suitable host plants are available. The Panel agrees with the Spanish PRA on the following points with regard to the risk assessment area: (i) the potential consequences of the organism for rice crops are major; (ii) the probability for establishment of the organism is very likely and (iii) the probability of spread is estimated as likely. The Panel disagrees with the Spanish PRA on the following points and considers (i) the effects on the environment to be massive under suitable environmental conditions in the PRA area and (ii) the probability of entry of the organism to be high. Regarding risk reduction options the Panel agrees with the Spanish PRA that no single risk reduction method is sufficient to halt the introduction and spread of *Pomacea* spp. snails in the PRA area. However, a legislative ban on import of *Pomacea* spp. is the only risk reduction option identified that can reduce the probability of entry. The many other risk reduction options listed will help to reduce the probability of spread within the PRA area. The Panel considers that the risk reduction options should target the *canaliculata* complex, as *Pomacea insularum* and *P. canaliculata*, as well as other species from the complex, are almost indistinguishable. This is of particular importance for risk reduction options addressing both breeding and trade of the organism.

KEY WORDS

apple snail, pest risk analysis, *Pomacea canaliculata*, *Pomacea insularum*, natural wetlands, rice fields

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SUMMARY

Following a request from the European Commission, the EFSA Panel on Plant Health has delivered a scientific opinion on the evaluation of the pest risk analysis on *Pomacea insularum*, the island apple snail, prepared by the Spanish Ministry of Environment and Rural and Marine Affairs.

For the evaluation of the Spanish PRA the Panel followed the EFSA guidance on evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA, 2009) and the guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a). The Panel has developed, for the purpose of this opinion, rating descriptors for the different components of the risk (entry, establishment, spread and potential consequences) and for the uncertainties. This is to provide transparent and clear justification when a rating different from that in the PRA is given. With regard to the risk management options, the Panel reviewed the document in terms of whether the options have been identified and evaluated for their effectiveness in reducing the risk.

The Panel considers the Spanish PRA to be clear and to provide appropriate supporting evidence.

However, unlike the Spanish PRA the Panel considers that it is scientifically more correct to include both species, *P. insularum* (d´Orbigny, 1835) and *P. canaliculata* (Lamarck, 1819), in the assessment. These two species are almost indistinguishable and have very similar impacts on invaded ecosystems.

Moreover the Panel highlights additional limitations of the Spanish PRA:

(i) The risks for habitats other than rice fields and natural wetlands, such as slow-flowing rivers and small water bodies, are not considered. These ecosystems may serve as reservoirs for the snails and as an infrastructure for spread. Understanding the movements of snail populations between rice fields and other aquatic ecosystems requires proper consideration of their population dynamics in natural environments.

(ii) The contribution of the spread of eggs as a natural means of dispersal, particularly through slow-flowing rivers and the network of artificial canals, is insufficiently discussed.

(iii) The environmental impact assessment is presented in very general terms, although detailed available information shows that environmental consequences in the risk assessment area could be massive under suitable environmental conditions. In particular, information is lacking on how snail population density could be the key variable in predicting the environmental consequences.

(iv) The estimates for the potentially endangered area are probably too limited with regard to the climatic suitability of and host plant availability in the PRA area.

Based on the evidence provided in the pest categorization stage of the Spanish PRA, as well as on additional information collected, the Panel confirms that a full pest risk assessment for the *canaliculata* complex is justified.

The Panel finds the information on the consequences to cultivated and managed plants, as described in the Spanish PRA, adequate but believes that it omits essential information about the environmental consequences, and the Panel considers it insufficient to state that infestation by *P. insularum* in wetland areas could be very detrimental to the conservation of such areas without providing any predictions or scenarios. Studies on the effects of *P. canaliculata* on natural wetland ecosystems show strong negative and fairly predictable impacts on biodiversity, ecosystem functioning and ecosystem services.

To evaluate the probability of establishment of the organism in the risk assessment area, the Panel performed a simple climate-matching analysis. The results indicate that climate will not prevent further establishment and spread of *Pomacea* spp. in the risk assessment area. However, considerable uncertainty remains regarding the northern and altitudinal climatic limits for the establishment of the species. Other abiotic or biotic factors may limit the potential area of establishment to a narrower extent than the area determined by the climatic conditions of the risk assessment area alone. After an evaluation of the published information about the wide host plant range of *Pomacea* spp., the Panel concludes that establishment and spread will not be limited by food resources in the PRA area. The Spanish PRA concludes that the endangered area corresponds with the rice-growing areas and natural wetlands along the EU's Mediterranean coast, but results from the climate-matching analysis conducted by the Panel indicate that climate is not a limiting factor for spread and further establishment in the PRA area. Large areas of Europe have climatic conditions very similar to those in the areas of native distribution of *Pomacea* spp. snails. Furthermore, the Panel concludes that suitable host plants are available within these zones. As the snails are currently intentionally imported into the PRA area, they are associated with the pathways mentioned in the Spanish PRA, and survival before, during and after transport is highly probable owing to the provision of suitable conditions during intentional transport. The Spanish PRA describes several ways in which the snails are transferred to a suitable host (intentional release, escape from outdoor aquaria and water gardens, and escape from outdoor aquaria rearing snails), but the Panel would like to add that specific characteristics of the snail (survival periods of several months during dry periods, survival on many different host plants) may enhance the probability of its transfer.

The Panel agrees with the Spanish PRA that the potential consequences of the organism for cultivated and managed plants are major with low uncertainty, but the Panel considers the effects on the environment to be massive instead of major with low uncertainty because of the very serious environmental effects observed in areas invaded previously. The Panel agrees with the Spanish PRA that the probability of establishment of the organism in the risk assessment area is very likely with low uncertainty. However, owing to the lack of biological data on the organism, the Panel considers the uncertainty high regarding the northernmost limit of distribution in the PRA area. The Panel also agrees with the rating for spread given in the Spanish PRA, which is "likely". The Panel agrees with the conclusion in the PRA that the import of *P. insularum* for the pet/aquarium trade or for weed control is more relevant than the other pathways listed. However, the Panel considers the rating for the probability of entry of the organism into the Spanish PRA to be too low. The Panel ranks the probability of entry as high, rather than moderately likely, as in the Spanish PRA, based on the fact that the organism can currently be freely imported and released in the PRA area.

The Panel agrees with the final conclusion reached in the Spanish PRA regarding the introduction and spread of the organism in the PRA: likely with low levels of uncertainty.

Risk reduction options are well reviewed and described in the Spanish PRA. As pointed out in the PRA, no single risk reduction method is sufficient to halt the introduction and spread of *Pomacea* spp. snails in the PRA area, but legislation is intended to reduce the probability of entry, and the many risk reductions options listed will help to reduce the probability of spread within the PRA area. If legislation is considered, the Panel suggests that it should target the entire *canaliculata* complex, and not only *P. insularum*, as misidentification of species is likely and further import of *P. insularum* and *P. canaliculata* cannot be excluded. Likewise, if a ban on both breeding and trade of the organism is considered, the Panel suggests that such a ban should include the whole *canaliculata* complex. The Panel found that the risk reduction options listed in the Spanish PRA cover those that are used in integrated pest management of *Pomacea* spp. elsewhere in the world. The Panel identified some weak points that need further attention: (i) the effects on non-target organisms as a result of the mentioned risk reduction options are only superficially touched upon and need to be further developed; (ii) more attention should be given to early detection and control of the snail's eggs to prevent further dispersal; and (iii) the issue of provision of information deserves more attention as knowledge of the snail problem at the level of stakeholders, environmental management professionals and the public is crucial to allow early detection, to prevent further spread and to generate rapid reports of its presence to the managing authorities.

The Panel recognises that the evaluation of the impact of *Pomacea* spp. on animal and human health falls outside its remit; however, it wishes to note that, owing to the seriousness of this potential impact, it should be assessed by the competent authorities.

As the Panel found essential information about the environmental consequences in the Spanish PRA lacking and available studies on the effects of *Pomacea* spp. on natural wetland ecosystems show strong negative and fairly predictable impacts on biodiversity, ecosystem functioning and ecosystem services, the Panel recommends that an appropriate environmental risk assessment is conducted according to the recently developed EFA PLH Guidance Document (EFSA Panel on Plant Health (PLH), 2011a: Guidance on the environmental risk assessment of plant pests) to give a better estimate of the potential effects of apple snails on biodiversity and ecosystem processes in the PRA area.

Further, the Panel recommends a detailed climatic study, which should not only give a clearer idea of the extent (particularly the northern limits) of the wetlands that are vulnerable but should also help to clarify the number of possible generations of *Pomacea* spp., their population density and the level of economic and environmental impacts that can be expected.

Because of the grave concern for rice production and wetland ecology in the EU, the Panel recommends to target research for the study of the biology of *Pomacea* spp. snails in the Ebro Delta to reduce important uncertainties highlighted in the PRA.

Finally, the Panel recommends exploring and testing new control techniques to improve those already used, because no single currently used risk reduction option has the potential to eradicate the snail from the area of infestation at present. Moreover, many of the currently used risk reduction options have negative effects on non-target organisms and the associated crop and natural wetland environment.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

The current European Union plant health regime is established by Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community (OJ L 169, 10.7.2000, *p*.1).

The Directive lays down, amongst others, the technical phytosanitary provisions to be met by plants and plant products and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union, the list of harmful organisms whose introduction into or spread within the Union is prohibited and the control measures to be carried out at the outer border of the Union on arrival of plants and plant products.

The island apple snail *Pomacea insularum* (d'Orbigny, 1835) is one of the largest freshwater snails. *P. insularum*, as well as other species belonging to the same genus, shows outside of its native distribution range (South America) a highly invasive behaviour, since it is polyphagous (a generalist) and it has a high reproductive rate. Apple snails are considered to be serious pests of rice and they can also have devastating effects on natural wetlands.

P. insularum and related species are presently not regulated in the EU as organisms harmful to plants or plant products under Council Directive 2000/29/EC. Consequently they can be freely imported. Moreover, the breeding and sale as well as the possession of these snails, which seem to be popular among aquarists, are not forbidden.

In 2009 Spain reported the first outbreak ever in the EU of *P. insularum*, in the Ebro Delta. The following year the snail was also found in rice fields, causing in some cases substantial damage. A pest risk analysis (PRA) for *P. insularum* for the EU territory was prepared by the Spanish Ministry of Environment, and Rural and Marine Affairs. This PRA rates the probability of introduction and spread of *P. insularum* as likely and it concludes that the potential economic and environmental impact in the endangered area upon its establishment would be major.

On 22 July[4] and 19 August 2011[5], Spain took national temporary emergency measures to eradicate and, if not possible, to contain the spread of *P. insularum* and *P.caniculata* and to prevent new introductions as well as the spread out aquaria/contained facilities. The following is now prohibited on the Spanish territory: detention, transport, movement, trade of living (at any stage of development) or dead specimens of the two snail species, including the prohibition of internal and external trade.

In order to decide on the follow-up to the Spanish temporary emergency measures against *P. insularum and P.caniculata* the Commission has decided to seek a scientific opinion from EFSA.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is requested, pursuant to Article 29(1) and Article 22(5) of Regulation (EC) No 178/2002, to provide a scientific opinion on the pest risk analysis on *Pomacea insularum*, the island apple snail, for the EU territory prepared by the Spanish Ministry of Environment, and Rural and Marine Affairs.

In particular, EFSA is requested to determine whether this PRA identifies all relevant pathways for the introduction of the pest as well as whether it identifies and characterises all appropriate risk management options. EFSA is also requested to assess whether the PRA sufficiently addresses the risk posed by *Pomacea* spp., other than *P. insularum*.

(4) Orden ARM/2090/2011, de 22 de julio, por la que se establecen medidas provisionales de protección frente al caracol manzana «*Pomacea insularum* y *Pomacea canaliculata*», BOLETÍN OFICIAL DEL ESTADO, Núm. 179 Miércoles 27 de julio de 2011 Sec. I. Pág. 84263.

(5) Orden ARM/2294/2011, de 19 de agosto, por la que se modifica la Orden ARM/2090/2011, de 22 de julio, por la que se establecen medidas provisionales de protección frente al caracol manzana «*pomacea insularum*» y «*pomacea canaliculata*», BOLETÍN OFICIAL DEL ESTADO, Núm. 202 Martes 23 de agosto de 2011 Sec. I. Pág. 93345.

ASSESSMENT

1. Introduction

This document presents the scientific opinion of the Panel on Plant Health (hereinafter referred at as the Panel) on the pest risk analysis on *Pomacea insularum*, the island apple snail, prepared by the Spanish Ministry of Environment and Rural and Marine Affairs (hereinafter referred at as the Spanish PRA or PRA). The Panel is requested to evaluate this document, and in particular to determine whether all relevant pathways for the introduction of the pest have been identified and if all appropriate risk reduction options are identified and characterised in the document under scrutiny. The Panel is also requested to assess whether the document sufficiently addresses the risk posed by *Pomacea* spp. other than *P. insularum.*

1.1. Scope of the opinion

The Panel defines the scope of the evaluation as follows.

(i) The pest risk assessment area is the EU territory restricted to the area of application of Council Directive 2000/29/EC, which is the EU territory excluding French overseas departments, Canary Islands and Ceuta and Melilla.

(ii) Owing to the fact that *Pomacea insularum* (d'Orbigny, 1835) and *Pomacea canaliculata* (Lamarck, 1819) are two almost indistinguishable species within the *canaliculata* complex, the Panel analyses address both species. The common name "apple snail" is used in this opinion to designate the two species of freshwater aquatic snails, *P. insularum* and *P. canaliculata*.

(iii) The evaluation of the areas of concern is focused on rice fields and natural wetlands in the EU territory. The Panel considers in its evaluation the potential consequences the two species, *P. insularum* and *P. canaliculata*, may cause in rice crops, and a preliminary environmental risk assessment is presented.

(iv) The concern that *Pomacea* spp. snails are a vector of parasites that may cause diseases in humans as well as animals is mentioned but not assessed in this opinion.

1.2. Methodology for evaluation

The Panel follows the EFSA guidance on evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA, 2009) and the guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a).

The Panel has developed, specifically for the purpose of this opinion, rating descriptors to provide transparent and clear justification when a rating is given. The detailed description of these ratings is presented in Appendix A, for the different components of the risk assessment (entry, establishment, spread and potential consequences) and for the uncertainties. The Spanish PRA did the ratings without using any rating guidance. Apart from other factors explained below, this resulted in two cases in different ratings from the Panel and the Spanish PRA.

With regard to the risk management options the Panel reviewed the document in terms of whether the options have been identified and evaluated for their effectiveness in reducing the risk.

The evidence considered by the Panel in its evaluation is obtained from the literature references provided in the document under scrutiny, specific literature searches performed by the Panel and literature obtained using expert knowledge in the field.

For the purpose of evaluating the probability of establishment of the organisms in the risk assessment area, and owing to the limited availability of data on the biological and climate response parameters of the organism, the Panel performed a simple climate-matching analysis. Using CLIMEX (Sutherst and Maywald, 1985) the climate of the geographical regions where the species are known to occur can be compared with the climate of other areas of the world. The Match Climates function compares the climates of different locations to provide a rough assessment of the pest establishment potential (Sutherst and Maywald, 2001). The climates similarity is expressed by the "composite match index" (CMI), which is the product of six component indices indicating similarity in the climate variables maximum temperature, minimum temperature, total rainfall, relative humidity, rainfall pattern and soil moisture (Appendix B). Each of these component indices can range between 0 and 1, with a value of 1 indicating an exact match with the "Home" location. All indices can be weighted individually (using match index weights) to emphasise the more important variables. The default weight setting is 1.0 for each index, except the indices for relative humidity and soil moisture, which have a default weighting of zero. In this analysis the default weighting was used. When data from locations in different hemispheres are compared, CLIMEX automatically displaces data from the southern hemisphere by 6 months. Results from the climate matching can be used to indicate potential new areas in which the climate would allow establishment of the species.

Beyond the simple climate matching based on the 30-year 1961–90 climate average, the Panel also ran the simulations with +1 °C and +2 °C scenarios to include the global warming perspective.

Further delineation of the endangered area was based on investigations on the availability of wetlands and rice cropping fields having climatic similarity with areas within the native distribution of the species.

2. Evaluation of documents submitted to EFSA

2.1. General review of the document presented

The document under scrutiny, titled "Pest Risk Analysis on the introduction of *Pomacea insularum* (d'Orbigny, 1835) into the EU", was performed according to the Guidelines of the European and Mediterranean Plant Protection Organization (EPPO) Pest Risk Analysis [EPPO standard PM 5/3(4)] (EPPO, 2009).

In general, the PRA is clear and provides appropriate evidence to support the statements. However, regarding the snail species that is the subject of this opinion, the Panel considers that it would be scientifically more reliable to refer to the *canaliculata* complex, or at least to both *P. insularum* and *P. canaliculata*, as these two species are hard to separate and have very similar impacts. Also, it is not sufficiently proven that only *P. insularum* is present in the Ebro Delta.

In addition, the Panel identified further issues that are addressed in this opinion.

- Regarding habitats, as well as rice fields and wetlands, other water bodies should be considered, in particular slow-flowing rivers and small water bodies.
- The spread of eggs is not discussed in sufficient detail. In particular, the fact that the eggs can attach to boats is mentioned only briefly without elaborating on the consequences for spread.
- The environmental impact assessment, presented in the "Assessment of economic consequences" is insufficiently addressed. The Panel observes that much more detailed information is available, which shows that the environmental consequences in the risk assessment area could be massive depending on the environmental conditions.
- Limited information is provided on the biology of *Pomacea* spp., particularly the feeding biology of the pests.

- The estimated extent of the endangered area is probably too limited with regard to the climatic suitability of this area.

Some of the references in the PRA are either missing from the reference list or cited incorrectly. For example, Cowie et al. (2004) (page 8), and Oya and Miyahara (1987) (page 10) are cited in the PRA but not listed in the reference list; on page 9, Rawlings et al. (2007) is cited regarding occurrence of egg clutches on different structures, but this information cannot be found in that article; on page 18, Wada (2006) is cited, whereas the information on crop rotations is found in Wada (2004). The thesis of Ramakrishnan (2007) is cited in the Spanish PRA but not mentioned in the list of references. However, this does not influence the statements and conclusions presented in the PRA.

2.2. Biology of the pest: *Pomacea* spp.

The pest of concern and the issues concerning the taxonomy and systematics in *Pomacea* spp. are adequately described in the PRA.

The Panel notes that *P. insularum* and *P. canaliculata* are two very similar species with large, round shells (commonly up to 80 mm shell height) that may be greenish, golden, black or brownish in colour, with or without dark spiral bands (see Figure 1). The large variation in appearance within both species indicates that they cannot be distinguished from each other based on shell colour or shell morphology alone.

Figure 1: Adult golden apple snail (courtesy of N. Carlsson).

Also, the Panel notes that the apple snails possess several important biological features that render them highly invasive.

All *Pomacea* spp. are native to South or Central America and the Caribbean, except for *P. paludosa*, which extends its natural distribution into the south-east of the USA (Cowie, 2002). Like other Ampullariidae, *Pomacea* spp. snails are regarded as moderately amphibious. They have both gills and lungs and can respire both aquatically and aerially (Seuffert and Martín, 2010), allowing them to survive in poorly oxygenated waters. Another important physical feature that aids survival in ephemeral habitats, such as rice fields and wetlands, is the operculum or "shell door" that enables the snail to retire into its shell and firmly close it. This discourages predators and allows the snail to hibernate buried in the mud within the protective moisture of its shell for periods of several months when their habitat dries out (Oya et al., 1987).

Fecundity in both *P. insularum* and *P. canaliculata* is extremely high. In favourable conditions females are able to deposit a number of egg batches, each of several hundred eggs, every week, on any emergent object. Egg masses are pink in colour (see Figure 2) and quite conspicuous and may be rapidly dispersed by human activities if they are attached to boat hulls or other objects that are moved around. Both snail species have separate sexes (Halwart, 1994), and the females are able to store sperm after copulation for 140 days (in *P. canaliculata*) which can be used to fertilise series of egg batches in the absence of a male (Estebenet and Cazzaniga, 1993; Estebenet and Pizani, 1999).

Figure 2: Deposited eggs of *Pomacea* spp. on a boat hull in Lao PDR (courtesy of N. Carlsson).

Both species crawl around actively in search of their preferred diet, which consists mainly of aquatic plants, but periphyton (algae, small crustaceans and other sessile organisms that are attached to rocks, submerged wood and the sediment), detritus and fish and snail eggs are also readily consumed by these omnivorous snails. Their broad diet suggests that they are able to remain at relatively high densities even after they have depleted the available aquatic plants, as they can be sustained by less preferred food sources (Carlsson et al., 2004).

All aspects of their biology are affected by temperature. At high mean temperatures, as in the tropics, all feeding, growth and reproduction rates are high and the average lifespan is approximately 1 year. At lower average temperatures, as in the subtropics or in the warmer temperate zones, feeding and reproduction become seasonal and periods of inactivity are induced. The lifespan of the snails in these climates is, however, much longer and may be up to 3–4 years (Estebenet and Martín, 2002; Seuffert et al., 2010).

For management reasons, the separation between the species may not be very important, as their voracious appetite for aquatic plants (Morrison and Hay, 2011) and, therefore, potential effects on invaded crops and ecosystems are likely to be similar.

2.3. Pest categorization

2.3.1. Pest identity

The taxonomy of *P. insularum* is well described in the Spanish PRA. *P. insularum* as such is a single taxonomic entity that can be distinguished (though with difficulty) from other entities of the same rank. However, DNA analysis of nine specimens, as referred to in the Spanish PRA, is not sufficient to determine whether only *P. insularum* is present in the risk assessment area. A mixture of species from the *Canaliculata* complex is often found in the aquarium trade, and the Panel cannot rule out the possibility that species other than *P. insularum* are present in the invaded area (see also section 2.2).

2.3.2. Presence or absence of the pest in the pest risk assessment area

The pest (and possibly related species; see sections 2.1 and 2.3.1) has established in the Ebro Delta in Spain. As the organism is freely available in the aquarium trade, it cannot be excluded that the organism and related species are also already established in other areas in the pest risk assessment area. An initial literature search (including the EPPO reporting service from 1967 to October 2011, the EPPO Plant Quarantine Data Retrieval system (PQR), and the CABI Crop Protection Compendium (CPC)) did not reveal any evidence that *P. insularum* or *P. canaliculata* have established in other parts of the PRA area.

2.3.3. Regulatory status

The following measures against the snails are listed in the Spanish PRA to control and stop its entry, establishment and spread. These measures have been assumed and implemented by Spanish administrations and rice farmers as the organism was not regulated in the EU at the time the Spanish PRA was prepared:

- monitoring of the snail;
- early drainage of paddy fields on the left part of the Delta to establish unfavourable conditions for the snail for a period of at least 6 months;
- collection and destruction of adults and subadult specimens and elimination of eggs in the left hemi Delta;
- burning of rice stubble to kill the snails in highly infested fields;
- chemical treatment on paddy fields (metaldehide 5 % and etofenprox 30 %);
- trials on chemical substances to control the snail in rice fields;
- application of quicklime to the irrigation and drainage network of the Delta;
- installation of barrier traps throughout the network of irrigation channels to stop the snail's invasion dynamics;
- installation of floating barriers in the river, at the two points of invasion of the river habitat from the flood plain of the left side of the Delta;
- placement of fixed barriers adjacent to the riverbank to prevent the spread of the snail by creeping counter-currents;
- modifications of the water inlets and outlets of the rice fields to protect rice plots from snail infestation or reinfestation;
- mandatory proper cleaning of harvesters and agricultural machinery under official surveillance before crossing the river to avoid the spread of the pest to the other side of the Ebro Delta;
- performance of a PRA on the introduction of *P. insularum* into the EU.

In 2010 the organism invaded rice fields in the Ebro Delta in Spain. Before then it was not known to occur in the EU territory and was not regulated in the EU. Therefore, the Spanish Ministry for the Environment and Rural and Marine Affairs established provisional protective measures against the apple snails *P. insularum* and *P. canaliculata* to prevent their introduction from third countries and their spread to other zones (BOE, 2011a;b). Details on the Spanish emergency measures can be found in section 2.11 (Evaluation of the risk reduction options).

2.3.4. Potential for establishment and spread

The Spanish PRA provides evidence, supported by references, that there is a potential for the organism to establish and spread in the PRA area. The presence of rice as an important host plant is indicated by listing the main rice-cultivating countries in the EU. Information is also given that, in addition to rice fields, other suitable habitats (wetlands) are widely available in the PRA area. The ecoclimatic conditions for the pest to establish in the PRA area are discussed; stating that establishment of the organism would also be possible in other rice-growing areas and wetlands in the Mediterranean region. In addition, it should be noted that the pest has already established in the PRA area.

2.3.5. Potential for consequences

The PRA lists effects of both *P. insularum* and *P. canaliculata*. Given that the Panel also considers these two species together in this opinion because of their similarities, it is acceptable that the PRA describes the effects for both species. The PRA gives a short overview of the impacts on rice cultivation in invaded areas (Asia, USA, Europe), and summarises the feeding behaviour of *P. insularum*. The PRA also mentions that the Mediterranean wetland ecosystems and their plants are at risk, but does not go into detail. Evidence for the effects on rice and natural wetlands is supported by references.

2.3.6. Conclusion of the pest categorization stage

Based on the evidence given in the categorization stage of the Spanish PRA, as well as on information collected by the Panel, the Panel confirms the conclusion that a full pest risk assessment for the pest is justified:

- The identity of the pest is described (although *P. canaliculata* or the *canaliculata* complex should be included in the PRA).
- The presence of the pest in the risk assessment area is described,
- The regulatory status is outlined.
- A broad assessment of the pest's potential for establishment and spread, including confirmation of the availability of hosts and habitats, is given.
- The potential for consequences in the risk assessment area is evaluated and confirmed.

2.4. Evaluation of potential consequences

The PRA concludes that *P. insularum* is a major pest of rice, which is grown at several other locations in the PRA area. According to the PRA, rice is the only aquatic crop plant in the PRA area and therefore the only crop plant at risk from *Pomacea* spp., even though natural wetland plants are likely to be strongly negatively affected by *Pomacea* spp.

In general, the Panel agrees with the conclusions considering the effects on rice crops, but considers that many crops grown in fields that are temporarily flooded and adjacent to *Pomacea*-infested rice fields or wetlands may be attacked as well, considering the broad diet of the pest.

2.4.1. Consequences to cultivated and managed plants

In the PRA, *P. insularum* is described as a serious pest of rice. Although damage to rice in the Ebro Delta has been limited until now, the snails could in a period of 3–4 years cause catastrophic damage according to the Spanish PRA. The PRA also states that at some plots in the Ebro Delta the attack of snails has been extremely virulent. The Panel agrees with the Spanish PRA that the threat is real and that potential consequences for the crop are major. The Panel also considers that further detailed studies should be performed to properly assess the potential consequences the snails could cause on rice production.

Rice is, to the Panel's knowledge, the main cultivated plant at risk from *Pomacea* spp. in the PRA area. The PRA sufficiently reviews the diet of *P. insularum* and *P. canaliculata*. The PRA reports feeding of *P. insularum*/*P. canaliculata* on 33 different plant species of six different plant genera, most of which are wild plant species. Some are found both in the wild and in cultivation. The Spanish PRA further reports that many of these species and genera can be found in the PRA area. After evaluating the Spanish PRA and the literature, the Panel is of the opinion that, besides rice, few cultivated plants are at high risk in the PRA area. However, these polyphagous snails are likely to consume many different crops in fields that are temporarily flooded and adjacent to invaded rice fields or wetlands, and this is recognised in the PRA.

Unfortunately, there is very little information on the feeding behaviour of *Pomacea* spp. in the PRA. Such information is very important in the analysis of potential effects from the snail and in the development of control strategies. The following information is missing from the Spanish PRA:

- Temperature has a striking effect on most activities in *Pomacea* species and feeding rates sharply increase with temperature (Estebenet and Martín, 2002).
- The snails stop feeding when the water level drops below the height of the shell (Halwart, 1994).
- Smaller snails have a much higher foraging capacity than larger snails (Carlsson and Brönmark, 2006).
- Although the PRA stresses that both *P. insularum* and *P. canaliculata* are primarily macrophytophagous and extremely polyphagous, it is important to expand on this, as their broad diet suggests that they may survive at relatively high densities on less preferred food even after most aquatic plants have been consumed.
- Any eradication efforts must focus on both rice fields and the adjacent wetlands, canals and rivers, as these systems are interconnected, especially during flooding.

2.4.2. Environmental consequences

The PRA acknowledges that wetlands harbour great biodiversity and that one of the greatest threats to wetland communities is the spread of invasive species (Lacoul and Freedman, 2006; Zedler and Kercher, 2005). In the PRA, the environmental damage caused by the pest within its current distribution outside the PRA area is reviewed. Both *P. canaliculata* and *P. insularum* have devastated wetlands in South-East Asia by consuming large quantities of many different aquatic plant species (Carlsson, 2006; Morrison and Hay, 2011). According to the PRA, several important conclusions can be formulated about wetlands and the environmental consequences of apple snails.

- Aquatic plants maintain biodiversity by providing varied and structurally complex habitats for macro-invertebrates, zooplankton and juvenile fish (Dielh, 1988, 1992; Persson and Crowder, 1998). Aquatic plants serve as food or substrate for food (periphyton) consumed by macro-invertebrates (James et al., 2000), fish and waterfowl (Lodge et al., 1998).
- Macrophytes play a key role in nutrient cycling and are important natural "biofilters" that may ensure minimum water quality (Carlsson, 2006). Carlsson et al. (2004) experimentally demonstrated that invasion of Asian wetlands by *P. canaliculata* can dramatically reduce species richness and the abundance of macrophytes, causing greater nutrient concentrations and increased phytoplankton biomass. Similar effects can be expected from the invasion of *P. insularum*, given the already presented similarities between this species and *P. canaliculata*.

- Chemical control of the snails in irrigation channels or rice fields implies that part of the employed chemicals or their residues would also reach the surrounding natural wetlands. The use of synthetic pesticides for apple snail control usually pollutes the aerial, soil and aquatic environments and poses hazards to those who apply them (farm workers) and non-target organisms such as fish, frogs and beneficial arthropods (Ranamukhaarachchi and Wickramasinghe, 2006). Significant and long-lasting downstream effects of those pesticides on marine ecosystems can also occur (Ranamukhaarachchi and Wickramasinghe, 2006).

- Prolonged periods of keeping rice fields dry reduce the value of this managed ecosystem for many wild species of plants and animals (Forés and Comin, 1992).

The PRA summarises the predicted environmental damage in the PRA area as follows.

- Wetlands and rice fields often are adjacent in the PRA area, and infestation of these wetland ecosystems by *P. insularum* would be very detrimental to their conservation. However, the environmental effects in the PRA area could be lower than those found in South-East Asia as the organism is less active at the lower mean temperatures occurring in the PRA area.

- Although the environmental effects in South-East Asia are mainly caused by *P. canaliculata*, the species identified in the Ebro Delta in Spain, *P. insularum*, exhibits even greater feeding versatility. The wider trophic niche occupied by *P. insularum* could contribute to a potentially greater environmental impact in terms of different types of host plants and habitats that could be threatened by the snails.

The Panel considers the general effects of severe reductions in aquatic plant species and biomass in South-East Asia to be described sufficiently in the PRA. However, the ecology of *Pomacea* spp. in native South American habitats or in invaded habitats (i.e. the USA) is insufficiently described. Apart from temperature, many other factors are likely to influence the effects of *Pomacea* spp., such as its interaction with other organisms in the recipient community. Accordingly, it is important to mention that in the native area of distribution, South America, *P. canaliculata* and *P. insularum* are not considered to be problematic organisms even in areas where they occur at high densities.

An appropriate ecosystem-based analysis could help in projecting the potential effects on biodiversity and ecosystem processes caused by apple snails in the PRA area. The Panel considers it insufficient to state that infestation by *P. insularum* in wetland areas could be very detrimental to their conservation without providing any predictions or scenarios. Although the vast majority of studies on *P. insularum* and *P. canaliculata* in South-East Asia have focused on the snail's impact on rice production, studies on the effects of *P. canaliculata* on natural wetland ecosystems (e.g. Carlsson et al., 2004) show strong negative and fairly predictable impacts on biodiversity, ecosystem functioning and ecosystem services.

Based on data reported in literature, the Panel assigns a primary importance to the snail population density (Carlsson et al., 2004), but this importance is not adequately considered in the PRA. Some potential direct and secondary effects on biodiversity, ecosystem functioning and ecosystem services are related to pest density and could therefore be predicted for the PRA area. At moderate snail densities preferred plant species are likely to be reduced or lost from invaded wetlands, i.e. a direct effect on plant biodiversity. This reduction in aquatic plant species richness is expected to cause secondary reductions in organisms that depend on these particular aquatic plant species at any life stage. At high snail densities we could expect sharp reductions in most palatable plant species and an increasing shunting of nutrients from aquatic plants to phytoplankton, i.e. a strong effect on ecosystem functioning. This process may lead to a drastic ecosystem shift from clear water and aquatic plant dominance to turbid water and dominance by planktonic algae. Such shifts have attracted much attention in aquatic ecology as they are quite stable and not easily reversible (Scheffer et al., 1993). They are typically mediated by high nutrient loads (Scheffer, 1998), but they have also been shown to be driven by herbivory from *P. canaliculata* (Carlsson et al., 2004). In addition to the damage to plants and invertebrates mentioned in the PRA, a general ecological understanding of many fish and amphibian species, both inside and outside the PRA area, will allow prediction of reductions in their reproductive success as they wrap their eggs around aquatic plants. These general effects on biodiversity and ecosystem functioning might be similar in most invaded wetland habitats that are dominated by aquatic plants if *P. insularum* or *P. canaliculata* snails became established at high densities.

The Panel finds that some aspects of natural wetlands are insufficiently considered in the PRA. In Asia these natural wetlands have been described as “biological supermarkets” that provide food for humans, fodder for animals and important ecosystem services such as ensuring maintenance of minimum water quality for rural economies (Carlsson, 2006). The role of wetlands as ecosystem service-providing units in the PRA area might be somewhat less important than in Asia and is limited to certain areas. However, their aesthetic value and their role in ecotourism, such as bird watching, are very important. These values could be negatively affected by the *Pomacea* spp.-induced transformation of wetland ecosystems.

The assessment of environmental consequences of the *Pomacea* spp.-induced transformation of wetland ecosystems presented in the Spanish PRA demonstrates some limits in the capacity to predict the interaction of the snails and the receiving communities and ecosystems. These limits affect the possibility of extrapolating the findings in Asia to the PRA area. Given that projections of environmental consequences are based on a scenario exercise, a more structured and ecologically sound approach would strongly contribute to providing insight into the future development of the snail invasion and its consequences. In particular, the following aspects might be considered for the development of an environmental risk assessment for *P. canaliculata* and *P. insularum* in the PRA area.

(i) Consideration of the snail population density. The environmental consequences of snail invasion have been proven to be dependent on the snail population density (see above). For the development of an environmental risk assessment for *P. canaliculata* and *P. insularum* in the PRA area it appears to be essential to project not only the potential area of invasion, based on simple climate matching, but also to produce a scenario of potential impact based on adequate consideration of the snail’s biology and its ecology at the basis of population dynamics. The development of a snail population dynamics model may assist the computation of the potential population density over all the suitable areas in the PRA area. This model should include temperature-dependent responses of development, survival and reproduction. The role of host availability and density can also be taken into account in model projections, if data are available.

(ii) Development of scenarios of potential consequences. To develop a scenario of potential consequences the following information is required: (a) projection of the potential population density; (b) a hypothesis on pest spread potential; (c) information on the distribution of the potentially affected habitats including habitats other than rice fields and natural wetlands that may be invaded by the pest such as rivers, shallow lakes and ponds (these ecosystems are also likely to be effected by *P. insularum* and *P. canaliculata* and may serve as reservoirs for the snails and as an infrastructure for spread). Such information can support the estimation of (1) the environmental consequences on natural wetlands and (2) the potential impact on rice fields.

(iii) Perform a structured evaluation based on biodiversity and ecosystem services. The recently published guidance on the environmental risk assessment of plant pests (EFSA Panel on Plant Health (PLH), 2011a) provides a structured methodological framework for assessing the environmental risks of plant pests and is very suitable for development of an environmental risk assessment for *P. canaliculata* and *P. insularum* in the PRA area. The guidance emphasises the importance of assessing the consequences on both the structural (biodiversity) and the functional (ecosystem services) aspects of the environment. This new approach includes methods for assessing the environmental effects on both aspects (structural and functional) for the first time in a pest risk assessment scheme and is particularly suitable for a plant pest such as *Pomacea* spp., which represents an important driving force of wetland ecosystems change.

2.4.3. Other consequences

The PRA mentions that *Pomacea* spp. snails are suitable hosts for a number of parasites, including *Angiostrongylus cantonensis*, which may cause eosinophilic meningoencephalitis in humans, a potentially deadly disease. Little is known about the harm this nematode causes to other organisms, but it may infect domestic and wild animals (Prociv et al., 2000).

As the origin of the *Pomacea* spp. snails in Spain is unknown, the actual parasite status of this population also remains unknown. In the PRA, the means of spread to humans was not described. The parasite is spread via consumption of undercooked snails, or via consumption of contaminated vegetables (Lv et al., 2011). The latter is probably a more likely and potentially more serious pathway in the PRA area.

The Panel recognises that the evaluation of the impact of *Pomacea* spp. on animal and human health falls outside its remit; however, it wishes to note that, owing to the seriousness of this potential impact, it should be assessed by the competent authorities.

2.5. Evaluation of probability of establishment

Considering that *P. insularum* already has established and caused damage in the Ebro Delta, and that spread is still ongoing there, the Spanish PRA states that it can be asserted that the climatic conditions in that area – and the temperature regime in particular – are adequate for this snail to thrive there. Furthermore, the PRA indicates that other rice-producing areas and neighbouring wetlands in the Mediterranean region are likely to have temperature regimes similar to the Ebro Delta and are, therefore, also adequate for establishment of *P. insularum*. The PRA also states that the number of generations per year will be probably lower on the Mediterranean coast than in warmer climates, referring to Albrecht et al. (1999) and Wu et al. (1995).

The Panel agrees with these statements of the Spanish PRA. The general climatic requirements of the Ampullariidae for survival have been regarded as an average annual minimum temperature above 10 °C and 600 mm of annual rainfall (Berthold, 1991). However, there still exists considerable uncertainty about the climate responses of *Pomacea* spp. The Spanish PRA cites the thesis of Ramakrishnan (2007), which states that 15 °C is the lower lethal temperature limit of *P. insularum*. This contradicts other information in the literature. Karatayev et al. (2009) found that *P. insularum* survived for over 2 days at water temperatures as low as 6 °C without noticeable mortality, and Zhou et al. (2003) reported the ability of *P. canaliculata* to survive at even lower temperatures using hibernation as an adapting strategy. Valuable information about climate tolerance of the species can be found from areas where *Pomacea* spp. has been introduced. A study conducted on *P. canaliculata* in the northernmost population in Japan showed that at water temperatures down to 2 °C, overwintering success was dependent not on temperature but on other factors (Ito, 2002). This information suggests a great degree of uncertainty regarding the northernmost distribution of the species in Europe.

Baker (1998) reviewed the pest status of golden apple snails in Asia, and attempted to predict their potential distribution, in particular in Australia, should they become established there. In his study (Baker, 1998), Baker selected six sites within the core native distribution of *P. canaliculata* in Brazil (Cáceres, Corumbá), Paraguay (Asunción), Uruguay (Salto) and Argentina (Corrientes, Buenos Aires) and matched their climate with sites in Asia and Australia using CLIMEX (Sutherst and Maywald, 1985; Sutherst et al., 1995). As the study by Baker (1998) is the only publication modelling the potential for establishment of *P. canaliculata* based on climate, the Panel used these data as a starting point for its analysis, even though this study involved only simple climate matching. Martín et al. (2001) report from a survey on the geographical distribution of *P. canaliculata* in the Buenos Aires province of Argentina states that *P. canaliculata* occurs south of the reservoir of Paso de Las Piedras in the Sauce Grande basin. This is the southernmost recorded population of the species within its native distribution. Based on this information, the Panel performed a climate-matching analysis based on the same native locations selected by Baker (1998) but with the addition of the location of Paso de Las Piedras reported by Martín et al. (2001), as this location could potentially represent a "worst case" example because it was hosting a population on the limit of its native distribution. The climates at these seven locations in South America were compared with the climate in Europe. The output from the climate matching was drawn on maps for Europe, with an additional overlay of data on the distribution of wetlands and rice cropping fields extracted from the CORINE Land Cover database[6]. Because *P. insularum* is already established at one location in the risk assessment area, the Panel found it interesting to utilise this information in an initial analysis, taking the opposite approach to the normal procedure of climate matching, that is one in which the climate of a "home" location of the organism is matched with a number of "away" locations. Before comparing the climates from the selected locations in the native area of *Pomacea* spp., the climate of the Ebro Delta was matched (compared) with the climate of the whole continent of South America (Figure 3).

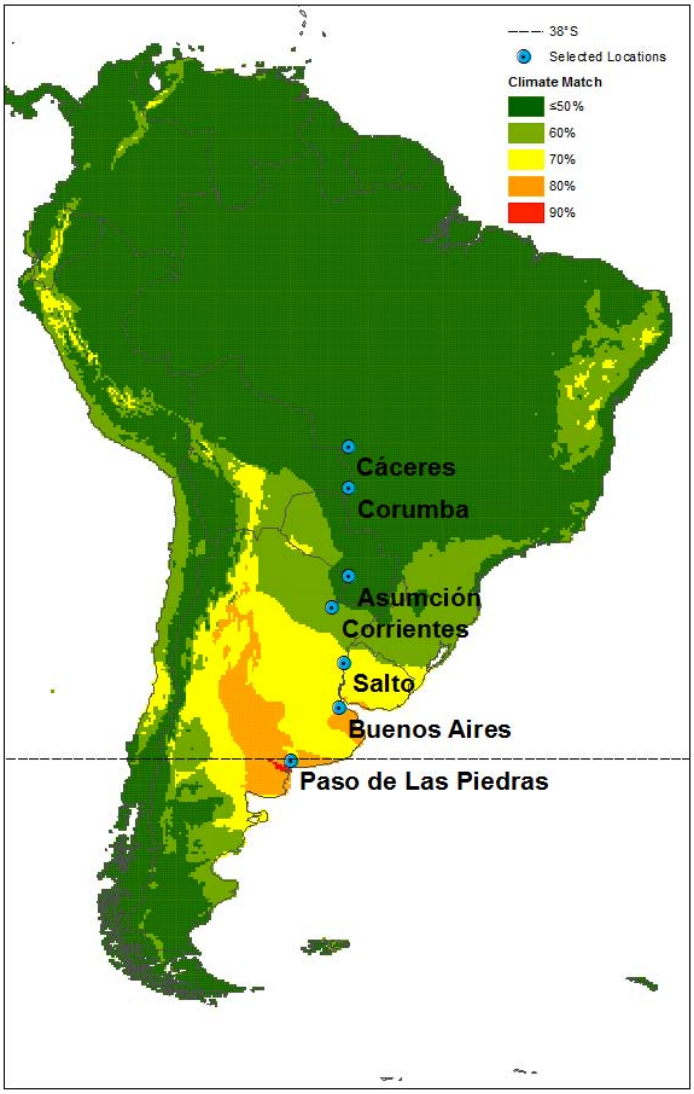

Figure 3: Climate in South America compared with the climate of the Ebro Delta, Spain. Shown here are the six locations selected by Baker (1998) as kernel areas of the distribution of *P. canaliculata* to be matched with Asia and Australia.

6 CORINE Land Cover: available at http://www.eea.europa.eu/publications/COR0-landcover.

The map resulting from this initial pre-comparison of the climate in the Ebro Delta in Spain with that of South America reveals that the area of South America where the climate is most similar to that of the Ebro Delta is located close to, but even further south than, the southernmost location inhabited by *Pomacea* spp. in South America (Martín et al., 2001).

In the next step of the climate-matching analysis, the seven previously described locations, the geographical locations of which six are shown in Figure 1, were matched with Europe. Out of these seven locations, the climate of Paso de Las Piedras showed the closest match (in terms of the highest level on the climate match index) with the European climate (Figure 4). Therefore, only the results from the climate match index of Paso de las Piedras are used here to represent a worst-case scenario; the results for the other six locations are given in Appendix B.

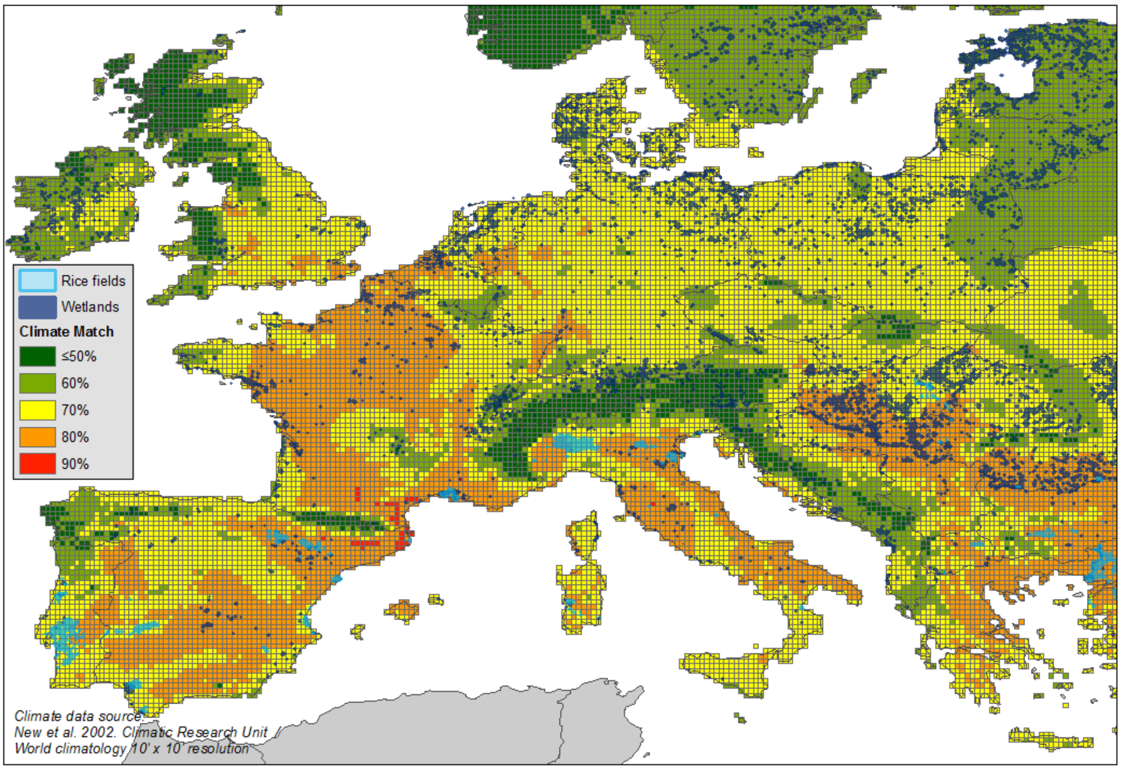

Figure 4: Climate match of Paso de las Piedras, Argentina, with Europe, indicating areas of wetland and rice cropping.

For the purpose of comparison, the Panel also ran a climate-matching exercise whereby the climate of the Ebro Delta was matched with the climate in the rest of Europe, the result of which is shown in Figure 5.

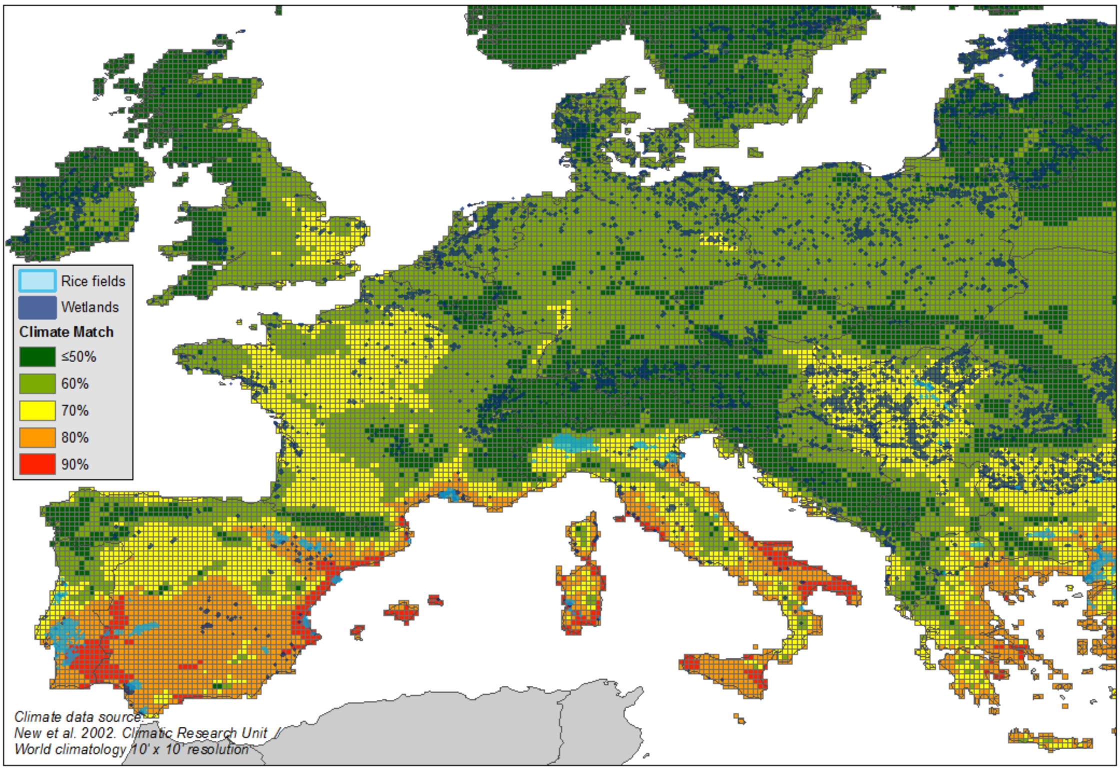

Figure 5: Climate match of the Ebro Delta with Europe, indicating areas of wetland and rice cropping.

In order to investigate the sensitivity to variations in temperature of the climate match of the South American locations with Europe, the Panel performed a simple sensitivity analysis whereby the temperature regimes were given a perturbation of +1 °C and +2 °C. The results, in terms of the effects on climate match for the total area of Europe, and for two land and land use categories, are given in Tables 1 and 2.

Table 1: Climate match areas of land (thousands of hectares) of Paso de las Piedras in Argentina with Europe

	Current climate			+1 °C warming			+2 °C warming		
Match index	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetland**
0.2	920			427			145		
0.3	22 337			16 929			12 829		
0.4	116 252		19	82 432		16	56 614		13
0.5	225 584		58	200 642		30	168 910		23
0.6	290 997	60	365	286 460	79	299	290 265	148	211
0.7	314 228	370	686	326 645	266	652	338 108	182	664
0.8	125 167	373	234	180 931	458	364	224 059	474	448
0.9	861	0.2	0.025	1 881	0.03	0.877	5 416	0.03	3
Total	1 096 347	804	1 361	1 096 347	804	1 361	1 096 347	804	1 361

The general trend that can be observed from Table 1 is that climate warming results in a general movement of more European land to a greater level of climate similarity with Paso de las Piedras in Argentina.

Table 2: Climate match areas of land (percentage of totals) of Paso de las Piedras in Argentina with Europe.

	Current climate			+1 °C warming			+2 °C warming		
Match index	Total area	Rice fields	Wetland	Total area	Rice fields	Wetland	Total area	Rice fields	Wetlan d
0.2	0.08			0.04			0.01		
0.3	2.04			1.54			1.17		
0.4	10.60		1.38	7.52		1.17	5.16		0.98
0.5	20.58		4.27	18.30		2.19	15.41		1.69
0.6	26.54	7.51	26.82	26.13	9.81	21.97	26.48	18.39	15.48
0.7	28.66	46.05	50.38	29.79	33.15	47.88	30.84	22.66	48.74
0.8	11.42	46.41	17.15	16.50	57.03	26.72	20.44	58.94	32.92
0.9	0.08	0.03	0.00	0.17	0.00	0.06	0.49	0.00	0.19

Temporal variability in meteorological conditions and how such variability may affect the species is not discussed in the Spanish PRA. Although it seems clear that *P. insularum* is established in the Ebro Delta, temporal variability in meteorological conditions may have effects on the population not observed so far, as well as it may affect both northern and altitudinal limits for establishment of the species in the risk assessment area.

The conclusion that can be drawn from the above climate-matching analyses is that the results indicate that climate will not prevent further establishment and spread of *Pomacea* spp. in the risk assessment area. This conclusion is based both on the climate match for the native area with the risk assessment area (e.g. Figure 4) and the climate match for the Ebro Delta, where the snail is present, with the rest of the risk assessment area (Figure 5). In both cases, there exist areas beyond the current distribution of the pest in the risk assessment area that have very high climatic similarity. The uncertainty associated with this conclusion is related both to the remaining uncertainty on temperature responses of the pest and whether the occurrence of the pest in the Ebro Delta is actually a real establishment according to the definition of the International Standard for Phytosanitary Measures ISPM 5 (FAO, 2011): i.e. perpetuation, for the foreseeable future, of a pest within an area after entry. Given that the snail was detected in the Ebro Delta in 2009 and therefore is likely to have occurred there for a limited period of time only, there is the possibility that the meteorological conditions in this period have been particularly suitable for the pest, and therefore have allowed for a temporary occurrence only of the species within the risk assessment area.

However, considerable uncertainty remains regarding the northern and altitudinal climatic limits for establishment of the species. Other abiotic or biotic factors may limit the potential area of establishment to a narrower extent than the area determined by the climatic conditions of the risk assessment area alone.

2.5.1. Characteristics of the pest affecting the probability of establishment

The PRA concludes that *Pomacea* spp. snails have several characteristics that make them highly invasive: they have a high fecundity, a broad aquatic plant diet and a striking invasion history elsewhere. The Panel would like to point out that several other features of *Pomacea* spp. biology aid invasion. The snails are moderately amphibious and possess both gills and lungs and may exhibit both aquatic and aerial respiration (Seuffert and Martín, 2010). This allows them to survive even in poorly oxygenated water. Another important physical feature that aids survival in many places, including ephemeral habitats such as rice fields or wetlands, is the operculum or "shell door" that enables the snails to retreat into their shell and close it firmly. This allows the snail to hibernate buried in the mud within the protective moisture of its shell for periods of several months when the habitat dries out

(Oya et al., 1987). Besides their preferred diet of aquatic plants, these omnivorous snails also consume periphyton, detritus and fish and snail eggs. Thus, they may survive at relatively high densities by using less preferred food sources (Carlsson et al., 2004), even after they have depleted the available aquatic plants.

2.5.2. Availability of hosts plants

The diet of *P. canaliculata* and *P. insularum* is sufficiently reviewed in the PRA. The list of host plants in Table 1 of the PRA indicates how polyphagous apple snails are. *P. canaliculata* and *P. insularum* are primarily macrophytophagous and readily consume vascular plants, in contrast to the periphyton resources commonly associated with other aquatic snails (Burks et al., 2010). Several studies on host plant preference by different *Pomacea* spp. have reported inconsistent results (described in Morrison and Hay, 2011). This may be explained by failure to identify the correct *Pomacea* spp. used in the experiment or different feeding behaviours in different strains of the same *Pomacea* species. The PRA clearly indicates that many plant species in the PRA area are likely to serve as hosts and that most of the aquatic species could be consumed by *P. insularum* and *P. canaliculata,* leaving only a few unpalatable emergent plant species in the aquatic systems where there are high snail densities. No studies have been found on the trophic niche of *P. insularum* in the Ebro Delta area, but the Panel agrees with the conclusion of the PRA that *P. insularum* can feed on many different plant species in aquatic or flooded areas, and the availability of suitable host plants results in the possibility of the establishment of *Pomacea* spp. elsewhere in the PRA area. Thus, the Panel is of the opinion that, owing to the polyphagous diet of *P. insularum* and *P. canaliculata*, establishment of these species will not be limited by food resources in the PRA area.

The host plant list in the Spanish PRA for *Pomacea* spp. may be incomplete. An aquaria experiment by Carlsson (Dr Nils Carlsson, member of EFSA working group on *Pomacea*, personal communication, 2011) showed that *Pomacea* spp. readily consumed all of five Swedish aquatic plant species offered and that they reproduced and sustained on this diet for 5 months until the experiment was terminated. The plant species were *Potamogeton natans*, *P. perfoliatus*, *Myriophyllum alterniflorum*, *Hippuris vulgaris* and *Callitriche cophocarpa*.

2.5.3. Suitability of the environment

Apart from the climatic requirements of the pest discussed above, the Spanish PRA emphasises that key environments for *P. insularum* to establish and thrive, such as flooded rice fields and natural wetlands, are habitats that exist in the risk assessment area. The PRA also addresses salinity as a factor that may impact the survival of *P. insularum* (Marfurt and Burks, 2005). But, with reference to Marfurt and Burks (2005) documenting a certain tolerance to salinity of the species, as well as the observed success of the species at the salinity levels found in the Ebro Delta and in other rice-growing areas of the world, the PRA concludes that salinity does not hinder the pest's spread and damage. The Panel agrees that areas with habitats of flooded rice fields and wetlands (as summarised in Table 1) and the availability of aquatic plants in such areas suggest a suitable environment for *Pomacea* spp. within the risk assessment area. In the previously mentioned survey on the southern limit of the species' native distribution, Martín et al. (2001) state that temperature might not be the only limiting factor in the distribution of the apple snails in South America. Although information on the temperature responses of apple snails is accumulating (Estebenet and Martín, 2002; Zhou et al., 2003) considerable uncertainty remains in this aspect. Nevertheless, the information available indicates that neither climate nor salinity will prevent further establishment in the risk assessment area.

2.5.4. Evaluation of current cultural practices and control measures

The PRA describes how early flooding of rice fields provides favourable conditions for the establishment of *P. insularum*, whereas tillage, in particular ploughing with heavy machinery, can kill snails buried in the soil. In the risk assessment area, early flooding of fields is often done for environmental purposes, and tillage is not effective in killing snails because of the small size of the rice fields. In addition, crop rotation, which might decrease the establishment potential of the pest, is not possible throughout the risk assessment area, and especially not in the Ebro Delta because of the saline conditions. Irrigation and drainage water, as well as mechanical harvest, are likely to favour spread and the reinfestation of rice fields. Therefore, the Panel supports the conclusion of the PRA that the managed environment in the risk assessment area is highly favourable for pest establishment.

The fact that *Pomacea* spp. are present and reproduce in the Ebro Delta indicates that existing management practices have not been effective in preventing their establishment. The Panel therefore agrees with the rating of "very likely" in the PRA. The PRA does not specify which pest management practices are applied in rice fields threatened by the pest, except those that are directly targeted against the snails in the Ebro Delta.

According to Chataigner and Mouret (1997), in the Camargue, France, pesticides are applied, but only herbicides, algicides and treatments (not specified) against *Chilo suppressalis* (striped rice borer). Elsewhere in the world, mainly synthetic chemical molluscicides are used for the control of *Pomacea* spp. (e.g. metaldehyde, copper sulphate, niclosamide). However, these are extremely toxic to non-target organisms and to the environment (San Martín et al., 2008).

2.6. Evaluation of probability of spread after establishment

The PRA recognises that spread of *P. insularum* can occur by natural migration and by human assistance. Natural migration requires access to water currents or flooding events, such as those caused by heavy rains (Tu and Hong, 2002; Cowie, 2002). The PRA lists some mechanisms of human-assisted spread.

- Aquaculture and release from aquaria. Because of the popularity of *Pomacea* spp. snails among aquarium hobbyists, they are reared in aquaculture facilities in the PRA area. This allows deliberate movement to outdoor aquaculture facilities (Cowie, 2002). However, the release of unwanted individuals (Smith, 2006) seems to represent the major mechanism supporting the spread of the snails.

- Accidental dispersal through boats or other means. For instance, eggs will be deposited on any emergent object, including boat hulls. If these boats are transported to other aquatic environments, the eggs may hatch far away from where *Pomacea* spp. snails have established. The mechanism is common in Asia (Figure 2), and in the Ebro Delta snails adhering to boats have already been detected.

- Agricultural practices. Soil contamination through agricultural field machinery – for example harvesters or ploughs – would contribute to the spread of the snail not only within a rice-growing area. Also irrigation and movement of plants intended for propagation (Smith, 2006) would increase the probability of dispersal.

In the Spanish PRA the probability of the pest to spread rapidly in the PRA area by natural means is rated moderately likely, with a low level of uncertainty associated with this estimation. The Panel considers that this evaluation deserves more attention for the reasons mentioned below. The evaluation in the PRA is mostly related to the importance of the natural means of spread within rice-growing zones (Wada, 2006). However, the area under threat is much larger than rice-growing zones and linked natural wetlands. The affected area should include slow-flowing rivers, as they will be impacted, and the littoral vegetated zone harbours great biodiversity. These rivers and the network of natural and artificial canals connecting water basins can be considered as a powerful infrastructure for natural spread (Yusa et al., 2006). The consideration of habitats other than rice fields and natural wetlands as potential habitats for establishment and the availability of slow-flowing rivers and canals as natural means for dispersal have serious implications for the forecasting of natural spread. Furthermore, the continuity of water habitats in most of the climatically suitable areas may represent an important element that guarantees the interchange of snail populations between the rice fields and the natural wetlands, the two most sensitive habitats where damage occurs.

The PRA correctly identifies as likely the probability of rapid spread by human assistance, with an associated low level of uncertainty. Rice-growing areas in the EU are not evenly distributed. However, there are several ways in which *P. insularum* can spread to still non-infested rice-growing areas or wetlands in the EU. The relative contribution of agricultural practices and deliberate release of individuals from aquaria remains poorly understood and is not addressed in the PRA. Zhou et al. (2003) reported that snails are mainly disseminated through human cultivation and transport of rice seedlings; however, these human-assisted mechanisms related to agriculture are less important in the PRA area than they are in Asia.

In conclusion, the Panel accepts the final evaluation reached in the PRA regarding the probability of introduction and spread of *P. insularum* into the PRA area, which is rated as likely with a low level of uncertainty. The contribution of natural spread could play a role that is more important than the one recognised in the PRA, but the expected rate of natural dispersal is low. Human-assisted dispersal supports the possibility of spread over long distances, and a scattered distribution of *P. insularum* may occur particularly during the initial phase of colonisation.

2.7. Identifying the endangered area

The Spanish PRA concludes that the endangered area corresponds with the rice-growing areas and natural wetlands along the EU's Mediterranean coast, as well as the Guadalquivir Marshes (on the southern Atlantic coast in Spain). The Panel agrees that the endangered area includes the areas identified by the Spanish PRA, but the results from the preliminary analyses undertaken by the Panel suggest a wider endangered area than that identified by the Spanish PRA.

The Panel has identified the potential endangered area on the basis of an analysis of land use and climate. According to the terms of reference, two categories of habitat are of interest: rice fields and natural wetlands. Information on the spatial distribution and extent of these ecosystems was obtained using the database in CORINE Land Cover[6]. The data files obtained for the two types of ecosystem were used to add the two information layers to the maps from the climate-matching exercise (see section 2.5). The results from the climate matching indicate that climate is not a limiting factor for spread and further establishment in the PRA area. Vast areas of Europe have climatic conditions very similar to those in areas within the current distribution of *Pomacea* spp. snails. Notably, most of the rice cultivation areas fall into climatically suitable areas, with a climate match index greater than 0.7, and most of the natural wetlands areas fall into areas with a climate match index greater than 0.6. The Panel also reached the conclusion that suitable host plants are available within these zones. The recognised importance of natural spread, as well the availability of suitable habitats other than rice fields and natural wetlands (e.g. slow-flowing rivers), identifies a great part of southern, as well as parts of central, Europe as potentially endangered areas. A high level of uncertainty is associated with the northern limit of the potential endangered area, which makes it difficult to draw a reliable conclusion about this limit. With the support of a population model that can summarise the effect of biotic and abiotic variables on the snail population dynamics, it could be possible to reduce the uncertainty and make more precise projections on the potential northern limit of establishment.

The climatically suitable areas in Europe (see section 2.5) have been identified as those areas showing the greatest similarity with the climate in the native locations of *Pomacea* spp. snails' distribution such as the southernmost record for the species (Paso de las Piedras in the south of Buenos Aires province, Argentina). The overlap of the climatically suitable areas in Europe with the information layers representing the two suitable habitats for the pest defined in the terms of reference shows how large areas in the PRA area occupied by rice fields and natural wetlands will be potentially affected by the spread of the pest. Most of the rice cultivation areas have a climate match index greater than 0.7, and most of the natural wetlands have a climate match index greater than 0.6.

2.8. Evaluation of probability of entry

P. insularum and other *Pomacea* spp. are imported intentionally to the PRA area mainly as ornamental species for the aquarium trade, but several unintentional pathways are also listed in the PRA. The overall rating given by the Spanish PRA for entry of the snails into the PRA area is “moderately likely”. According to the information available, the snails have already been introduced into the PRA area and are still being imported (i.e. they are associated with the pathway at its origin), surviving transport and storage and have few limitations for transfer to a suitable host in the risk assessment area. Thus, the Panel disagrees with the Spanish PRA’s rating and finds that the probability of both intentional and unintentional entry of *Pomacea* spp. snails into the PRA area is high.

2.8.1. Identification of pathways

As already stated, *P. insularum* and other *Pomacea* spp. are imported intentionally to the PRA area, mainly as ornamental species for the aquarium trade. Several other pathways are listed in the PRA. *Pomacea* spp. snails may be unintentionally associated with aquatic plants or live tropical fish that are imported for the aquarium trade or with commercial or non-commercial shipments of aquatic plants, or may be intentionally imported as food items or as agents for aquatic weed control. It is concluded in the PRA that importation of *P. insularum* for the pet/aquarium trade and for aquatic weed control are the most relevant pathways. The PRA also states that “if the conclusions of the present assessment were that *P. insularum* poses an unacceptable threat for plants or the environment in the PRA area that cannot be adequately managed, subsequent changes in EU legislation should also affect official inspections of imported aquatic plants and live tropical fishes at the EU’s ports of entry – in order to reject the entry of consignments infested with the snail”. The Panel agrees with the conclusion in the PRA that the import of *P. insularum* for the pet/aquarium trade or for weed control is more relevant than the other pathways listed.

2.8.2. Probability of the pest being associated with the pathway at origin

The PRA states that, as the pest is intentionally imported, an assessment of its entry potential is not required, and that the intentionally imported volume is minor but of moderate frequency. The Panel agrees with these conclusions, even though the uncertainty is medium to high as pointed out in the PRA. The Panel suggests that unintentional introductions should also be evaluated; however, these may be harder to predict or prevent. Information about the danger of releasing *Pomacea* spp. snails into the natural environment could, for example, be directed towards the aquarium industry. The Panel is of the opinion that the sale or breeding of *Pomacea* spp. snails could be banned within the PRA area to reduce establishment and spread. Unintentional introduction of *Pomacea* spp. on imported and infested aquatic plants for use in garden ponds might be difficult to regulate and would require phytosanitary inspections.

2.8.3. Probability of survival before, during and after transport or storage

For the main pathway, intentional introduction, this question is irrelevant, as the aim is to introduce the snails alive. For unintentional introductions, several characteristics of the snails, not mentioned in the PRA, may promote survival before, during and after transport or storage. Like other Ampullariidae, *Pomacea* spp. snails are regarded as moderately amphibious as they have both gills and lungs and can exhibit both aquatic and aerial respiration (Seuffert and Martín, 2010), allowing them to survive in poorly oxygenated water, which could be the case in the conditions under which aquatic plants are transported. Another important physical feature that may aid survival in adverse transport conditions is the operculum or “shell door” that enables the snails to retreat into their shell and close it firmly. This prevents drying out of the snails (Oya et al., 1987). Eggs are laid out of the water and may therefore survive dry transport until they hatch after a couple of weeks (Barnes et al., 2008).

It is assumed with low uncertainty that the water temperatures in which tropical fish are transported are also suitable for *Pomacea* spp.

2.8.4. Probability of transfer to a suitable host

Several pathways to suitable habitats and hosts are listed in the PRA:

- intentional release by aquarium hobbyists;
- escape from outdoor aquaria, water gardens and aquaculture facilities;
- escape from outdoor aquaculture facilities intended for rearing snails.

Several characteristics of the snails may promote transfer to a suitable host. The presence of both gills and lungs and the operculum are features that aid successful transfer to a suitable host by overcoming adverse conditions. The operculum discourages predators and allows the snail to hibernate buried in the mud within the protective moisture of the shell for periods of several months when the habitat dries out (Oya et al., 1987). Eggs that are transported will also survive for several weeks before they hatch.

2.9. Analysis of uncertainty

In addition to the main uncertainties already listed in the PRA (number and distribution of open air aquaculture facilities in the PRA area, importance of trade in *P. insularum* within the PRA area, range of host plant species in the endangered area, tolerance to extreme temperatures, average number of egg clutches per season and per female, clutch size, clutch yields and feeding activity in the PRA area, impacts of control measures for *P. insularum* on existing biological or integrated systems for other rice pests, and the environmental impact in Mediterranean natural wetlands), the Panel identifies the following uncertainties.

- As a mixture of species from the *canaliculata* complex is often found in the aquarium trade, the Panel cannot rule out the possibility that *Pomacea* spp. other than *P. insularum* are present in the invaded area. This is supported by the fact that the PRA mentions that DNA analysis has been conducted for only nine specimens, which is not sufficient to verify that all the populations of apple snails present in the Ebro Delta belongs to the *P. insularum* species.
- Because the snails are easily obtainable in the pet and aquarium trade, it cannot be ruled out that they have also been introduced to other suitable habitats in the risk assessment area.
- A study conducted on *P. canaliculata* in the northernmost population in Japan showed that, at water temperatures down to 2 °C, overwintering success was dependent not on temperature but on other factors (Ito, 2002). This suggests a great degree of uncertainty for the northern and altitudinal climatic limits for establishment of the species. Other abiotic or biotic factors may limit the potential area of establishment to a narrower extent than the area determined by the climatic conditions in the risk assessment area alone. Only better experimental data and/or the use of a model able to summarise the effects of biotic and abiotic variables on the snails' population dynamics can support an estimation of the potential northern limit of establishment.

The volume and frequency of intentional imports from outside the risk assessment area are not known. This also includes Internet trade. In addition, there is uncertainty about the volume and frequency of unintentional introductions.

The Panel concludes that uncertainty regarding the probability of entry, establishment and potential for consequences as such is low, but high regarding the importance of trade (with regard to volume and frequency of intentional and unintentional introductions) and the extent of the endangered area, in particular for the northern limit of potential establishment in the risk assessment area. In addition, there is also some uncertainty on the details of the environmental consequences in the risk assessment area. Regarding the uncertainty related to the risk of *Pomacea* spp. for the potential endangered area, the Panel considers it low.

2.10. Conclusion of the pest risk assessment stage

The rating by the Panel was done based on the rating guidance presented in Appendix A. The Spanish PRA did not use any rating guidance (see section 1.2).

Risk component	Spanish PRA rating	Panel rating	Description
Potential consequences for cultivated and managed plants	Major	Major	Besides rice, few cultivated plants are at high risk in the PRA area under normal circumstances. The Panel agrees with the conclusions of the PRA
Potential consequences for the environment	Major	Massive	The Panel does not agree with the conclusions of the PRA, which considers environmental consequences to be only major. The Panel found evidence that the pest of concern can strongly reduce preferred plant species in invaded wetlands and indirectly the species that depend on those. Moreover, at higher densities, the snail can cause an almost complete collapse of the aquatic plant community, leading to a shift from a plant-dominated, clear water state, to a turbid, algae-dominated state. Such a transformation of an entire ecosystem may have drastic and long-lasting effects on biodiversity and ecosystem services
Establishment	Very likely	Very likely	The pest is already established, therefore the Panel considers the overall probability of establishment of *Pomacea* spp. in the risk assessment area as very likely and agrees with the rating given in the PRA
Spread	Likely	Likely	The contribution of natural spread could play a role that is more important than recognised in the PRA, but the expected rate of natural dispersal is low. Human-assisted dispersal might lead to spread over long distances, and a scattered distribution of *P. insularum* may occur particularly during the initial phase of colonisation. The Panel agrees with the rating given in the PRA
Entry	Moderately likely	High	The overall rating of the PRA for entry of the snails is moderately likely. Based on the information available and the fact that the snails have already been introduced into the PRA area, the Panel disagrees with this conclusion and finds that the probability of both intentional and unintentional entry of *Pomacea* spp. snails into the PRA area is high

2.11. Evaluation of risk reduction options

The PRA provides a good overview of the risk reduction options. As pointed out in the PRA, no single risk reduction method is sufficient to prevent the spread of *Pomacea* spp. snails in the PRA area.

The PRA concludes that, as the snail has already entered the PRA area, actions must be taken in order to both:

- prevent its spread within the endangered area of the EU, which is essential given both the invasive character of the species and the difficulty in eradicating it once it is established; and
- minimise the snail's population size and the associated damage and eventually eradicate it in the Ebro Delta area.

The following risk reduction options are listed in the PRA:

- legislation changes in order to ban importation of *P. insularum* into the EU;
- banning both breeding and trade of this species within the EU;
- surveillance at both rice fields and wetlands in the endangered area of the EU, as well as in the surroundings of outdoor aquaculture facilities where *P. insularum* is/was present;
- collection and destruction of adult and subadult snails and destruction of egg clusters of *P. insularum* present in rice fields and water channels and on the riverbanks;
- keeping rice fields dry for long periods, combined with mechanical cultivation, to increase snail mortality;
- modification of the water inlets and drainage outlets of the plots in order to hinder any further spread of the snail in rice fields;
- installation of barrier traps throughout the irrigation network – combining this measure with baiting improves mechanical removal of snails;
- chemical treatment in restricted areas of the paddy fields where the infestation levels are very high, as well as in the irrigation and drainage network of the Ebro Delta;
- placement of barriers at the points of invasion of the river from the flood plain, as well as adjacent to the riverbank, in order to prevent the spread of the snail by creeping counter-currents;
- the use of saponins, which are said to be the chemicals most suitable for use in the Ebro Delta's rice fields, although this kind of treatment is quite new and there is little experience of it at a global scale (Joshi et al., 2008; San Martín et al., 2008);
- pest monitoring in order to assess the evolution of the snail population in the PRA area, the damages that it causes and the effectiveness of the control measures;
- provision of information to visitors to the Ebro Natural Park, in order to prevent them from contributing to the spread of the pest;
- elimination of apple snails adhering to the hulls of boats in the area;
- design and implementation of research in order to identify for new control techniques and to improve those already known.

The Panel has the following comments on the above-mentioned risk reduction options.

- The risk reduction options listed in the Spanish PRA are well reviewed and described. Most of them have already been implemented or tested in the Ebro Delta.

- The Panel agrees that a ban on importation into the PRA area, and on breeding and trade within the PRA area of *P. insularum* or, better still, the entire *canaliculata* complex, would be an important step to reduce the risk of further establishment and spread of these organisms. The Panel considers that this risk reduction option should target the entire *canaliculata* complex, as the species within the complex are almost indistinguishable and possess highly invasive traits and the potential to harm both rice production and natural wetlands. An import ban of only *P. insularum* in the PRA area might not prevent further import of *P. insularum* and *P. canaliculata*, as misidentification of the species cannot be excluded.

- Likewise, the Panel considers it important that, if breeding and trade are to be prohibited, this should apply not only to *P. insularum*, as suggested in the PRA, but to the whole *canaliculata* complex.

- In general, many of the risk reduction options mentioned will only reduce snail numbers and may not be able to eradicate the snails.

- Detection and eradication of *Pomacea* spp. snails on boat hulls is a valuable approach, but it is probably even more important to target eggs that are moved from one area to another attached to boat hulls and other objects. Providing information to the public, farmers and environmentalists should extend beyond the invaded area. The eggs are easily spotted and aid early detection and eradication. This is the only way to halt further spread.

- Surveillance at both rice fields and wetlands in the endangered area of the EU, as well as in the surroundings of outdoor aquaculture facilities where *P. insularum* is/was present, is recommended in the PRA, but is not described in any detail. The Panel suggests that surveillance teams should be formed and instructed in how to identify the snails and what action to take if they find them. An important, but missing, piece of information in the PRA is that early infestations by *Pomacea* spp. are best detected by surveillance of egg masses as these are much easier to detect than the snails themselves.

- The PRA also recommends collection and destruction of adult and subadult snails and destruction of the egg clusters of *P. insularum* in rice fields and water channels and on the riverbanks. The Panel comments that this has been done for almost three decades in South-East Asia, and the experience suggests that this is an effective method only during dry periods, when snails congregate in pockets of water and both snails and eggs are easily accessed on foot.

- The Spanish PRA mentions that keeping rice fields dry for long periods, combined with mechanical cultivation, has been reported to contribute to the snail's destruction. The Panel agrees with this conclusion, but stresses that the environmental impacts of this practice could be more negative than stated in the PRA, in which negative effects only on birds visiting the rice field ecosystem are predicted.

- Modification of the water inlets and drainage outlets of the plots, in order to hinder any further spread of the snail in the rice fields, and installation of barrier traps throughout the irrigation network is a well-tested practice and is also described in the PRA. Combining this measure with baiting improves collection of snails. Traps baited with lettuce, cassava, taro leaves and other preferred host plants are widely used in Asia (Cowie, 2002). Though this is also mentioned in the PRA, a method has not been developed for use in Europe. Baited traps might, in the opinion of the Panel, play a valuable role in detecting and controlling snails. The Panel finds this method important as it has no negative effects on non-target organisms and has the potential to be developed further. However, in lowland areas where rice fields and wetlands interconnect, rising water tables may quickly reconnect the snails with the rice fields. Also, if barriers are set up in large areas, they may impede the movement of other organisms.

- Another option mentioned in the PRA is chemical treatment in restricted areas of the paddy fields where snail infestation levels are very high, as well as in the irrigation and drainage network of the Delta. As pointed out in the PRA, there are several non-target effects from chemical treatments that have to be carefully weighed against the often meagre benefits, as chemical treatment often shows insufficient effectiveness. There are several factors that reduce the effectiveness of chemicals that are not mentioned in the PRA. The most important is obvious: chemicals deployed in water have no effects on the snail's eggs, which are laid above the water. Further, depending on the chemical, their effects may be quickly diluted by time, rain or flooding.

- According to the PRA, saponins seem to be most useful chemical for application in the Ebro Delta's rice fields, although this kind of treatment is quite new and there is little experience of it at a global scale (Joshi et al., 2008; San Martín et al., 2008). The Panel agrees that little is known about the potential non-target effects of saponins and stress that these should be properly examined before they are used on a large scale.

- The PRA proposes pest monitoring in order to assess the evolution of the snail population in the PRA area, the damage that it causes and the effectiveness of the control measures. The Panel agrees with this approach, as no single currently available risk reduction option has the potential to eradicate the snail from the area of infestation and, further, most risk reduction options have negative effects on non-target organisms and the environment.

- The PRA also proposes actions directed at informing and educating visitors to the Ebro Natural Park, in order to prevent them from contributing to the spread of the pest. The Panel finds this important but wants to stress that information should also be disseminated to farmers and birdwatchers and others who visit wetlands areas over a much larger area. This could aid more rapid detection and eradication if such groups are asked to look for the conspicuous egg masses.

- In the PRA, elimination of apple snails adhering to the hulls of boats is suggested. Adult *Pomacea* spp. snails do not adhere strongly to emergent objects, and several species even react to mechanical disturbance by dropping to the bottom substrate (Snyder and Snyder, 1971). The eggs, on the other hand, are glued to emergent objects, thus making boat hulls potent dispersal vectors (Carlsson, 2006). Elimination to prevent further spread should therefore focus more on *Pomacea* spp. eggs than on the snails themselves.

- The design and implementation of research would be important to identify new control techniques and improve those already known. The Panel strongly encourages this approach, as at present no single risk reduction option has the potential to eradicate the snail from infested areas and most risk reduction options used have negative effects on non-target organisms and the associated environment. If developed, effective and sustainable methods to combat the snail may be developed and used both in the PRA area and elsewhere.

In conclusion, the Panel considers that the risk reduction options listed in the Spanish PRA cover those that are used in integrated pest management of *Pomacea* spp. elsewhere. However, the Panel identified some weak points that need further attention, i.e. (i) non-target effects as a result of the mentioned risk reduction options are only superficially touched upon and need to be further developed; (ii) more attention should be given to early detection and control of the snail eggs to prevent further dispersal; and (iii) the issue of provision of information deserves more attention as knowledge about the snail problem at the level of stakeholders, environmental management professionals and the public is crucial to allow early detection, to prevent further spread and to generate rapid reporting of the presence of the pest to the managing authorities.

In addition to the risk reduction options mentioned in the Spanish PRA, the Panel also evaluated protective measures against the apple snails, *P. insularum* and *P. canaliculata*, published in the Boletín Oficial del Estado (Official Stage Gazette) of Spain (BOE, 2011a;b). In summary, these measures consist of:

1. establishing protective measures against the import into and spread within national and European Community territories;

2. adopting measures for eradication or, where this is not possible, isolation of the organisms;

3. requiring that harvesting equipment that is moved from areas where the apple snail is present to other areas that are free of the pest is accompanied by a certificate, issued by the competent authority in the place of origin, which specifies that the equipment has been cleaned to prevent the spread of the pest;

4. prohibiting the possession, breeding, transport, traffic and trade, including foreign and domestic trading, of live specimens (at any stage of development) or dead specimens and their remains of the apple snail species *P. insularum* and *P. canaliculata* in the national territory.

The Panel has the following comments.

- Ad 1. As it is not clear what the protective measures against import into and spread within Spain and the European Community territory are, it is difficult to evaluate their contribution to risk reduction. However, the Panel supposes that the measures referred to in the Boletín Oficial are those also mentioned in the Spanish PRA. These measures are evaluated above.

- Ad 2. Eradication has been attempted in other regions of the world and has usually not been successful (Ranamukhaarachchi and Wickramasinghe, 2006). Measures to isolate the organism have been discussed above in this section, as well as their potential contribution to risk reduction.

- Ad 3. Cleaning of harvesting equipment – a measure mentioned in the Spanish PRA – may contribute to reduction of spread but cannot, in the opinion of the Panel, completely prevent spread.

- Ad 4. Prohibition of the possession of live specimens of the apple snail is supposed to reduce the risk of establishment and spread of the snail, but, in the opinion of the Panel, cannot completely prevent it.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Following a request from the European Commission, the EFSA Panel on Plant Health has delivered a scientific opinion on the evaluation of the pest risk analysis on *Pomacea insularum*, the island apple snail, prepared by the Spanish Ministry of Environment and Rural and Marine Affairs.

For the evaluation of the Spanish PRA the Panel followed the EFSA guidance on evaluation of pest risk assessments and risk management options prepared to justify requests for phytosanitary measures under Council Directive 2000/29/EC (EFSA, 2009) and the guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a). The Panel has developed, for the purpose of this opinion, rating descriptors for the different components of the risk (entry, establishment, spread and potential consequences) and for the uncertainties. This is to provide transparent and clear justification when a rating different from that in the PRA is given. With regard to the risk management options, the Panel reviewed the document in terms of whether the options have been identified and evaluated for their effectiveness in reducing the risk.

The Panel considers the Spanish PRA to be clear and to provide appropriate supporting evidence.

However, unlike the Spanish PRA the Panel considers that it is scientifically more correct to include both species, *P. insularum* (d´Orbigny, 1835) and *P. canaliculata* (Lamarck, 1819), in the assessment. These two species are almost indistinguishable and have very similar impacts on invaded ecosystems.

Moreover the Panel highlights additional limitations of the Spanish PRA:

(i) The risks for habitats other than rice fields and natural wetlands, such as slow-flowing rivers and small water bodies, are not considered. These ecosystems may serve as reservoirs for the snails and as an infrastructure for spread. Understanding the movements of snail populations between rice fields and other aquatic ecosystems requires proper consideration of their population dynamics in natural environments.

(ii) The contribution of the spread of eggs as a natural means of dispersal, particularly through slow-flowing rivers and the network of artificial canals, is insufficiently discussed.

(iii) The environmental impact assessment is presented in very general terms, although detailed available information shows that environmental consequences in the risk assessment area could be massive under suitable environmental conditions. In particular, information is lacking on how snail population density could be the key variable in predicting the environmental consequences.

(iv) The estimates for the potentially endangered area are probably too limited with regard to the climatic suitability of and host plant availability in the PRA area.

Based on the evidence provided in the pest categorization stage of the Spanish PRA, as well as on additional information collected, the Panel confirms that a full pest risk assessment for the *canaliculata* complex is justified.

The Panel finds the information on the consequences to cultivated and managed plants, as described in the Spanish PRA, adequate but believes that it omits essential information about the environmental consequences, and the Panel considers it insufficient to state that infestation by *P. insularum* in wetland areas could be very detrimental to the conservation of such areas without providing any predictions or scenarios. Studies on the effects of *P. canaliculata* on natural wetland ecosystems show strong negative and fairly predictable impacts on biodiversity, ecosystem functioning and ecosystem services.

To evaluate the probability of establishment of the organism in the risk assessment area, the Panel performed a simple climate-matching analysis. The results indicate that climate will not prevent further establishment and spread of *Pomacea* spp. in the risk assessment area. However, considerable uncertainty remains regarding the northern and altitudinal climatic limits for the establishment of the species. Other abiotic or biotic factors may limit the potential area of establishment to a narrower extent than the area determined by the climatic conditions of the risk assessment area alone. After an evaluation of the published information about the wide host plant range of *Pomacea* spp., the Panel concludes that establishment and spread will not be limited by food resources in the PRA area. The Spanish PRA concludes that the endangered area corresponds with the rice-growing areas and natural wetlands along the EU's Mediterranean coast, but results from the climate-matching analysis conducted by the Panel indicate that climate is not a limiting factor for spread and further establishment in the PRA area. Large areas of Europe have climatic conditions very similar to those in the areas of native distribution of *Pomacea* spp. snails. Furthermore, the Panel concludes that suitable host plants are available within these zones. As the snails are currently intentionally imported into the PRA area, they are associated with the pathways mentioned in the Spanish PRA, and survival before, during and after transport is highly probable owing to the provision of suitable conditions during intentional transport. The Spanish PRA describes several ways in which the snails are transferred to a suitable host (intentional release, escape from outdoor aquaria and water gardens, and escape from outdoor aquaria rearing snails), but the Panel would like to add that specific characteristics of the snail (survival periods of several months during dry periods, survival on many different host plants) may enhance the probability of its transfer.

The Panel agrees with the Spanish PRA that the potential consequences of the organism for cultivated and managed plants are major with low uncertainty, but the Panel considers the effects on the environment to be massive instead of major with low uncertainty because of the very serious environmental effects observed in areas invaded previously. The Panel agrees with the Spanish PRA that the probability of establishment of the organism in the risk assessment area is very likely with low uncertainty. However, owing to the lack of biological data on the organism, the Panel considers the uncertainty high regarding the northernmost limit of distribution in the PRA area. The Panel also agrees with the rating for spread given in the Spanish PRA, which is "likely". The Panel agrees with the conclusion in the PRA that the import of *P. insularum* for the pet/aquarium trade or for weed control is more relevant than the other pathways listed. However, the Panel considers the rating for the probability of entry of the organism into the Spanish PRA to be too low. The Panel ranks the probability of entry as high, rather than moderately likely, as in the Spanish PRA, based on the fact that the organism can currently be freely imported and released in the PRA area.

The Panel agrees with the final conclusion reached in the Spanish PRA regarding the introduction and spread of the organism in the PRA: likely with low levels of uncertainty.

Risk reduction options are well reviewed and described in the Spanish PRA. As pointed out in the PRA, no single risk reduction method is sufficient to halt the introduction and spread of *Pomacea* spp. snails in the PRA area, but legislation is intended to reduce the probability of entry, and the many risk reductions options listed will help to reduce the probability of spread within the PRA area. If legislation is considered, the Panel suggests that it should target the entire *canaliculata* complex, and not only *P. insularum*, as misidentification of species is likely and further import of *P. insularum* and *P. canaliculata* cannot be excluded. Likewise, if a ban on both breeding and trade of the organism is considered, the Panel suggests that such a ban should include the whole *canaliculata* complex. The Panel found that the risk reduction options listed in the Spanish PRA cover those that are used in integrated pest management of *Pomacea* spp. elsewhere in the world. The Panel identified some weak points that need further attention: (i) the effects on non-target organisms as a result of the mentioned risk reduction options are only superficially touched upon and need to be further developed; (ii) more attention should be given to early detection and control of the snail's eggs to prevent further dispersal; and (iii) the issue of provision of information deserves more attention as knowledge of the snail problem at the level of stakeholders, environmental management professionals and the public is crucial to allow early detection, to prevent further spread and to generate rapid reports of its presence to the managing authorities.

The Panel recognises that the evaluation of the impact of *Pomacea* spp. on animal and human health falls outside its remit; however, it wishes to note that, owing to the seriousness of this potential impact, it should be assessed by the competent authorities.

RECOMMENDATIONS

As the Panel found essential information about the environmental consequences in the Spanish PRA lacking and available studies on the effects of *Pomacea* spp. on natural wetland ecosystems show strong negative and fairly predictable impacts on biodiversity, ecosystem functioning and ecosystem services, the Panel recommends that an appropriate environmental risk assessment is conducted according to the recently developed EFA PLH Guidance Document (EFSA Panel on Plant Health (PLH), 2011a: Guidance on the environmental risk assessment of plant pests) to give a better estimate of the potential effects of apple snails on biodiversity and ecosystem processes in the PRA area.

Further, the Panel recommends a detailed climatic study, which should not only give a clearer idea of the extent (particularly the northern limits) of the wetlands that are vulnerable but should also help to clarify the number of possible generations of *Pomacea* spp., their population density and the level of economic and environmental impacts that can be expected.

Because of the grave concern for rice production and wetland ecology in the EU, the Panel recommends to target research for the study of the biology of *Pomacea* spp. snails in the Ebro Delta to reduce important uncertainties highlighted in the PRA.

Finally, the Panel recommends exploring and testing new control techniques to improve those already used, because no single currently used risk reduction option has the potential to eradicate the snail from the area of infestation at present. Moreover, many of the currently used risk reduction options have negative effects on non-target organisms and the associated crop and natural wetland environment.

DOCUMENTATION PROVIDED TO EFSA

1. Letter requesting a scientific opinion (Ref: SANCO E2/GC/ap (2011) 1105590/1070674). October 2010. Submitted by the European Commission.

2. Pest Risk Analysis on the introduction of *Pomacea insularum* (d'Orbigny, 1835) into the EU. April 2011. Prepared by the Spanish Ministry of Environment and Rural and Marine Affairs.

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APPENDICES

A. RATINGS AND DESCRIPTORS

In order to follow the principle of transparency, as described under paragraph 3.1 of the guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010a) – "(…) Transparency requires that the scoring system to be used is described in advance. This includes the number of ratings, the description of each rating (…)" – to provide clear justification when a rating is given. The Panel has specifically adapted for this scientific opinion rating descriptors from the pest risk assessments on *Gibberella circinata* (EFSA Panel on Plant Health (PLH) 2010b) and on *Monilinia fructicola* (EFSA Panel on Plant Health (PLH) 2011b).

The rating system comprises five levels with descriptors used to formulate separately the conclusions on entry, establishment, spread and impact. The Panel also provides rating descriptors for the uncertainties. The rating systems are described in the following tables.

1. Rating of probability of entry (for unintentional introduction)

Rating for entry	**Descriptors for *Pomacea* spp.**
Very unlikely	The likelihood of entry is very low because the pest: • is not or is only occasionally associated with the pathway at the origin; • is very easily detected at inspection; • may not survive during transport or storage; • cannot survive the current pest management procedures existing in the risk assessment area; and/or • may not transfer to a suitable host in the risk assessment area
Unlikely	The likelihood of entry is low because the pest: • is rarely associated with the pathway at the origin; • is easily detected at inspection; • survives at a very low level during transport or storage; • is strongly affected by the current pest management procedures existing in the risk assessment area; and/or • has considerable limitations for transfer to a suitable host in the risk assessment area
Moderately likely	The likelihood of entry is moderate because the pest: • is frequently associated with the pathway at the origin; • can be detected at inspection with some difficulty; • survives at a low level during transport or storage; • is affected by the current pest management procedures existing in the risk assessment area; and/or • has some limitations for transfer to a suitable host in the risk assessment area
Likely	The likelihood of entry is high because the pest: • is regularly associated with the pathway at the origin; • is difficult to be detected at inspection; • mostly survives during transport or storage; • is partially affected by the current pest management procedures existing in the risk assessment area; and/or

	• has very few limitations for transfer to a suitable host in the risk assessment area
Very likely	The likelihood of entry is very high because the pest: • is usually associated with the pathway at the origin; • cannot be detected at inspection; • survives during transport or storage; • is not affected by the current pest management procedures existing in the risk assessment area; and/or • has no limitations for transfer to a suitable host in the risk assessment area.

2. Rating of probability of establishment

Rating for establishment	**Descriptors for *Pomacea* spp.**
Very unlikely	The likelihood of establishment is very low because either the host plants and suitable habitats are not present in the risk assessment area or, when present, the environmental conditions are unsuitable; other considerable obstacles to establishment occur
Unlikely	The likelihood of establishment is low because, even though the host plants and suitable habitats are present in the risk assessment area, the environmental conditions are mostly unsuitable; other obstacles to establishment occur
Moderately likely	The likelihood of establishment is moderate because, even though the host plants and suitable habitats are present in the risk assessment area, the environmental conditions are frequently unsuitable; other obstacles to establishment may occur
Likely	The likelihood of establishment is high because the host plants and suitable habitats are present in the risk assessment area; no other obstacles to establishment occur
Very likely	The likelihood of establishment is very high because the host plants are present in the risk assessment area, and the environmental conditions are suitable for most of the host growing season; no other obstacles to establishment occur. Alternatively, the pest has already been established in the risk assessment area

3. Rating of probability of spread

Rating for spread	**Descriptors for *Pomacea* spp.**
Very unlikely	The likelihood of spread is very low because: • the pest has only one specific way of spreading, which is not present in the risk assessment area; • highly effective barriers to spread exist; • the host and/or suitable habitat is not or is occasionally present in the area of possible spread; and/or

	• the environmental conditions for invasion are unsuitable in the area of possible spread
Unlikely	The likelihood of spread is low because: • the pest has one to few specific ways of spreading and their occurrence in the risk assessment area is occasional; • effective barriers to spread exist; • the host and/or suitable habitat is not frequently present in the area of possible spread; and/or • the environmental conditions for invasion are mostly unsuitable in the area of possible spread
Moderately likely	The likelihood of spread is moderate because: • the pest has few specific ways of spreading (e.g. specific vectors) and their occurrence in the risk assessment area is limited; • effective barriers to spread exist; • the host and/or suitable habitat is moderately present in the area of possible spread; and/or • the environmental conditions for invasion are frequently unsuitable in the area of possible spread
Likely	The likelihood of spread is high because: • the pest has some unspecific ways of spreading, which occur in the risk assessment area; • no effective barriers to spread exist; • the host and/or suitable habitat is usually present in the area of possible spread; and/or • the environmental conditions for invasion are frequently suitable in the area of possible spread
Very likely	The likelihood of spread is very high because: • the pest has multiple unspecific ways of spreading, which all occur in the risk assessment area; • no effective barriers to spread exist; • the host and/or suitable habitat is widely present in the area of possible spread; and/or • the environmental conditions for invasion are mostly suitable in the area of possible spread

4. Rating of magnitude of the potential consequences on crops

Rating of potential consequences	**Descriptors for *Pomacea* spp.**
Minimal	Effects on crop production are not distinguishable from normal variation; no additional control measures are required
Minor	Crop production is not or occasionally reduced; additional control measures are not necessary
Moderate	Crop production is rarely reduced; additional control measures are sometimes necessary
Major	Crop production is frequently reduced; additional control measures are frequently necessary
Massive	Crop production is always reduced; additional control measures are always necessary

5. Rating of magnitude of the potential environmental consequences

Rating of potential consequences	**Descriptors for *Pomacea* spp.**
Minimal	Effects on species providing ecosystem services, including those arising from pest management measures (e.g. application of pesticides), via competition, changes in mutualism, impact on natural enemies or pathogens of the above organisms that may result in a negative effect on other species providing the ecosystem function, and/or impacts on biodiversity (e.g. on rare species, genetic diversity, population viability and habitat fragmentation) are not distinguishable from normal variation in the composition of the plant and animal communities
Minor	Effects on species providing ecosystem services, including those arising from pest management measures (e.g. application of pesticides), via competition, changes in mutualism, impact on natural enemies or pathogens of the above organisms that may result in a negative effect on other species providing the ecosystem function, and/or impacts on biodiversity (e.g. on rare species, genetic diversity, population viability, and habitat fragmentation) resulting in temporary changes in the composition of the plant and animal communities
Moderate	Effects on species providing ecosystem services, including those arising from pest management measures (e.g. application of pesticides), via competition, changes in mutualism, impact on natural enemies or pathogens of the above organisms that may result in a negative effect on other species providing the ecosystem function, and/or impacts on biodiversity (e.g. on rare species, genetic diversity, population viability and habitat fragmentation) are permanent, but the ecosystem is still dominated by macrophytes
Major	Effects on species providing ecosystem services, including those arising from pest management measures (e.g. application of pesticides), via competition, changes in mutualism, impact on natural enemies or pathogens of the above organisms that may result in a negative effect on other species providing the ecosystem function, and/or impacts on biodiversity (e.g. on rare species, genetic diversity, population viability and habitat fragmentation) result in a perturbed ecosystem with decreased macrophyte and increased phytoplankton communities
Massive	Effects on species providing ecosystem services, including those arising from pest management measures (e.g. application of pesticides), via competition, changes in mutualism, impact on natural enemies or pathogens of the above organisms that may result in a negative effect on other species providing the ecosystem function, and/or impacts on biodiversity (e.g. on rare species, genetic diversity, population viability and habitat fragmentation) result in a change in the state of the ecosystem from a macrophyte- to a phytoplankton-dominated environment

6. Ratings used for describing the level of uncertainty

Rating	Descriptors
Low	No or few information or data are missing, incomplete, inconsistent or conflicting. No subjective judgement is introduced. No unpublished data are used. Where models are used: (i) input data are clearly described and contain only minor measurement errors; (ii) model assumptions, structure, methods, algorithms and limitations are clearly described; (iii) output is clearly described with sensitivity and uncertainty analysis.
Medium	Some information or data are missing, incomplete, inconsistent or conflicting. Subjective judgement is introduced with supporting evidence. Unpublished data are sometimes used. Where models are used: (i) input data are not clearly described and/or contain measurement errors; (ii) model assumptions, structure, methods, algorithms and limitations are not clearly described; (iii) output is not clearly described and neither sensitivity nor uncertainty analysis is available.
High	The greater part of information or data are missing, incomplete, inconsistent or conflicting. Subjective judgement may be introduced without supporting evidence. Unpublished data are frequently used. Where models are used: (i) input data are not described and/or contain measurement errors; (ii) model assumptions, structure, methods, algorithms and limitations are not described; (iii) output is not described and neither sensitivity nor uncertainty analysis is available

B. Technical details on Climate Matching with CLIMEX and Climate Match Indices

1. Technical details

In climate matching, comparisons of climate are made between one "Home" location where the pest is present and any number of "Away" locations. The level of similarity is given by the "composite match index" (CMI), which is the product of six component indices, I_{tmax}, I_{tmin}, I_{rain}, I_{rpat}, I_{hum} and I_{sm}, indicating similarity in maximum and minimum temperature, total rainfall, rainfall pattern, relative humidity (RH) and soil moisture, respectively. Each of these component indices can range between 0 and 1, with a value of 1 indicating an exact match with the "Home" location. All indices can be weighted individually (using CMI weights) to emphasise the more important variables. The default weight setting is 1.0 for each index, except the RH index, which has a default weighting of zero. When data from locations in different hemispheres are compared, data from the southern hemisphere are displaced by 6 months.

Default settings of weights:

Index	Weight	Default value
I_{tmin}	W1	1
I_{tmax}	W2	1
I_{tav}	W3	0
I_{rain}	W4	1
I_{rpat}	W5	1
I_{hum}	W6	0
I_{smst}	W7	0

The calculations used to derive the match indices are given below.

Maximum and minimum temperature match indices, I_{tmax}, I_{tmin} and I_{tav}

$I_{tmax} = \exp(-k_T T_{dmax})$

$I_{tmin} = \exp(-k_T T_{dmin})$

$I_{tav} = \exp(-k_T T_{dav})$

T_{dmax}, T_{dmin} and T_{dav} are the means of the weekly absolute differences in maximum, minimum and average temperatures, respectively, between the two locations. The constant, k_T, is set to 0.1, thus giving values for the index of 0.9 for a mean weekly difference of 1 °C, and 0.6 for a mean weekly difference of 5 °C.

Total rainfall match index, $I_{rtot} = \exp(-k_R R_d)$

where, $R_d = abs(R_T – R_M)/(1 + a (R_T + R_M))$,

R_T = annual rainfall at home location and

R_M = annual rainfall at matching location.

R_d is the difference in annual rainfall between the two locations, adjusted so that a (say) 100 mm difference in rainfall is more significant for locations with lower rainfall. CLIMEX uses values of 0.001 and 0.004 for the constants R_d and k_R, respectively. With these values, a difference in rainfall of 200 mm per year between two locations will result in an index of 0.64 if the average rainfall for the two locations is 400 mm, and a value of 0.85 if the average rainfall is 2000 mm.

Rainfall pattern index, $I_{rpat} = \exp(-k_P R_D)$

R_D is the mean of the absolute difference between the weekly rainfall of the "Home" and "Away" location, after the weekly rainfall of the "Home" location has been multiplied by R_z ($R_z = R_M/R_T$). R_M and R_T have the same meanings as in the previous section. The constant, k_P, is set to 0.005, thus giving values for the index of 0.9 for a mean weekly difference of 20 mm, and 0.6 for a mean monthly difference of 100 mm.

Humidity index, $I_{hum} = \exp(-k_H H_d)$
H_d is the mean of the weekly absolute differences in relative humidity between the two locations. The constant, k_H, is set to 0.024, so that a difference of 10 % gives an index of 0.8, and a difference of 20 % and index of 0.6.

Soil moisture index, $I_{sm} = \exp(-k_{SM} S_d)$
S_d is the mean of the monthly absolute differences in estimated soil moisture between the two locations. The constant, k_{SM}, is set to 1.2, so that a mean weekly difference of 0.1 in soil moisture gives an index of about 0.9 and a mean weekly difference of 0.2 gives an index of about 0.8.

The combined **temperature index**, $I_t = \frac{I_{min}\times W_1 + I_{max}\times W_2 \times I_{av}\times W_3}{W_1+W_2+W_3}$

The combined **moisture index**, $I_{tm} = \frac{I_{rtot}\times W_4 + I_{hum}\times W_6}{W_4+W_6}$

Rainfall pattern index, $I_{rp} = I_{rpat} \times W_5$

Soil moisture index, $I_{sm} = I_{smst} \times W_7$

The total **CMI** is then calculated as

$$CMI = \left(I_t^{wt} \times I_m^{wm} \times I_{rp}^{W_5} \times I_{sm}^{W_7}\right)^{1/(wt+wm+W_5+W_7)} \times 100$$

where ***wt*** is the maximum value of W_1, W_2 and W_3, and ***wm*** is the maximum of W_4 and W_6

2. Results

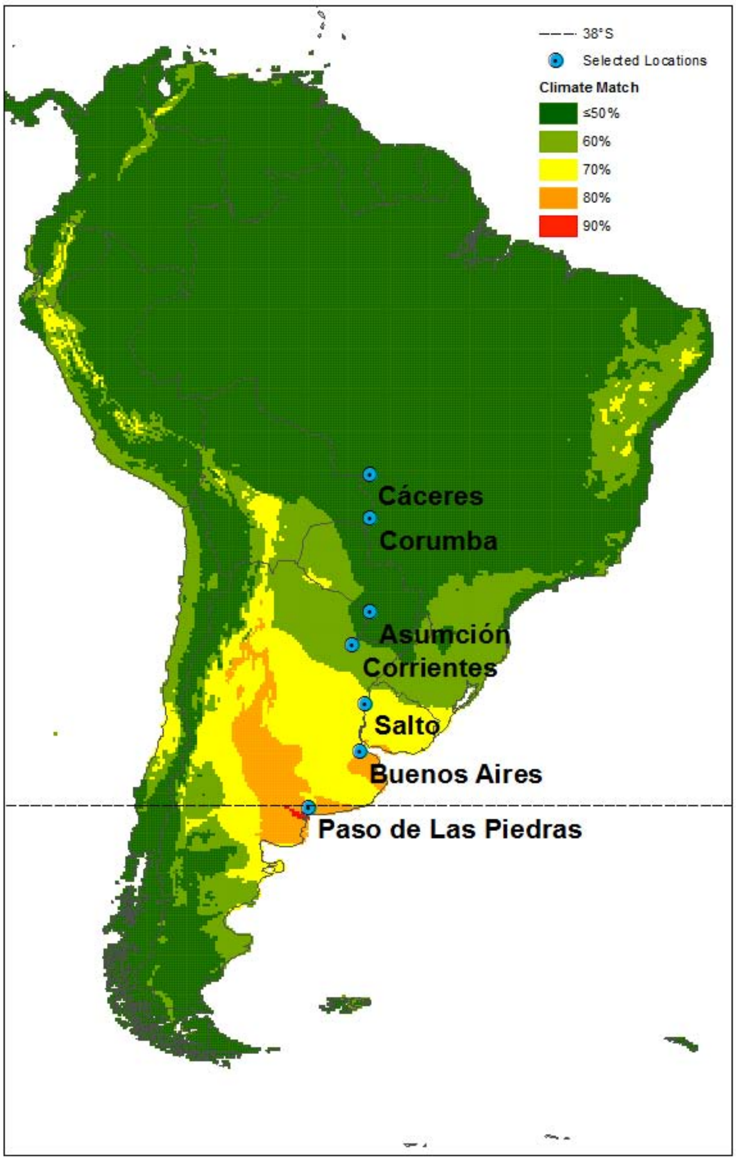

Figure 1: Climate match for South America compared with the climate of the Ebro Delta, Spain. Shown here are the six locations selected by Baker (1998) as kernel areas of the distribution of *P. canaliculata* to be matched with Asia and Australia.

2.1. Climate matching based on 1961–90 climate average

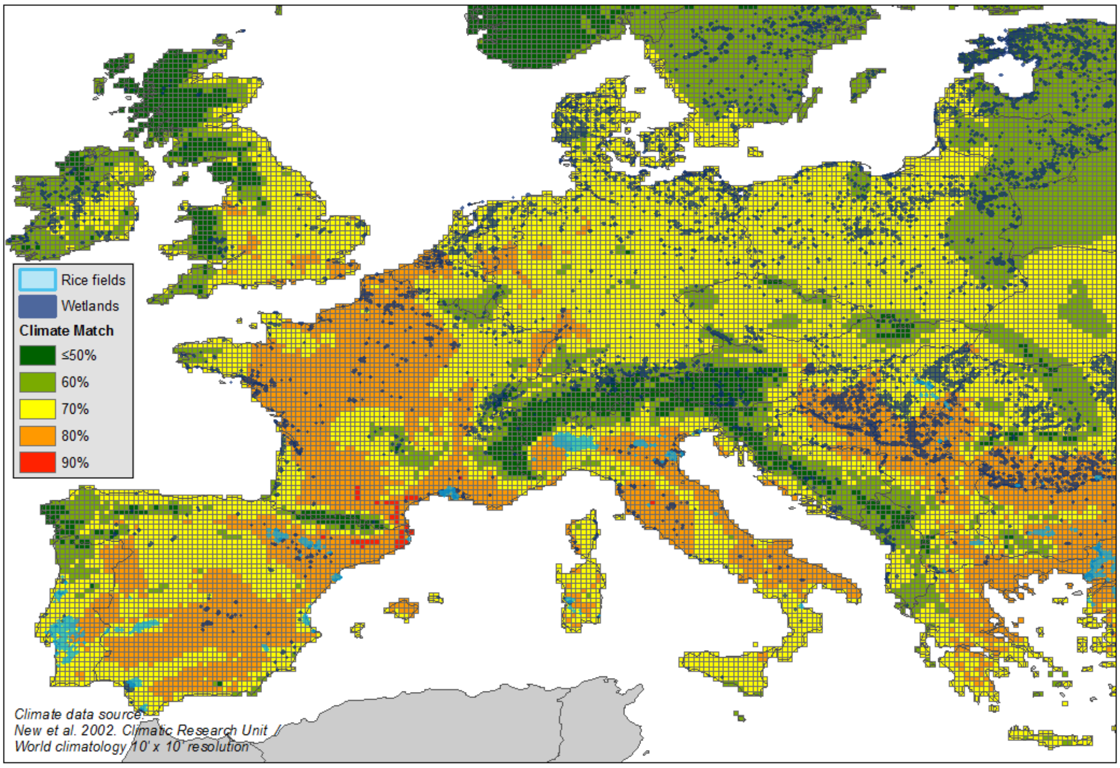

Figure 2: Climate match for Paso de las Piedras, Argentina, with Europe, indicating areas of wetlands and rice cropping.

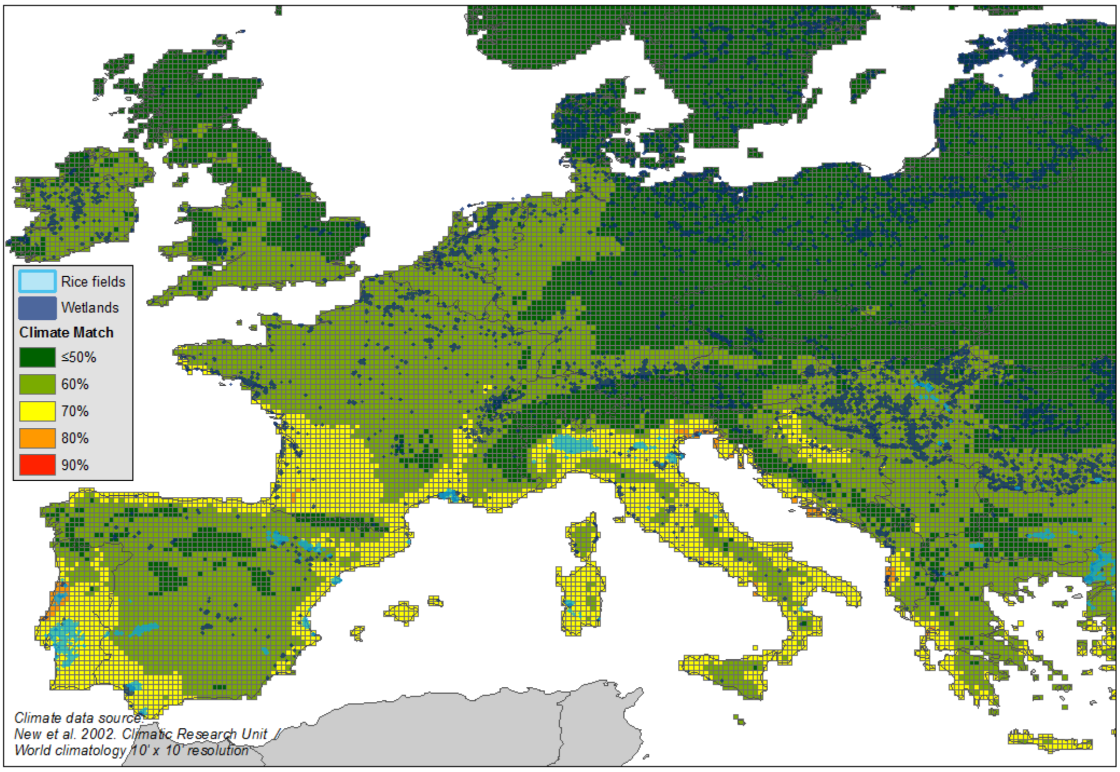

Figure 3: Climate match for Buenos Aires, Argentina, with Europe, indicating areas of wetlands and rice cropping.

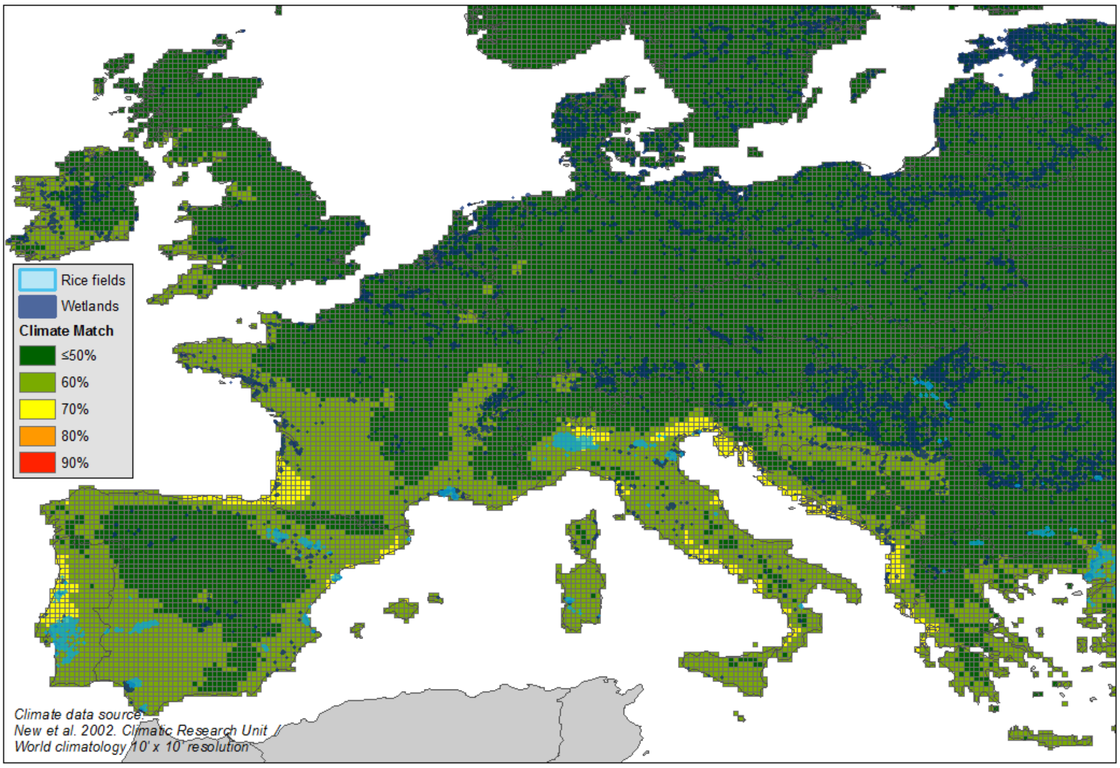

Figure 4: Climate match for Salto, Uruguay, with Europe, indicating areas of wetlands and rice cropping.

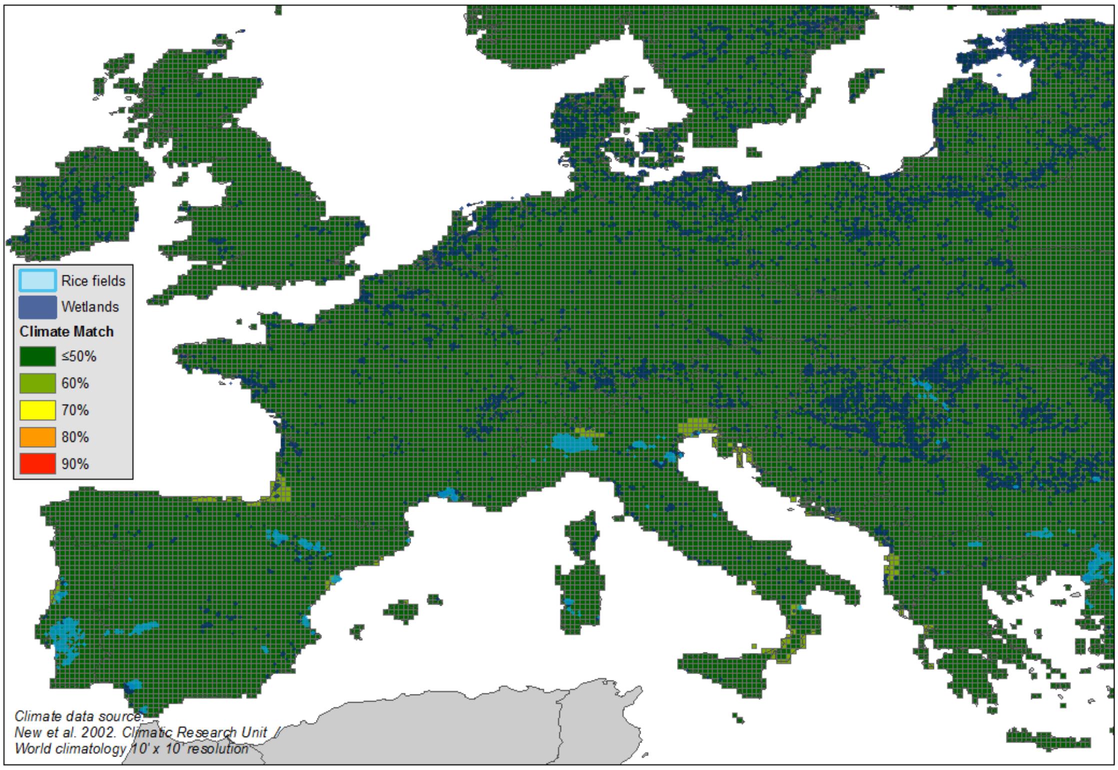

Figure 5: Climate match for Corrientes, Argentina, with Europe, indicating areas of wetlands and rice cropping.

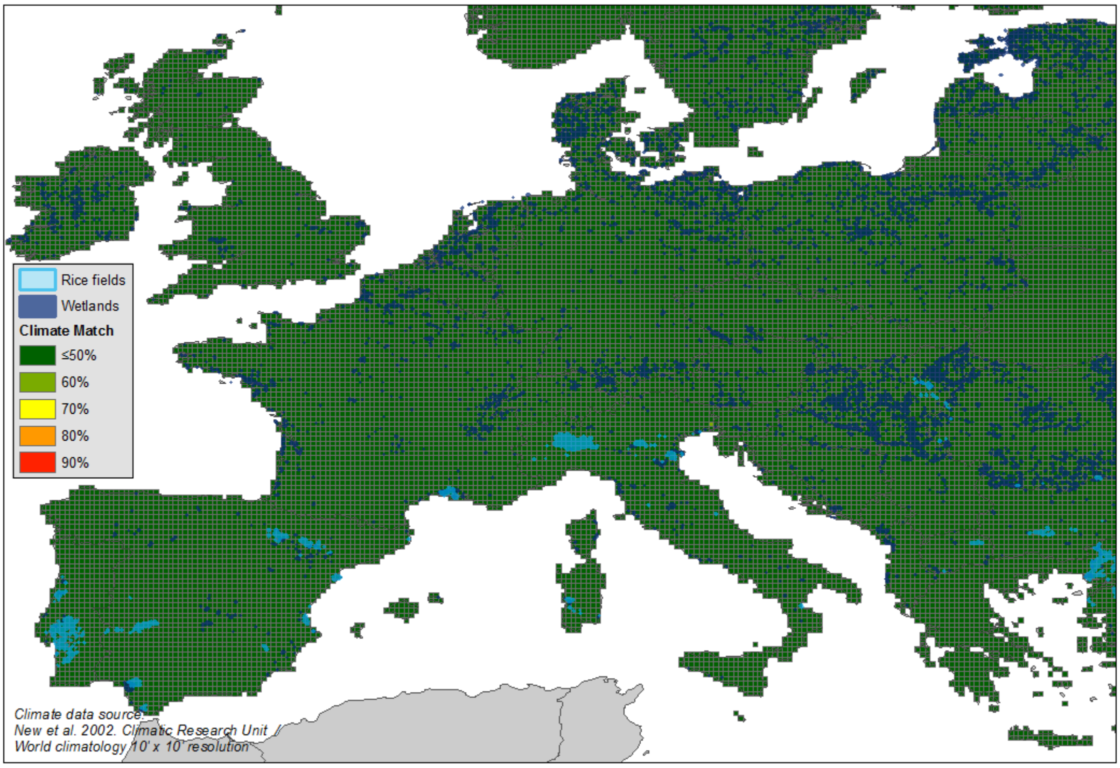

Figure 6: Climate match for Asunción, Paraguay, with Europe, indicating areas of wetlands and rice cropping.

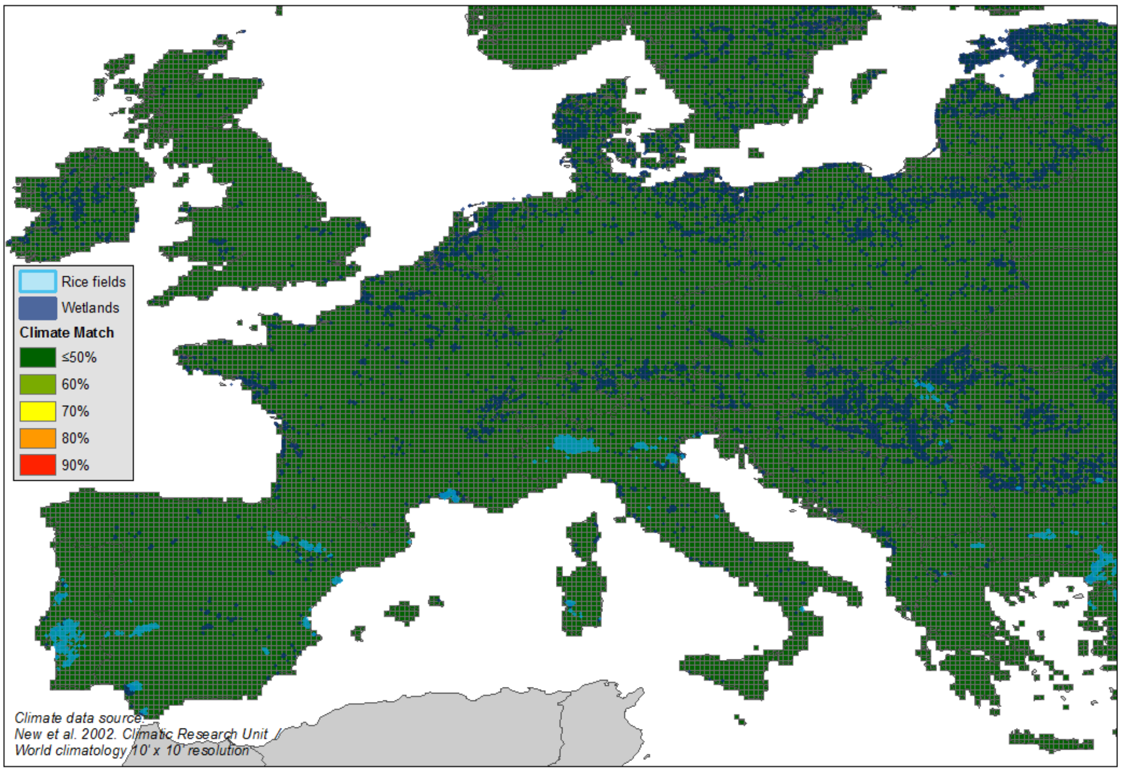

Figure 7: Climate match for Corumbá, Brazil, with Europe, indicating areas of wetlands and rice cropping.

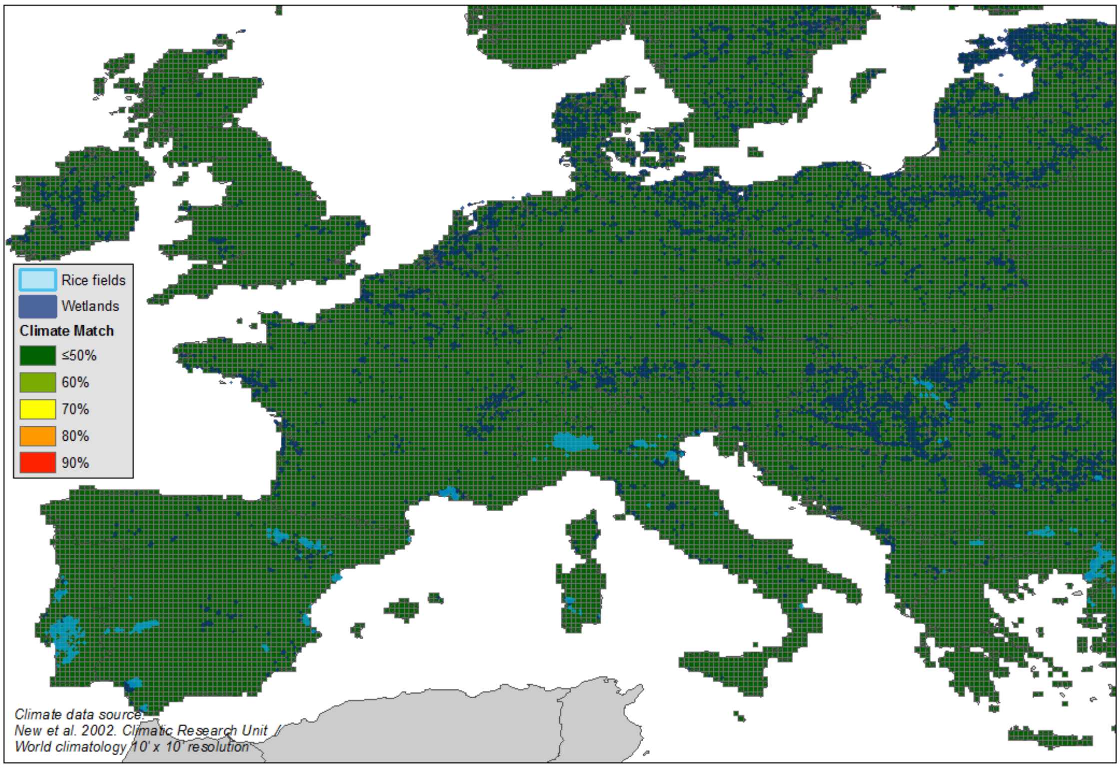

Figure 8: Climate match for Cáceres, Brazil, with Europe, indicating areas of wetlands and rice cropping.

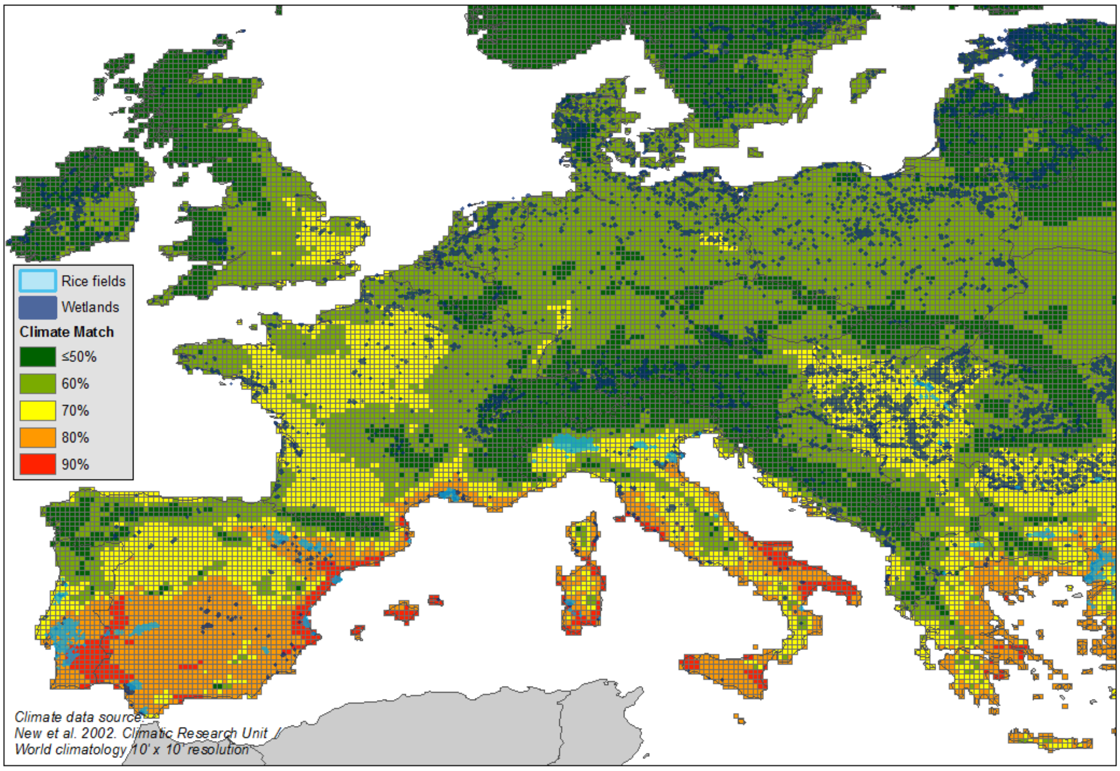

Figure 9: Climate match for the Ebro Delta with Europe, indicating areas of wetlands and rice cropping.

2.2. Climate matching based on 1961–90 climate average +1 °C scenario

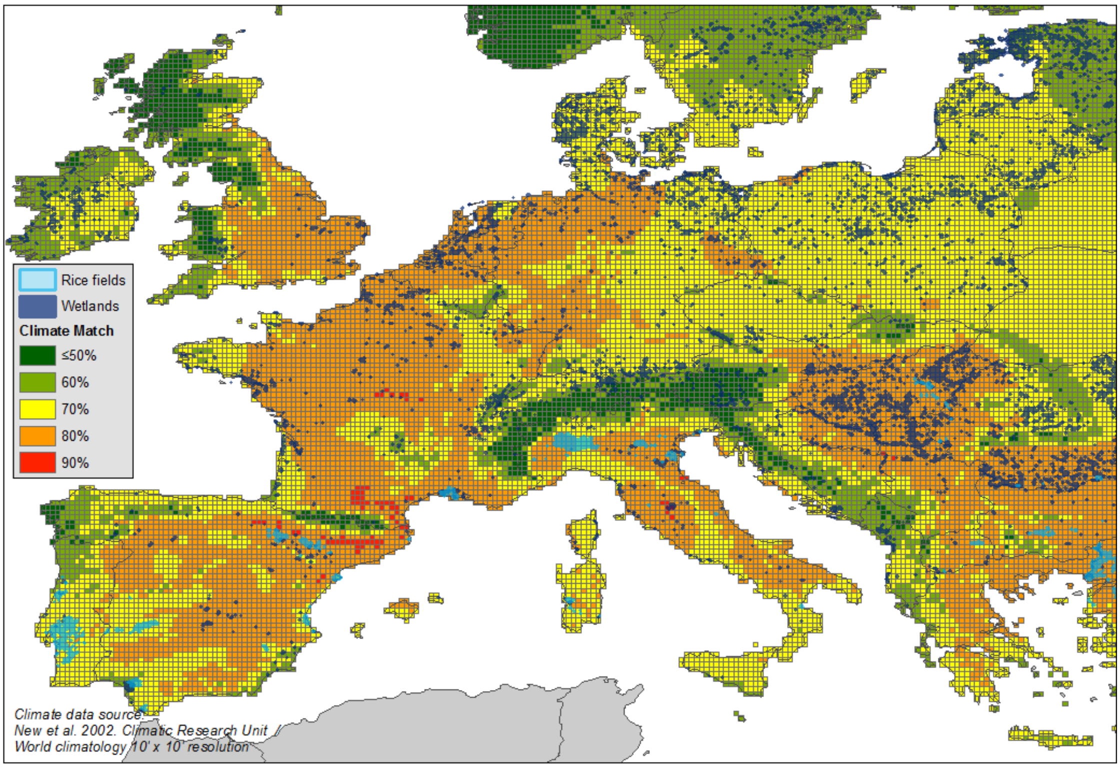

Figure 10: +1 °C scenario: climate match for Paso de las Piedras, Argentina, with Europe, indicating areas of wetlands and rice cropping fields.

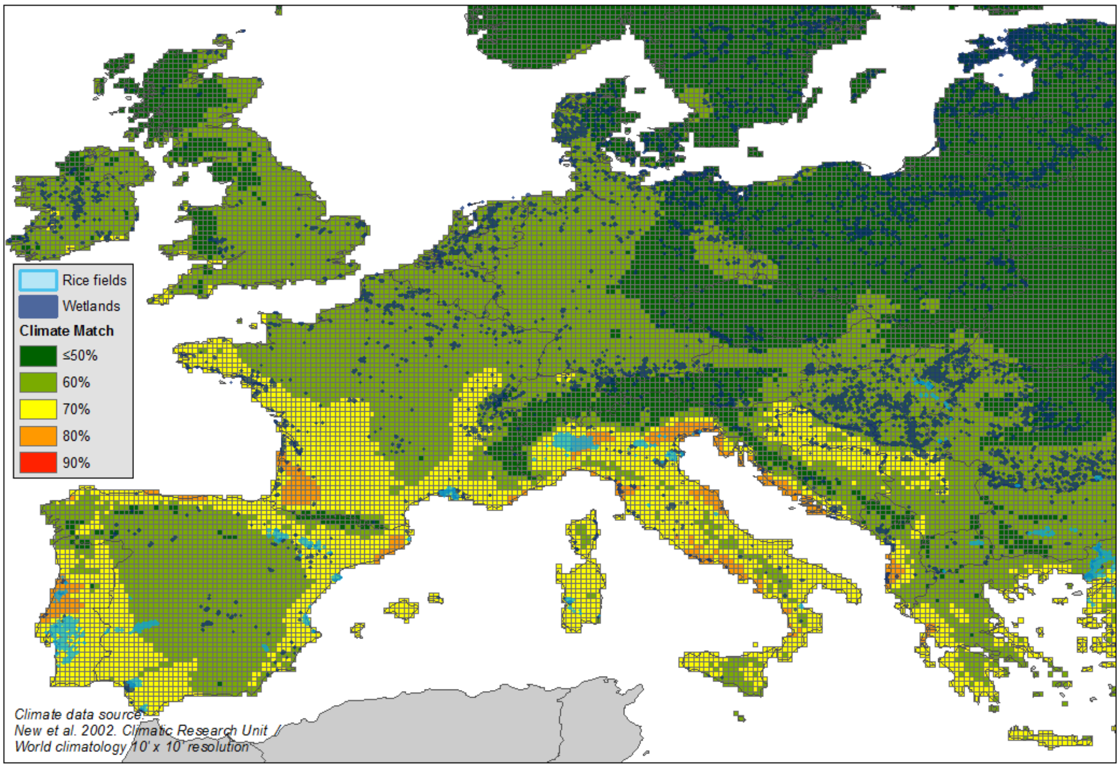

Figure 11: +1 °C scenario: climate match for Buenos Aires, Argentina, with Europe, indicating areas of wetlands and rice cropping.

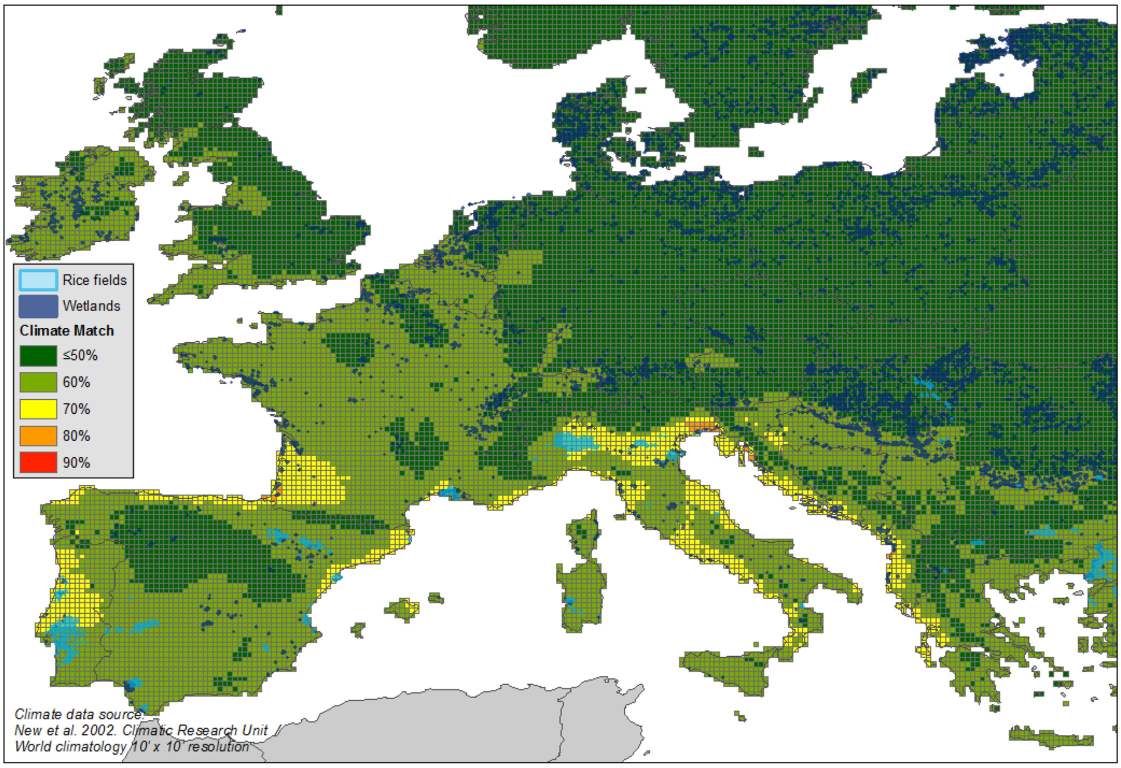

Figure 12: +1 °C scenario: climate match for Salto, Uruguay, with Europe, indicating areas of wetlands and rice cropping.

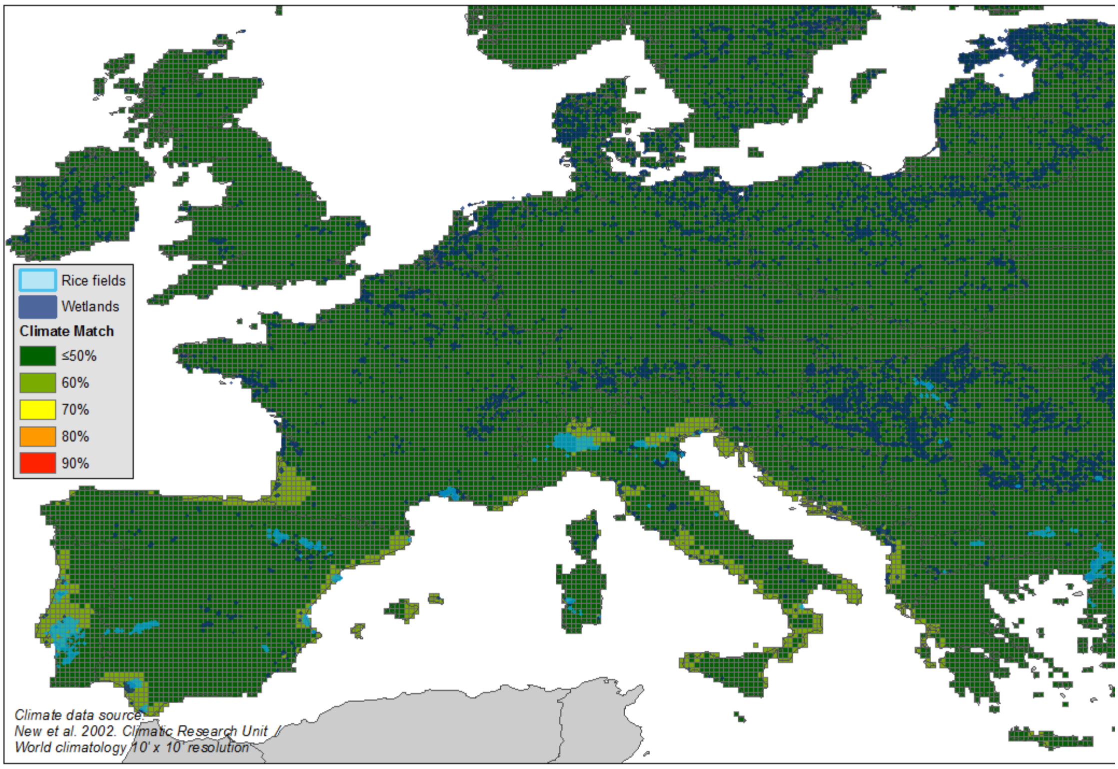

Figure 13: +1 °C scenario: climate match for Corrientes, Argentina, with Europe, indicating areas of wetlands and rice cropping.

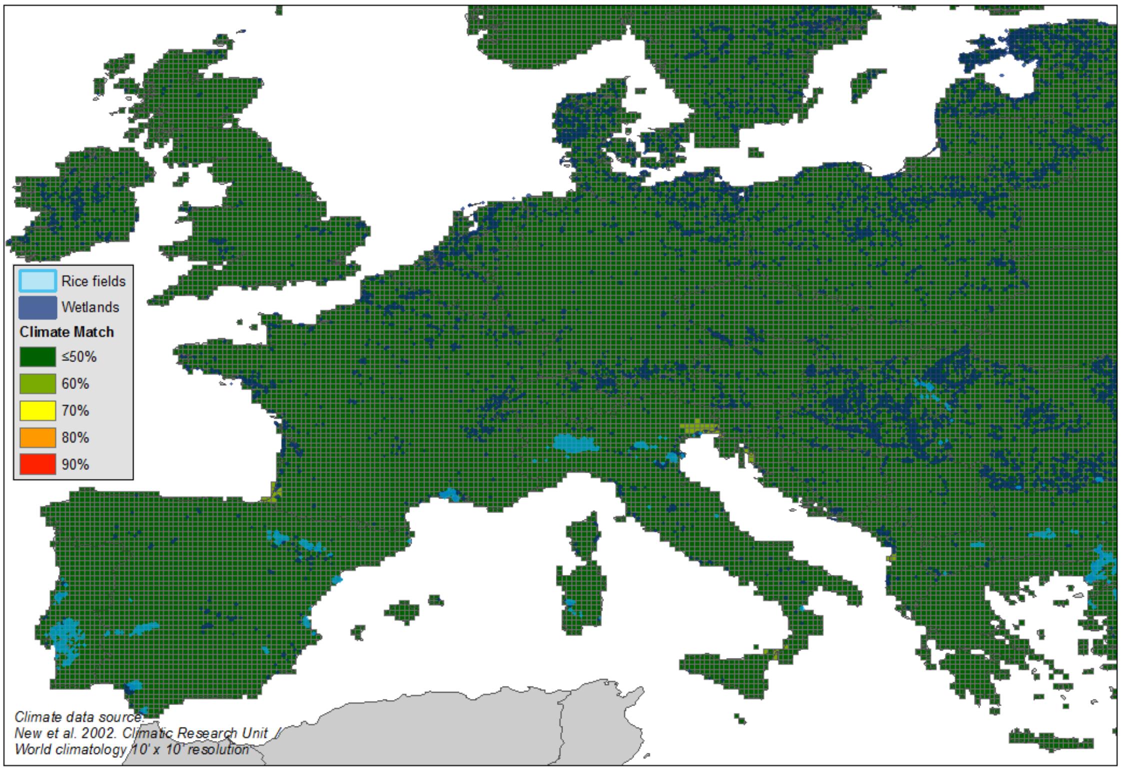

Figure 14: +1 °C scenario: climate match for Asunción, Paraguay, with Europe, indicating areas of wetlands and rice cropping.

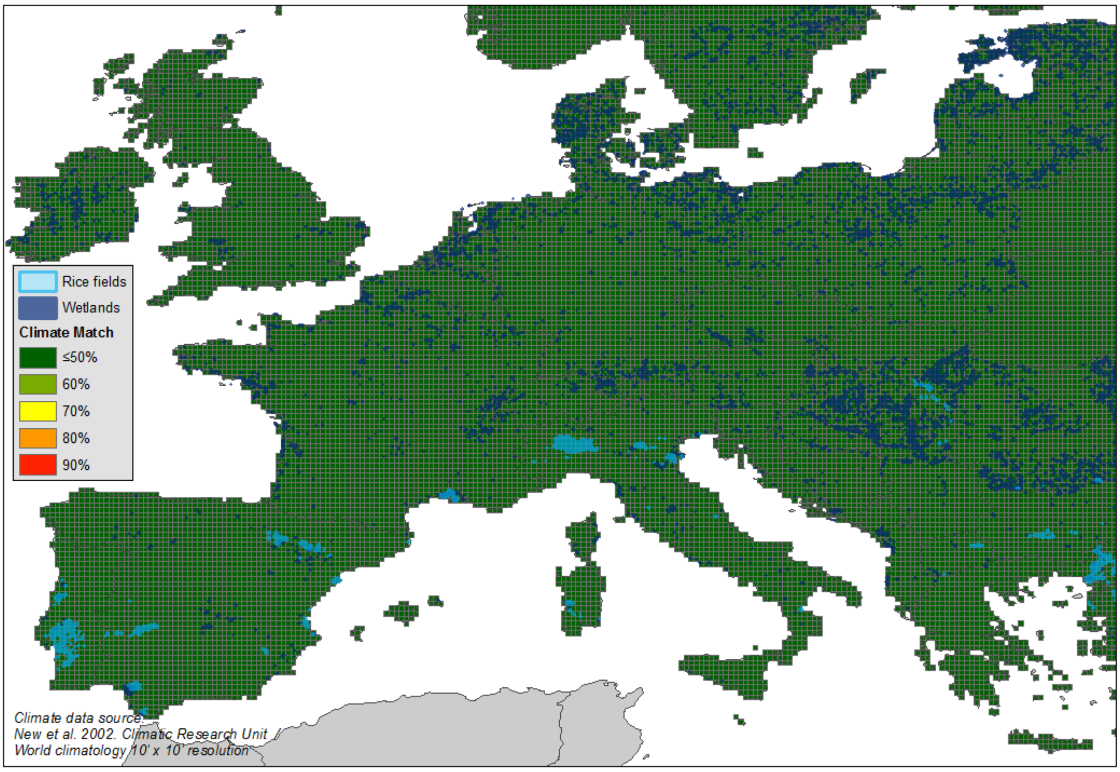

Figure 15: +1 °C scenario: climate match for Corumbá, Brazil, with Europe, indicating areas of wetlands and rice cropping.

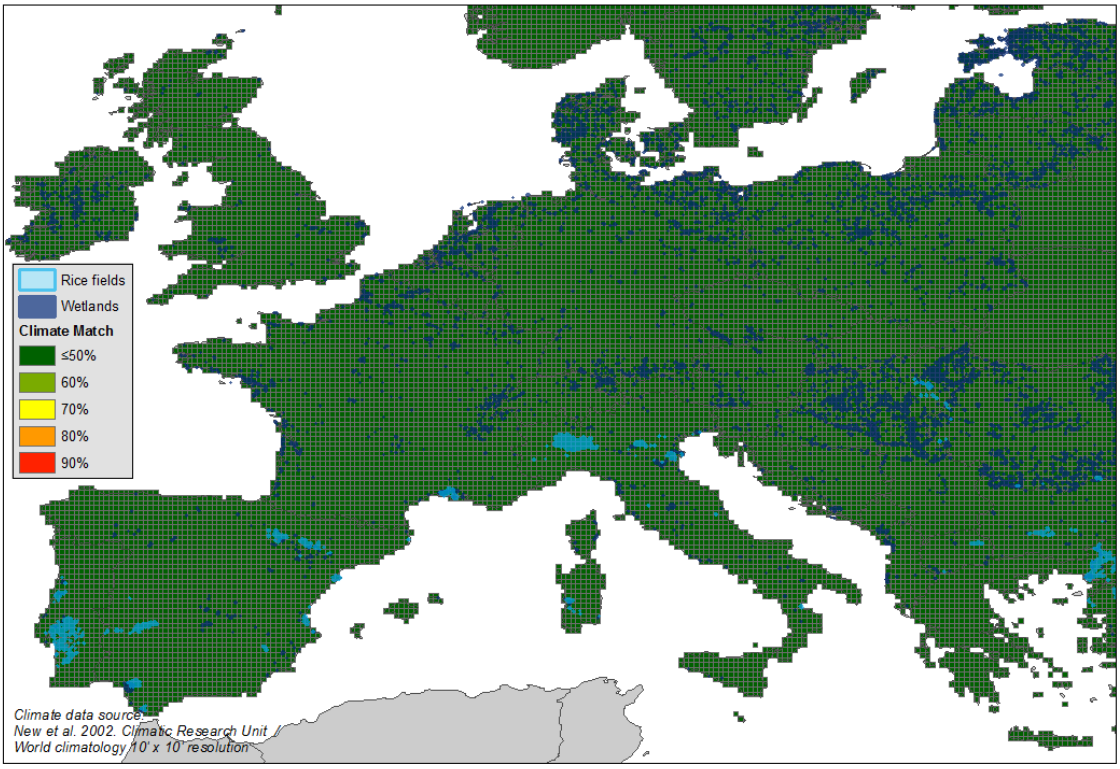

Figure 16: +1 °C scenario: climate match for Cáceres, Brazil, with Europe, indicating areas of wetlands and rice cropping.

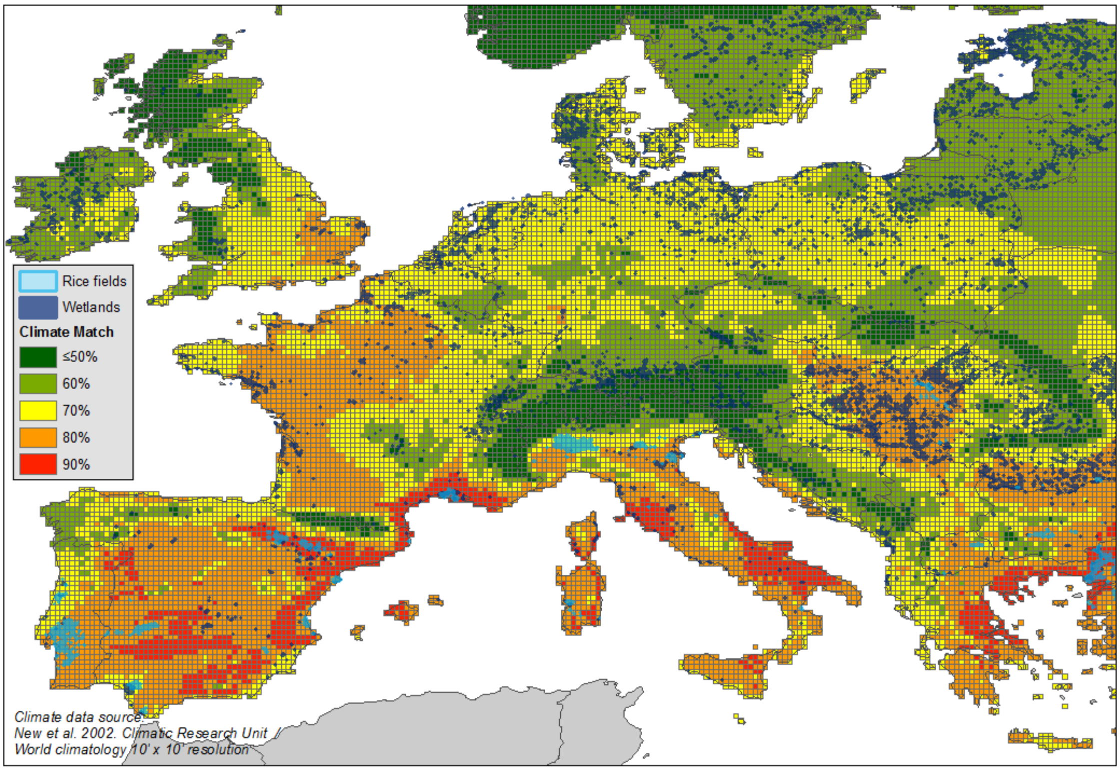

Figure 17: +1 °C scenario: climate match for the Ebro Delta with Europe, indicating areas of wetlands and rice cropping.

2.3. Climate matching based on 1961–90 climate average +2 °C scenario

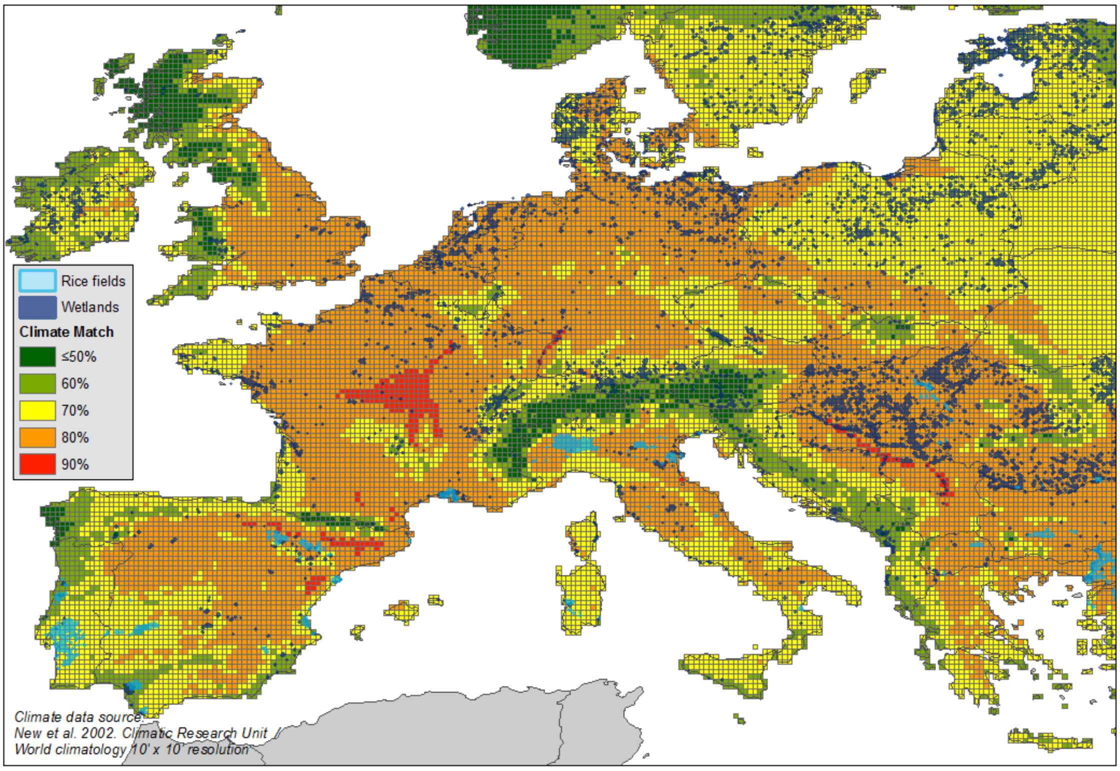

Figure 18: +2 °C scenario: climate match for Paso de las Piedras, Argentina, with Europe, indicating areas of wetlands and rice cropping.

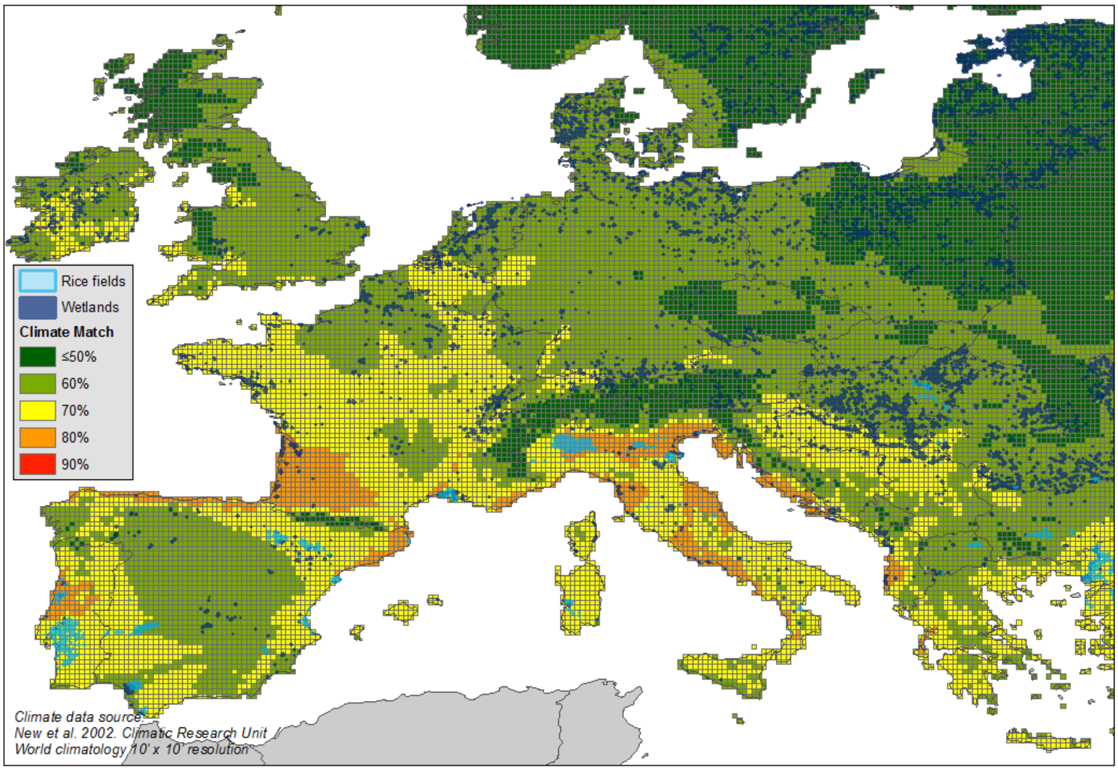

Figure 19: +2 °C scenario: climate match for Buenos Aires, Argentina, with Europe, indicating areas of wetlands and rice cropping.

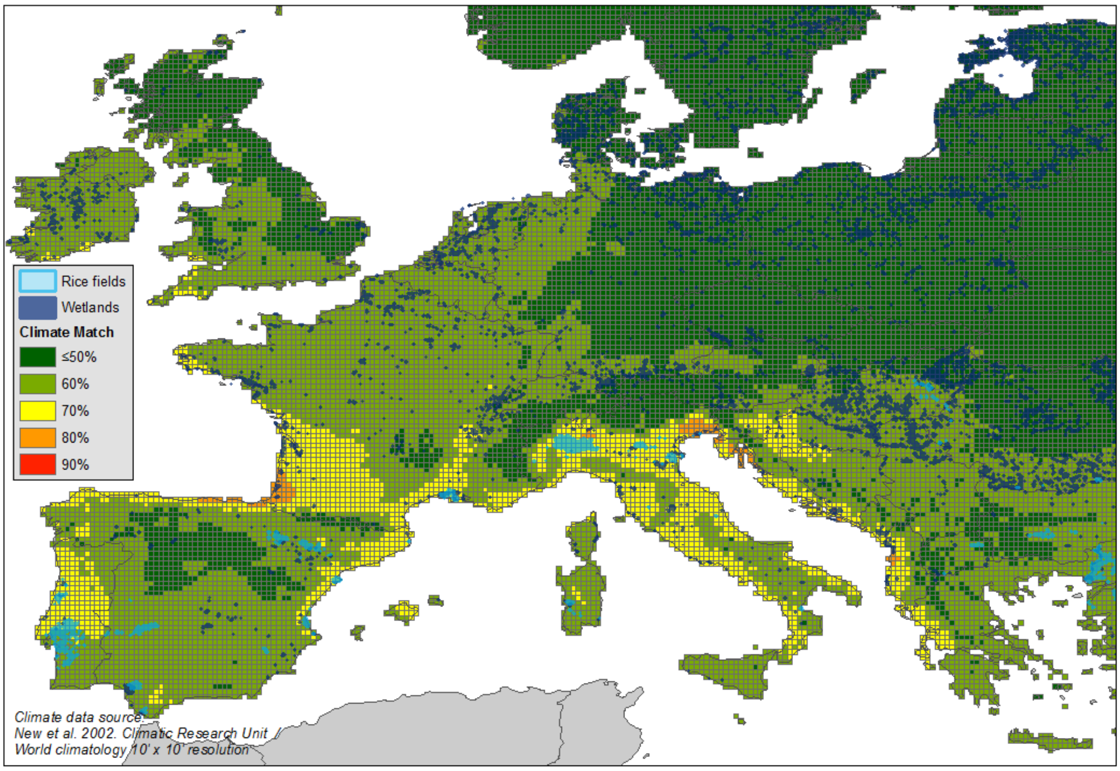

Figure 20: +2 °C scenario: climate match for Salto, Uruguay, with Europe, indicating areas of wetlands and rice cropping.

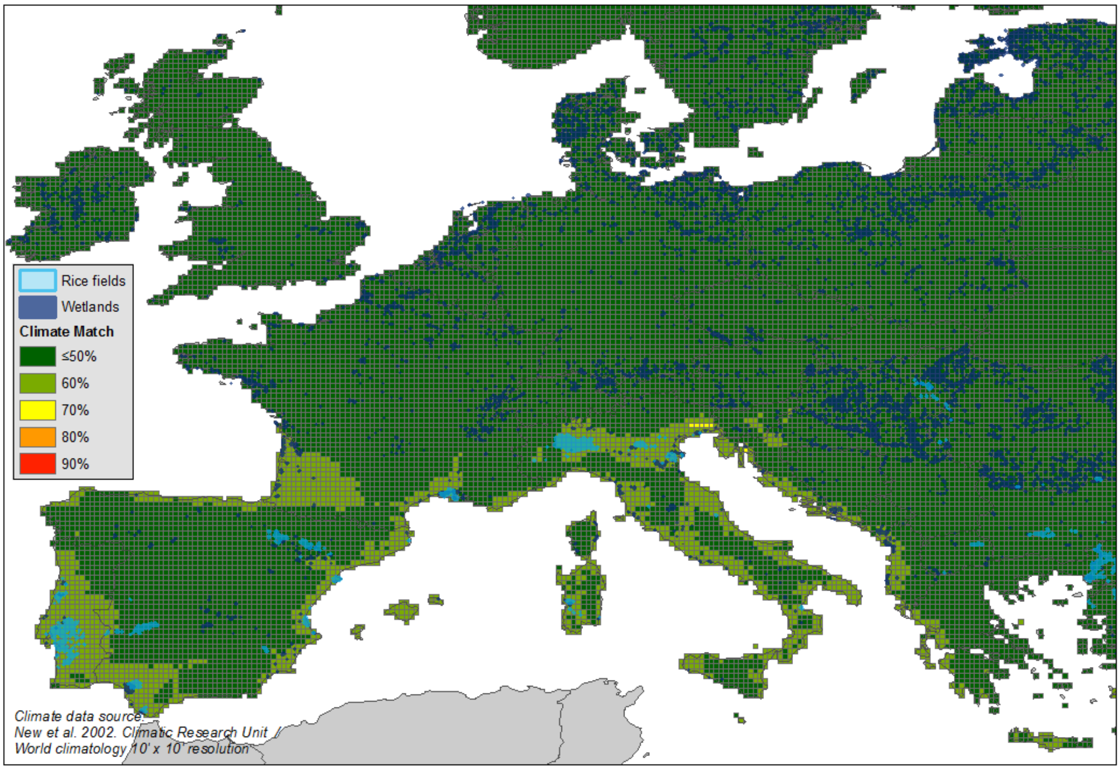

Figure 21: +2 °C scenario: climate match for Corrientes, Argentina, with Europe, indicating areas of wetlands and rice cropping.

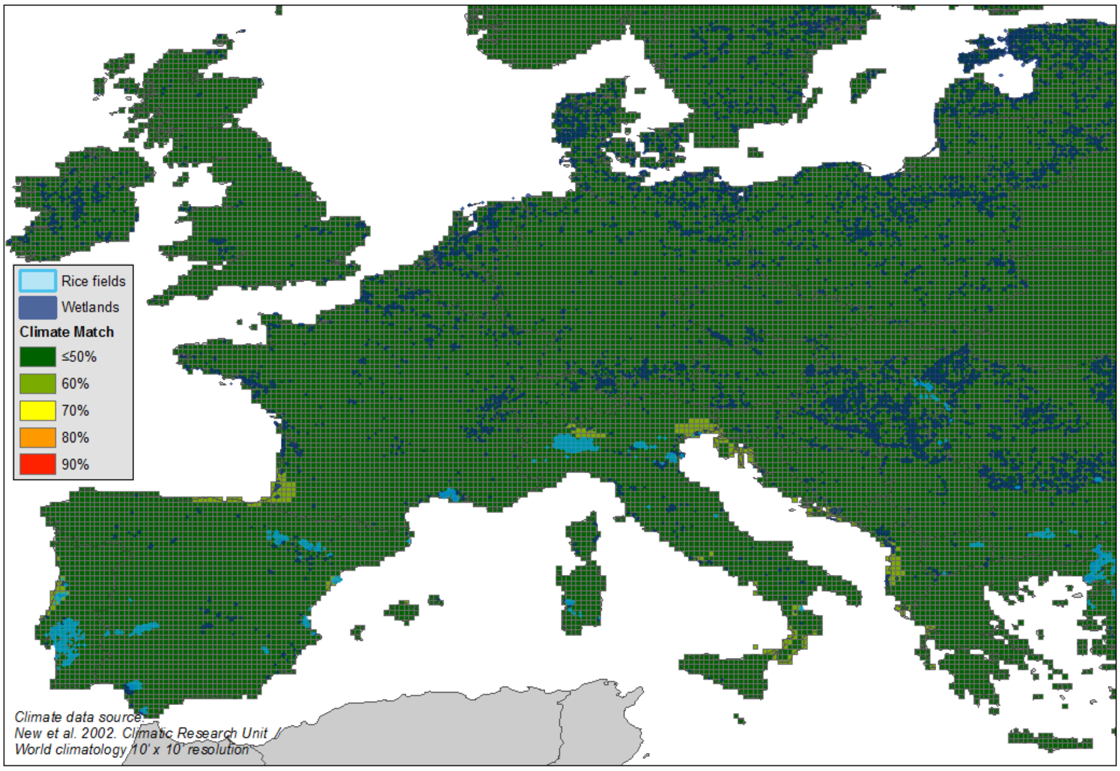

Figure 22: +2 °C scenario: climate match for Asunción, Paraguay, with Europe, indicating areas of wetlands and rice cropping.

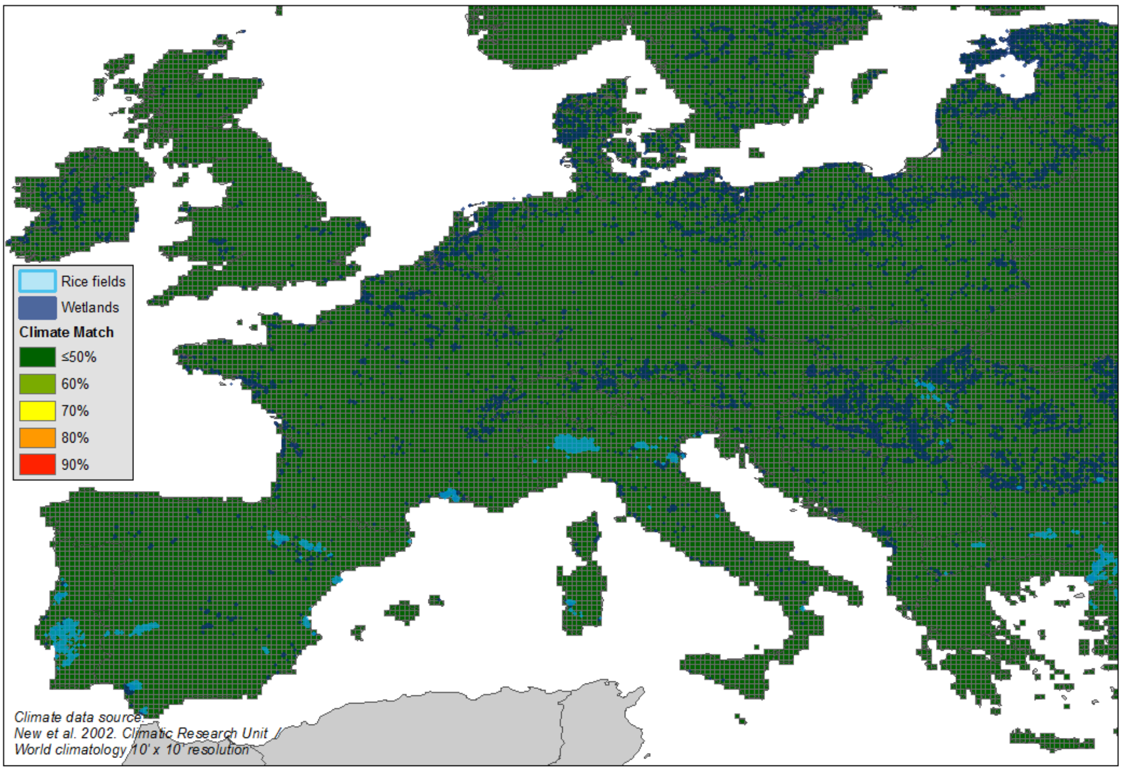

Figure 23: +2 °C scenario: climate match for Corumbá, Brazil, with Europe, indicating areas of wetlands and rice cropping.

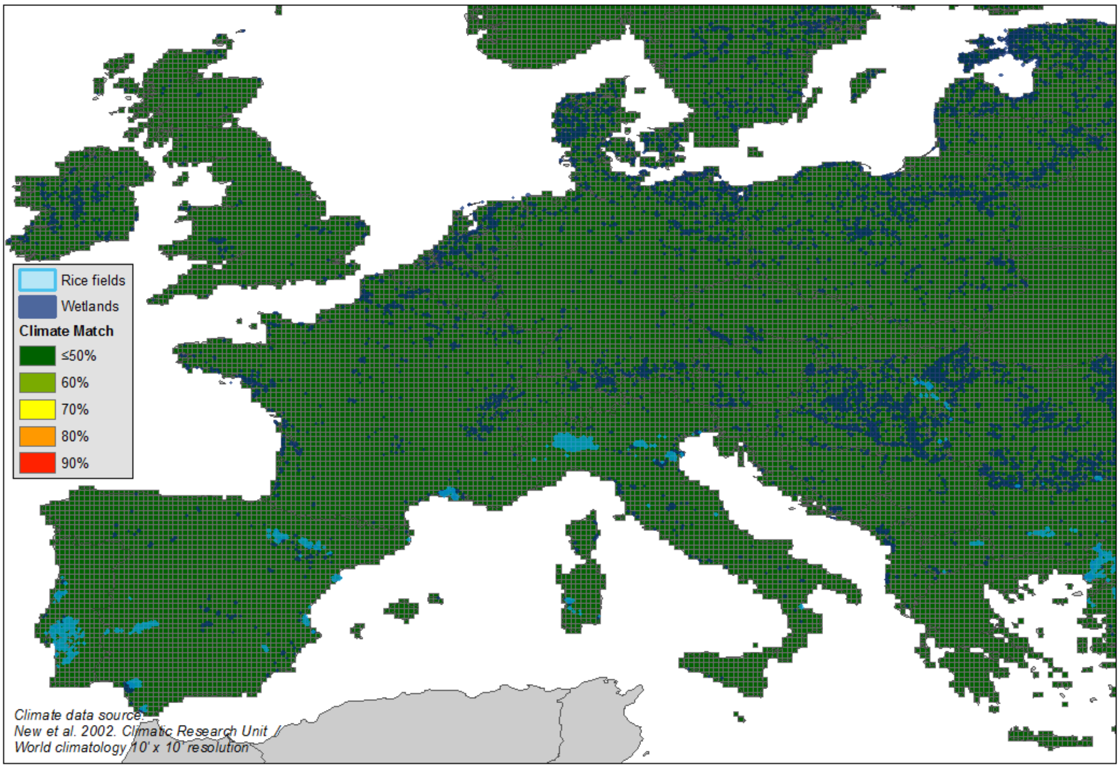

Figure 24: +2 °C scenario: climate match for Cáceres, Brazil, with Europe, indicating areas of wetlands and rice cropping.

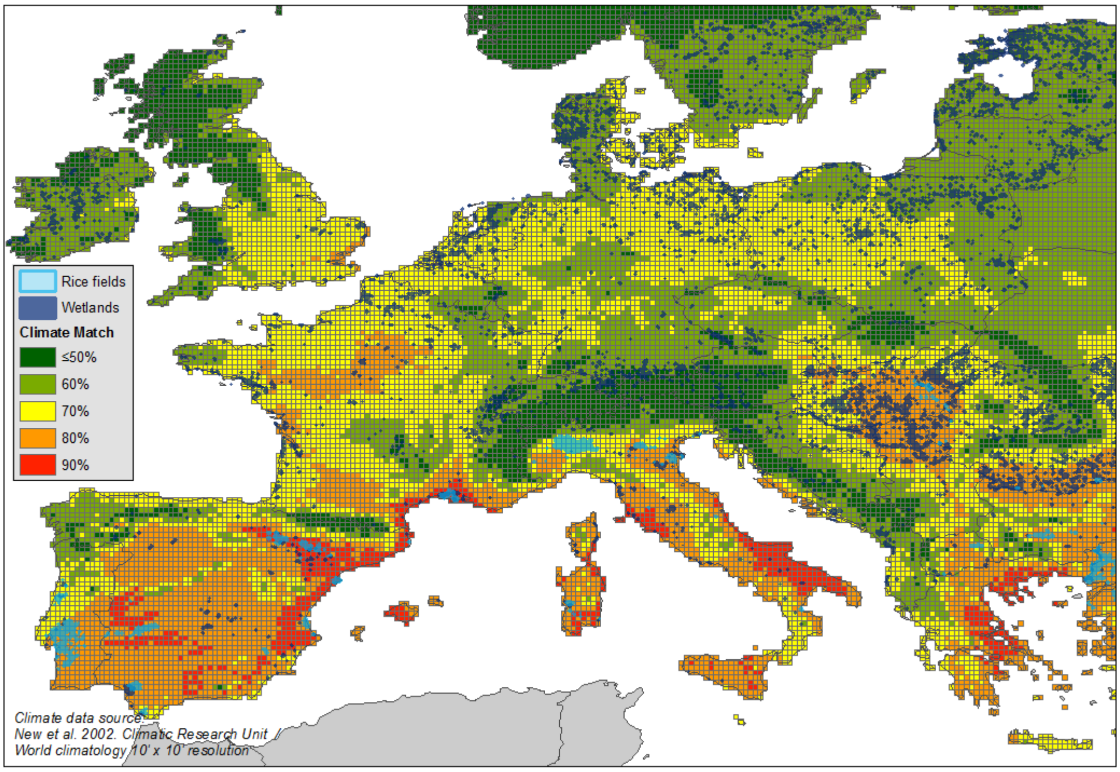

Figure 25: +2 °C scenario: climate match for the Ebro Delta with Europe, indicating areas of wetlands and rice cropping.

The climate match for Paso de las Piedras (Martín et al., 2001) with Europe was better than for Buenos Aires with Europe, therefore Paso de las Piedras was selected for calculation of the climate match areas following the hypothesis on perturbation of temperature regimes (+1 and +2 °C).

Table 1: Climate match areas of land (thousands of hectares) of Paso de las Piedras in Argentina with Europe

	Current climate			+1 °C warming			+2 °C warming		
Match index	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetland**
0.2	920			427			145		
0.3	22 337			16 929			12 829		
0.4	116 252		19	82 432		16	56 614		13
0.5	225 584		58	200 642		30	168 910		23
0.6	290 997	60	365	286 460	79	299	290 265	148	211
0.7	314 228	370	686	326 645	266	652	338 108	182	664
0.8	125 167	373	234	180 931	458	364	224 059	474	448
0.9	861	0.2	0.025	1 881	0.03	0.877	5 416	0.03	3
Total	1 096 347	804	1 361	1 096 347	804	1 361	1 096 347	804	1 361

The general trend that can be observed from Table 1 is that climate warming results in a general movement of more European land to a greater level of climate similarity with Paso de las Piedras in Argentina.

Table 2: Climate match areas of land (percentage of totals) of Paso de las Piedras in Argentina with Europe.

	Current climate			+1 °C warming			+2 °C warming		
Match index	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetland**	**Total area**	**Rice fields**	**Wetlan d**
0.2	0.08			0.04			0.01		
0.3	2.04			1.54			1.17		
0.4	10.60		1.38	7.52		1.17	5.16		0.98
0.5	20.58		4.27	18.30		2.19	15.41		1.69
0.6	26.54	7.51	26.82	26.13	9.81	21.97	26.48	18.39	15.48
0.7	28.66	46.05	50.38	29.79	33.15	47.88	30.84	22.66	48.74
0.8	11.42	46.41	17.15	16.50	57.03	26.72	20.44	58.94	32.92
0.9	0.08	0.03	0.00	0.17	0.00	0.06	0.49	0.00	0.19