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DE SANIDAD DE LA
PRODUCCIÓN PRIMARIA

Pest Risk Analysis on the introduction of *Pomacea insularum* (d'Orbigny, 1835) into the EU

Adult female and eggs of *Pomacea insularum* (by Miquel A. López)

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The present analysis of the risks posed by *Pomacea insularum* (d'Orbigny, 1835) has been made according to the Guidelines of the European and Mediterranean Plant Protection Organization (henceforth EPPO) Pest Risk Analysis [EPPO Standard **PM 5/3 (4)**][1].

[1] Decision support scheme for quarantine pests **09- 15190 (07-13727, 07-13670 ,07-13613, 07-13241, 06-12927, 06-12799, 06-12452, 05-11845, 05-11732, 04-11439 04-11364, 04-11310) PM 5/3 (4)**

Available at: http://archives.eppo.org/EPPOStandards/PM5_PRA/PRA_scheme_2009.doc

Stage 1: Initiation

1. Give the reason for performing the PRA.

Answer: PRA initiated by identification of a pest

Several species in the *Pomacea* genus, included *P. insularum*, are regarded as important invasive alien species (Rawlings *et al*., 2007, Burks *et al*, 2010).

The island apple snail (*Pomacea insularum*) was first detected in Spain in August 2009, more specifically at the left part of the Ebro Delta, in Catalonia (Fig.1). Since 2010 specimens of this species can also be found at paddy fields at the left hemi-delta of the Ebro River, being the attack extremely virulent at some plots. By November 2010, the presence of the pest had been confirmed in 299 rice plots, which represent some 571.5 ha. Of these, around 300 ha are considered to present a high density of the pest –in terms of number of egg clusters. The species is also present in around 130 km of irrigation channels, as well as in the final stretch of the Ebro River, along about 20 km. Recently the snail has also being detected on the right margin of the Ebro Delta.

Pest surveys indicate that the snail has rapidly spread throughout the area (www.gencat.cat, accessed on February 14th, 2011), since the conspicuous, aerial, pink egg clusters of this species are an easily visible sign of its presence, often providing the first sign of apple snail invasion (Barnes *et al*, 2008) -even if the density of adults is low. Moreover, in the majority of the 299 plots where the snail has been detected, its presence is limited to the water outlets, which confirms that the invasion process is, in general, still recent.

Up to date the measures undertaken in order to fight the snail and stop its spread have been the following:

- Monitoring of the snail. The monitoring area comprises: the rice plots of both the left and right hemi-deltas (11,512 and 1,450 ha, respectively), the drainage and irrigation network of the left hemi-delta (11,512 ha), the final stretch of the Ebro River (40 km) and perimeter areas of the River (3,000 ha), as well as the channels near the entrances (20 km).

- 9,500 ha of paddy fields on the left part of the Delta have been drained sooner than usual in order to maintain unfavourable conditions for the snail for a longer period of time –at least 6 months. Usually the paddy fields are without water from mid-January until mid-April, but right after last harvest ended, in October 2010, the affected fields were drained. The year before, 4,000 ha of paddy fields in the area were drained for a longer period than normal, but still not long enough to stop the spread of the snails, which reproduce extremely rapidly in irrigation ditches and hydrants.

- Collection and destruction of 341,213 adult and sub-adult specimens and elimination of a larger but unspecified number of egg clusters in the left hemi-delta. This actions have been carried out on three fronts:
  - The Delta irrigation channels. The majority of the collection took place along 85 km of channels, although egg clusters were located along 130 km of channels.
  - The riverbanks, along 4 km on each bank. This operation required previous plant clearing.
  - The rice fields. Rice stubble was burned to kill the snails in highly infested fields -30 ha in 2010.

- Chemical treatment on paddy fields (metaldehide 5% and etofenprox 30%). In 2010, this measure affected to 30 ha of paddy fields situated in the area where the organism was firstly detected.

- Application of quicklime to the irrigation and drainage network of the Delta (ongoing measure affecting to 20 km)

- Barrier traps have been installed throughout the network of irrigation channels in order to stop the snail's invasion dynamics (200 traps in 2010).

- Floating barriers have been placed on the river in 2010, at the two points of invasion of the river habitat from the flood plain of the left side of the Delta.

- 10 fix barriers have been placed adjacent to the riverbank, to prevent the spread of the snail by creeping counter-current.

- Modifications of the ricefields' water inlets and outlets are being implemented in order to protect rice plots from the snail's infestation or re-infestation.

- Proper cleaning of harvesters and agricultural machinery before crossing the river was ruled mandatory and conducted under official surveillance, in order to avoid the spread of the pest to the other side of the Delta.

- Trials on chemical substances to fight the snail at rice-fields have been conducted.

To date, both the costs from implementing the listed measures, and those associated with the damage caused by the snail have been assumed by Spanish administrations and rice farmers. On the other hand, *Pomacea insularum* is not yet regulated by any EU legislation.
Therefore, the present PRA is conducted in order to:

i) Estimate the potential risks posed by *P. insularum* to both the EU agriculture and natural environments, and eventually propose the regulation of this organism in the EU legislation.

ii) Inform the request by Spanish authorities of funds from the European Union Solidarity Fund.

Figure 1.1. Left part of the Ebro Delta and first outbreak of *P. insularum* (Source: Institut Cartogràfic de Catalunya)

Figure 1.2. Location of the Ebro Delta Natural Park (Catalonia, Spain).

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2. *Specify the pest of concern.*

After DNA analysis of 9 specimens –sequencing of mitochondrial COI[2] gen, the snail introduced in Spain has been classified as *Pomacea insularum*.

Scientific name	*Pomacea insularum* (d'Orbigny, 1835)
Other scientific names:	*Ampullarium insularum*
Common name:	Apple snail (English) Island apple snail (English) Channelled apple snail (English) Caracol manzana (Spanish)

For a long time there has been much confusion regarding the identification of the different species in the *Pomacea* genus. It is mainly after the invasion and destructive feeding on rice fields by *Pomacea canaliculata* and other pomacean species in southeast Asia, that the issue of clarifying the taxonomy and systematics of the genus, *Pomacea*, received substantial attention (Cazzaniga, 2002, as cited by Ramakrishnan, 2007). Species in this genus form what is known as the "*canaliculata* complex" or the "*canaliculata* group", commonly referred as channelled apple snails. The term "channelled apple snail" is descriptive of a morphology found in many apple snail species. It does not identify a single species or a monophyletic group (Rawlings *et al*, 2007). Difficulty in species identification is largely a consequence of the overall conservative external morphology of the group combined with phenotypic plasticity of *Pomacea* species (Rawlings *et al*, 2007). Combination of phylogenetic analyses of mtDNA sequences with examination of introduced populations and museum collections have allowed to clarify identities, introduced distributions, geographical origins, and introduction histories of apple snails in the USA (Rawlings *et al*, 2007). Likewise, phylogenetic analyses revealed presence and wide distribution in Asia of four introduced *Pomacea* species: *P. canaliculata*, *P. insularum*, *P. diffusa*, and *P. scalaris* (Hayes *et al*, 2008). Therefore, former reports on *P. canaliculata* spread throughout much of southern and eastern Asia, are probably in many cases misidentifications of *P. canaliculata* and *P. insularum* (Cowie *et al*., 2006; Hayes *et al*, 2008). Similarly, Hayes *et al.* (2008) indicated that P. *canaliculata* may have a more restricted distribution in South America than formerly thought, since previous accounts of its widespread distribution were probably the result of misidentification of several species, including *P. insularum*. According to R. Burks, *Pomacea canaliculata* and *P. insularum* differ in egg and clutch size, and hatching success rate (pers. comm. as cited by Hayes *et al.*, 2008). All these considerations made and given the similarities among *P. insularum* and *P. canaliculta*, citations regarding *P. canaliculata* (golden apple snail) are frequent in the present risk assessment.

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3. *Clearly define the PRA area.*

The PRA area considered will be the EU. Rice-fields and wetland natural habitats in warm regions, both regarded as suitable habitats for *Pomacea insularum*, are present in the PRA area (see answer to Q. 14).
Rice is grown on about 420,000 hectares of farmland in the European Union. Italy and Spain are by far the biggest producers, but Bulgaria, France, Greece, Hungary, Portugal and Romania all have a share in the 2.5 million tonnes of paddy rice grown annually in the EU (http://ec.europa.eu/agriculture/markets/rice/index_en.htm, accessed on March 4, 2011). Rice cultivation in Italy is mostly located in the northern regions (Po Valley) and extends at

[2] Cytochrome-oxidase

present over about 240,000 ha (including some small areas cropped in the Sardinia Island and southern Italy). Spain's rice-producing area was over 95,000 ha in 2008 (MARM, 2010) – mainly at: Cataluña, Valencia, Murcia, Andalucia, Aragón and Extremadura. Rice production in France is restricted to the Rhone Delta, in the Camargue region, with 24,000 ha (Chataigner & Mouret, 1997). Therefore, most rice producing areas in the EU are located nearby natural wetlands, for instance at river deltas (Po, Rhône or Ebro), lagoons (Valencia Lagoon) or marshy areas (Guadalquivir Marshes).

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4. Does a relevant earlier PRA exist?

Answer: *Yes*.

There is a recent Australian risk analysis for Golden Apple Snail (*Pomacea canaliculata*, Lamarck) based on the methodology in Biosecurity Australia's guidelines on Import Risk Analysis for Plants and Plant Products (2001). It can be found at: http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157 (accesed February 8th, 2011).

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5. Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?

Answer: *It is only partly valid*.

It is only partly valid since it has been carried out for another area and for a distinct pest species: *Pomacea canaliculata* (Lamarck).

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6. Specify all host plant species. Indicate the ones which are present in the PRA area.

Apple snails are extremely polyphagous (Cazzaniga, 2006). However, at least two species of apple snails, *Pomacea insularum* and *P. canaliculata*, are primarily macrophytophagous and readily consume vascular plants in contrast to periphyton resources commonly associated with other aquatic snails (Burlakova *et al*., 2008; Qiu & Kwong, 2009, both in Burks *et al.*, 2010). Feeding preferences of *Pomacea insularum* and *P. canaliculata* are similar (Morrison & Hay, 2010). Accessibility of the plant seems to have an impact on the rate of consumption of a plant species by apple snails, and both *P. insularum* and *P. canaliculata* prefer floating or submerged plants over emergent ones (Bachmann 1960, Bonetto and Tassara 1987, both as cited by Cazzaniga 2006; Burlakova *et al.* 2009). However, Boland *et al.* (2008) suggested that *P. insularum* may exhibit greater feeding versatility than *P. canaliculata*. They found that *P. insularum* consumed more resource with additional periphyton, while periphyton presence did not produce a noticeable effect on *P. canaliculata* consumption.

Channelled apple snails are important invaders and agricultural pests of rice and taro (*Colocasia esculenta*) in Southeast Asia, the Phillipines, Taiwan, China, Japan, Dominican Republic or Hawaii (Cowie, 2002; Carlsson, 2006) and are responsible of large economic losses (Ranamukhaarachchi & Wickramasinghe, 2006). Moreover, it is well known that they also become pests of other plants of direct economical importance such as morning glory (*Ipomoea aquatica*), lotus (*Nelumbo* spp), mat rush (*Juncus decipiens*), Chinese mat grass (*Cyperus monophyllus*), wild rice (*Zizania latifolia*), Japanese parsley (*Oenanthe stolonifera* or *O. javanica*), water chestnut (*Trapa bicornis*) or azolla (*Azolla* spp) (Mochida 1991).

In a study conducted by Burlakova *et al.* (2009) to predict the potential impact of *P. insularum* on aquatic ecosystems by testing its feeding rate on 16 plant species, high levels of consumption were recorded for: *Ceratophyllum demersum, Hymenocallis liriosme, Ruppia* *maritima, Sagittaria lancifolia, Colocasia esculenta* (elephant ear)*, Alternanthera philoxeroides* (alligator weed), and *Eichhornia crassipes* (water hyacinth). *Canna glauca*, *Hymenocallis liriosme*, *Panicum hemitomon*, *Sagittaria graminea*, and *Sagittaria lancifolia* were consumed at a moderate rate. In contrast, less than 10% of the biomass of *Spartina alterniflora*, *Scirpus californicus*, *Thalia dealbata*, and *Typha latifolia* was consumed. The palatability of macrophytes was negatively correlated with dry matter content. Palatability might be also positively correlated with protein content and low phenolic content (Elger & Lemoine, 2005). This is the case for submersed species and, to a lesser extent, for emergent ones but with broad, succulent leaves and stems and short stature (Burlakova *et al.*, 2009; Boland *et al.*, 2008).

In Florida, Morrison & Hay (2010) found that *Utricularia* sp. was the most preferred plant species. *Bacopa caroliniana*, *Sagittaria latifolia*, and *Nymphaea odorata* were of intermediate preference, and *Eleocharis cellulosa*, *Pontederia cordata*, *Panicum hemitomon* and *Typha* sp. were least preferred -avoided as foods.

According to the revision made by Smith (2006), *Pomacea canaliculata* also eats many other aquatic or semi-aquatic plants, such as *Chara* spp., *Eichhornia* spp. (water hyacinth), *Lemna* spp. (duckweed), *Pistia* spp. (water lettuce), *Rorippa* spp. (water cress), *Vallisneria* spp., *Zizania latifolia* (Manchurian wildrice), and perhaps as many as 60 species, being regarded a serious threat to natural wetland ecosystems (Carlsson, 2006). At least some of these plant species might be also hosts of *P. insularum*, given that by 2006 confusion among *Pomacea* sp. species still existed (see answer to Q.2 in Stage 1), and that both *P. canaliculata* and *P. insularum* show similar feeding habits (Morrison & Hay, 2010).

Moreover, applesnails have been reported attacking maize (*Zea mays* L.) and Citrus (*Citrus* L.) (Adalla and Morallo-Rejesus, 1989, as cited by Smith, 2006). Lettuce (*Lactuca sativa*) is a known preferred food of *P. insularum* (Burlakova *et al.*, 2009) and *P. canaliculata* (Estebenet & Cazzaniga 1992; Estebenet & Martin, 2002 both as cited by Burlakova *et al.,* 2009).

Host species of *P. canaliculata* and *P. insularum* mentioned in the literature are listed in table 1.

Table 1. Hosts of *Pomacea canaliculata* and/or *P. insularum* found on the literature.

Host Plant				***Pest***[3]	***References****
Family	**Species**	**Common name**	**Host Status**		
Alismataceae	*Sagittaria graminea*		Intermediate	P. insularum	*Burlakova* et al. *(2009)*
	Sagittaria lancifolia		Major	P. insularum	*Burlakova* et al. *(2009)*
	Sagittaria latifolia		Intermediate	P. canaliculata P. insularum	*Morrison & Hay (2010)*
Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb	Alligator weed	Major	P. insularum	*Burlakova* et al. *(2009)*
Apiaceae	*Oenanthe javanica* (Blume) DC.	Japanese parsley	Major	P. canaliculata	*Carlsson (2006)*
	Oenanthe stolonifera	Water dropwort		P. canaliculata	*Smith (2006)*
Aracea	*Colocasia esculenta* (L.) Schott	Taro, coco yam	Major	P. insularum P. canaliculata	*Burlakova* et al. *(2009); Carlsson (2006)*
	Pistia spp	Water lettuce	Major	P. canaliculata	*Smith (2006)*
Asteraceae	*Lactuca sativa*	Lettuce	Major	P. insularum P. canaliculata	*Burlakova* et al. *(2009); Boland* et al. *(2008)*
Azollaceae	*Azolla* spp	Azolla	Major	P. canaliculata	*Carlsson (2006)*
Brassicaceae	*Rorippa spp*	Water cress	Major	P. canaliculata	*Smith (2006)*

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Cannaceae	*Canna glauca* L.		Intermediate	P. insularum	*Burlakova et al. (2009)*
Ceratophyllaceae	*Ceratophyllum demersum*		Major	P. insularum	*Burlakova et al. (2009)*
Characeae	*Chara* spp.			P. canaliculata	*Smith (2006)*
Convolvulaceae	*Ipomoea aquatica* Forssk.	Morning glory	Major	P. canaliculata	*Carlsson (2006)*
Cyperaceae	*Cyperus monophyllus*	Chinese mat grass	Major	P. canaliculata	*Carlsson (2006)*
	Scirpus californicus (CA Mey) Palla		Minor	P. insularum	*Burlakova et al. (2009)*
	Scirpus maritimus		Minor	P. insularum	*Burlakova et al. (2009)*
Haloragaceae	*Myriophyllum spicatum* L.	Eurasian watermilfoil		P. insularum P. canaliculata	*Boland et al. (2008)*
Hydrocharitaceae	*Vallisneria* spp		Major	P. canaliculata	*Smith (2006)*
Juncaceae	*Juncus decipiens*	Mat rush	Major	P. canaliculata	*Carlsson (2006)*
Lemnaceae	*Lemna* spp	Duckweed	Major	P. canaliculata	*Smith (2006)*
Lentibulariaceae	*Utricularia sp*		Major	P. canaliculata P. insularum	*Morrison & Hay (2010)*
Liliaceae	*Hymenocallis liriosme* (Raf.) Shinners		Major	P. insularum	*Burlakova et al. (2009)*
Marantaceae	*Thalia dealbata* Fraser ex Roscoe		Minor	P. insularum	*Burlakova et al. (2009)*
Nelumbonaceae	*Nelumbo nucifera*	Lotus	Major	P. canaliculata	*Carlsson (2006)*
Nymphaeaceae	*Nymphaea odorata*		Intermediate	P. canaliculata P. insularum	*Morrison & Hay (2010)*
Poaceae	*Oryza sativa* L.	Rice	Major	P. insularum P. canaliculata	
	Panicum hemitomon Schult.		Intermediate	P. insularum	*Burlakova et al. (2009)*
	Spartina alterniflora Loisel		Minor	P. insularum	*Burlakova et al. (2009)*
	Zea mays L.	Maíz		P. canaliculata	*Smith (2006)*
	Zizania latifolia	Wild rice	Major	P. canaliculata	*Carlsson (2006)*
Pontederiaceae	*Eichchornia crassipes*	Water hyacinth	Major	P. insularum P. canaliculata	*Burlakova et al. (2009); Boland et al. (2008)*
	Pontederia cordata		Minor	P. insularum	*Burlakova et al. (2009)*
Ruppiaceae	*Ruppia maritima*		Major	P. insularum	*Burlakova et al. (2009)*
Rutaceae	*Citrus L.*	Citrus		P. canaliculata	*Smith (2006)*
Scrophulariaceae	*Bacopa caroliniana*		Intermediate	P. canaliculata P. insularum	*Morrison & Hay (2010)*
Trapaceae	*Trapa bicornis* Osbeck	Water chestnut	Major	P. canaliculata	*Carlsson (2006)*
Typhaceae	*Typha latifolia* L.		Minor	*P. insularum*	Burlakova *et al.* (2009)

Large amounts of algae and submerged, floating and emergent plants and animals inhabit rice fields along the growing season (Forés & Comín, 1992). For instance, most recent flora catalogue of the Ebro Delta area contain more than 500 plant species, many of which are rare. Besides rice, other species and genera regarded as hosts of *Pomacea* spp. can be found in the PRA area -e.g. *Chara* spp, *Lemna* spp and *Typha latifolia* (Curcó i Masip, 2001). Moreover, in the PRA area there can be found species of the same genus than host species on the list (table 1), which is the case of: *Ipomoea sagittata*, *Juncus acutus*, *Juncus articulatus*, *Juncus maritimus*, *Juncus subnodulosus*, *Juncus subulatus*, *Cyperus difformis*, *Cyperus laevigatus*, *Cyperus longus*, *Oenanthe lachenalii*, *Rorippa nasturtium-aquaticum*, *Sagittaria sagittifolia*, *Scirpus holoschoenus*, *Scirpus lacustris*, *Scirpus litoralis*, *Scirpus maritimus*, *Spartina versicolor* (Curcó i Masip, 2001). Moreover, given the polyphagous habits of *Pomacea insularum*, -in terms of both number of botanical species and families, many of the plant species growing at the rice areas and surrounding wetlands at the Ebro Delta will be likely foraged by these snails too and the same can be applied to the other rice growing areas and wetlands in Mediterranean Europe.

Uncertainties: there are few studies on trophic niches of *Pomacea insularum* in natural habitats, and none has been done in the Ebro Delta area, although it has been observed that it feeds on many differnt plant species.

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7. Specify the pest distribution

Recent studies on the taxonomy of the *Pomacea* genus, helped clarify the distribution of *P. insularum* and *P. canaliculata*. Table 2 reflects the distribution of both species according to Hayes *et al.* (2008) and Rawlings *et al.* (2007). Hayes *et al*. (2008) found that *P. insularum*'s distribution in its area of origin, South America, spreads from Buenos Aires Province, Argentina, through much of Brazil as far North as Amazonas. The different distributions of *P. insularum* and *P. canaliculata* may signal a difference in physiological tolerances, or may simply be the result of chance dispersal or vicariance[4] (Hayes *et al.*, 2008).

Table 2. Distribution of *Pomacea insularum* and *P. canaliculata* (Hayes *et al.*, 2008; Rawlings *et al.*, 2007).

Continent	Country		*P. insularum*	*P. canaliculata*
America	Argentina		X	X
	Brasil		X	Perhaps, southernmost part
	Bolivia		X	
	Paraguay		probably	X
	Uruguay		probably	X
	USA	Arizona		X
		California		X
		Florida	X	
		Hawaii		X
		Georgia	X	
		Texas	X	
Asia	Malaysia	Borneo	X	X
		Peninsula		X
	Cambodia		X	
	China			X
	Guam			X
	Hong-Kong*			X
	Japan			X
	Indonesia	Java		X
	Laos			X
	Myanmar			X
	Philippines			X
	Singapore		X	
	South Korea		X	X
	Taiwan		X	X
	Thailand		X	X
	Vietnam		X	X
Oceania	Papua New Guinea			X

* According to Laup (1991). Taxonomy not confirmed by DNA analysis.

[4] The separation or division of a group of organisms by a geographic barrier, such as a mountain or a body of water, resulting in differentiation of the original group into new varieties or species

Stage 2: Pest Risk Assessment
Section A: Pest categorization
Identify the pest (or potential pest)

8. Is the organism a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

Answer: Yes (see explanation to Q. 2.)

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda (Cuvier 1797)
Subclass: Prosobranchia (Milne Edwards 1848)
Order: Mesogastropoda (Thiele, 1927)
Superfamily: Viviparoidea (Gray, 1847)
Family: Ampullariidae (Guilding, 1828)

Source: Boanan and Pagulayan (2006)

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Determining whether the organism is a pest

10. Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

Answer: *Yes*.

Apple snails in genus *Pomacea* are widely known as agricultural pests across Southeast Asia; however, they are mostly considered harmless and useless organisms in Argentina, where they are autochthonous (Cazzaniga, 2006). Most snail problems in Asian countries are caused by species in the canaliculata group, the most cited species being *P. canaliculata* (Lamarck 1822), *P. insularum* (d'Orbigny 1835), *and P. lineata* (Spix in Wagner 1827) (Cowie *et al*. 2004). In fact, *P. canaliculata*, recognized as one of the most serious threats to rice production, also alters both the state and functions of invaded wetland ecosystems (Carlsson, 2006) and it is currently listed as among "100 of the World's Worst Invasive Alien species" (Lowe *et al*. 2000). In a survey conducted by Carlsson *et al.* (2004), high densities of golden apple snails (*P. canaliculata*) were associated with an almost complete absence of aquatic plants.

Boland *et al.* (2008) observed similar feeding trends between *P. canaliculata* and *P. insularum*, with a few notable exceptions. According to these authors, both adult and juvenile *P. canaliculata* consumed more than their respective *P. insularum* counterparts, but in the presence of periphyton, juvenile *P. insularum* consumed more by mass than juvenile *P. canaliculata*.

Some of the ecological and agricultural impacts in Asia associated with *P. canaliculata* are almost certainly attributable to *P. insularum* (Cowie *et al.*, 2006, and Rawlings *et al.*, 2007, as cited by Rawlings et a., 2007), which is also spread in the region (Hayes *et al*., 2008). Both comparison of feeding habits between *P. insularum* and *P. canaliculata* (Boland *et al.*, 2008) and of their reproductive biology (Barnes *et al.*, 2008) show enormous similarities between the two species as agricultural and environmental pests.

According to Rawlings *et al.* (2007) *Pomacea insularum* and *P. canaliculata* pose the greatest threat to agriculture and native wetland ecosystems in the U.S. According to a preliminary risk assessment on the matter, *Pomacea* spp. top the list of quarantine important alien non-marine snails and slugs for the U.S.A. (Cowie *et al.*, 2009).

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Presence or absence in the PRA area and regulatory status (pest status)

12. Does the pest occur in the PRA area?

Answer: *Yes*.

P. insularum is present at the left hemi-delta of the Ebro River (NE of the Iberian Peninsula) since August 2009, when it was first detected. Since then the population of the snail has rapidly increased, infesting paddy fields, irrigation channels and the riverbanks. According to the last estimates of the presence of *P. insularum* in the PRA: 571.5 ha of rice paddies are currently affected, and the species is also present in around 130 km of irrigation channels as well as at the final stretch of the Ebro River –along 20 km.

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13. Is the pest widely distributed in the PRA area?

Answer: *No*.

For the moment, it has just been reported at the Ebro Delta area in Spain.

Potential for establishment and spread in the PRA area

14. Does at least one host-plant species (for pests directly affecting plants) or one suitable habitat (for non parasitic plants) occur in the PRA area (outdoors, in protected cultivation or both)?

Answer: *Yes.*

In the EU, rice is grown at the following countries: Italy, Spain, France, Greece, Portugal, Bulgaria, Hungary and Romania. More specifically, the main rice producing areas in Europe are located at the Po Valley (in the Pavia province, Italy), the Rhone Delta (Camargue region, France), the Ebro Delta (Catalonia, Spain), the Ebro Valley (Navarra and Aragón, Spain) the Albufera of Valencia (Valencia, Spain), the Guadalquivir Marshes (in the surroundings of Doñana National Park in Andalucía, Spain), and at Extremadura as well (SW inner Spain).

Moreover, diverse wetland natural habitats can be found at most of those areas too, and given the polyphagous habits of *P. insularum*, many of the plant species present there, specially the submerged ones could be at risk (see answer to Q. 6).

P. insularum's egg clutches occur on different structures, such as emergent plants, trees, and concrete pillars (Howells *et al.*, 2006; Rawlings *et al.*, 2007). Specific characteristics of wetlands and shallow lakes surrounded by large emergent macrophytes, likely facilitate the invasion process of *P. insularum* by providing females with conditions that permit successful oviposition (Burks *et al.*, 2010). These conditions may be found in the PRA area, at least at flooded rice fields and wetlands by the Mediterranean coast, as well as at the Guadalquivir Marshes.

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15. If a vector is the only means by which the pest can spread, is a vector present in the PRA area?

Answer: *Not applicable.*

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16. Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?

Answer: Yes

Species of *Pomacea* are endemic throughout Central and South America and the Caribbean, with a single species *P. palludosa*, found in the southeastern United States (Howells 2001b, as cited in Ramakrishnan, 2007).

P. insularum mostly populates shallow areas in the macrophytes zones and lays egg masses above the water (Karatayev *et al.*, 2009). These authors also found that *P. insularum*, which is of subtropical origin, survived for over two days at water temperature as low as 6ºC without noticeable mortality. Another population of *P. insularum* that had existed for several years in northern Texas failed to survive, likely due to low winter temperatures. According to Ramakrishnan (2007), under the laboratory conditions *P. insularum* suffered 100% mortality at 15ºC within 25 days. However, snails were able to tolerate much lower temperature for a shorter period of time: at 2ºC all snails died only after 8 days of exposure, and at 5ºC, snails died after 10 days. These data indicate that the acute thermal limit for *P. insularum* is much lower than the chronic limit, and both of the limits should be taken into consideration in predicting the potential spread of the species.

In addition, *P. insularum* can burrow in the sediments of water bodies or in soil in rice fields and hibernate over the winter (Oya and Miyahara, 1987). There are no data on the lower temperature limit for the survival of hibernating *P. insularum*. However, it is likely that hibernating snails may survive lower winter temperatures.

The upper thermal limit for *P. insularum* is about 36ºC (Ramakrishnan, 2007).

Establishment and rapid spread of *P. insularum* at the Ebro Delta's rice fields indicate that climatic conditions at this area, mainly its mild winter and warm summer temperatures, would be adequate for the pest to thrive. On the other hand, the necessary presence of an aquatic environment for this snail would have been provided by typical long-lasting flooding of rice fields in the area, from April to December, which has likely played a major role in the performance of the snail.

Adequate ecoclimatic conditions for this snail are likely to be found elsewhere in the PRA area, at least at the rice-growing areas and wetlands by the Mediterranean, with aquatic environments and typical mild winter temperatures. According to Cazzaniga (2006), any place agriculturally apt for rice cultivation would be also suitable for *P. caniculata,* which can be made extensive to the very close species *P. insularum*. Moreover, world expert on apple snail, Dr. Ravindra Joshi, recently stated that *P. insularum* could be regarded as a continental threat in Europe (R. Joshi, personal communication, December 7, 2010).

On the contrary, and considering the above exposed lower temperature limits of *P. insularum*, temperature regimes in northern and continental Europe are not expected to be adequate for the snail.

Go to 17

Potential for economic consequences in the PRA area

17. With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

Answer: *Yes.*

Since:

- *P. insularum* is a major pest of rice, which is grown in several zones of the PRA area.
- In Southeast Asia, damages and control costs attributable to apple snail are enormous.
- *Pomacea insularum* and *P. canaliculata* pose the greatest threat to agriculture and native wetland ecosystems in the US (Rawlings *et al*, 2007).
- Any place agriculturally apt for rice cultivation can be suitable for *P. insularum* (Cazzaniga, 2006).
- In Europe, infestation of rice crops with the snail might easily lead to its spread to nearby natural wetland areas, since rice is often grown nearby high valuable wetland ecosystems –for instance the Ebro Delta's Natural Park, Valencia lagoon (Albufera), Doñana National Park (at the Guadalquivir Marshes) or the Camargue Regional Natural Park.
- *P. insularum* is highly polyphagous and voracious. Like other *Pomacea* snails, it is primarily macrophytophagous and prefers floating or submerged plants over emergent ones (Burlakova *et al.*, 2009). This snail may have caused considerable damage in natural environments in SE Asia (Rawlings *et al.*, 2007; Hayes *et al.*, 2008; Morrison & Hay, 2010) and many plant species in Mediterranean wetlands as well as these ecosystems as a whole would be also at risk.

Go to 18

Conclusion of pest categorization

18. This pest could present a risk to the PRA area.

Answer: *Yes.*

Given that:

- *Pomacea insularum* exhibits alarming invasive characteristics of high reproductive rates and generalist consumption patterns (Burks *et al.*, 2010).
- It could cause important rice crop losses, as well as significant damages on Mediterranean natural wetland ecosystems.
- At the rice-producing areas of the EU by the Mediterranean, mild winter temperatures would likely allow survival of *P. insularum*.
- Control of *P. insularum* is neither easy nor cheap. Eradication at a very early stage might still be possible, but there will be only a very narrow window of opportunity (Ranamukhaarachchi & Wickramasinghe, 2006)

The potential economic consequences are considered to be moderate and therefore non-negligible.

Go to section B

Section B: Assessment of the probability of introduction and spread and of potential economic consequences

1. Probability of introduction

Probability of entry of a pest

1.1 *Consider all relevant pathways and list them.*

Gastropods dominate among freshwater invertebrates introduced through the aquarium trade and related activities (Padilla & Williams, 2004), and are the most diverse component of exotic freshwater invertebrates in North America and Europe (Karatayev *et al.*, 2008, as cited in Karatayev *et al.*, 2009).

In the USA, expansion of apple snails' range to new areas has involved the live food trade (imported legally or illegally), nursery trade (eggs or juveniles attached to live plants), pet/aquarium trade (intended for rearing to be sold in pet stores), and deliberate smuggling (for any of the above purposes) (Smith, 2006). Similarly, Joshi *et al*. (2004) reported that the very close species *P. canaliculata* has been introduced in rice-growing countries by multiple pathways either deliberately or inadvertent.

In Georgia (USA), the suspected pathways of introduction of *Pomacea insularum* are deliberate and accidental releases by aquarium hobbyists
(at http://www.shellfish.uga.edu/invasive%20webitems/meet%20guests/apple%20snail.pdf, accessed February 15th, 2011).

Karatayev *et al.* (2009) revised introduction and spread of *Pomacea insularum* in Texas and reported that this snail was initially introduced to Texas through aquarium and ornamental trade (Howells 2001a; Howells *et al*., 2006). It appears that at least in some cases the subsequent spread of *P. insularum* in Texas could be due to repeated independent introductions also associated with the aquarium and ornamental trade.

Therefore, *Pomacea insularum* may have entered the EU either by intentional importation or via different pathways.

A) Intentional importation of *Pomacea insularum*.

Commerce in ampullariid snails has caused them to become widely distributed, particularly by the hobbyist aquarium industry because of the tolerance of several species such as *P. canaliculata* or *P. insularum* to the warmer temperatures desirable for rearing tropical fish (Smith, 2006). But their voracious appetite has caused these snails to develop a bad reputation in the trade and has likely contributed to their release in non-native areas such as the US (Cowie, 2005 as cited by Smith, 2006).

P. canaliculata has been intercepted on freight going into Australian ports. Data provided by AQIS shows there were 64 interceptions between September 1996 and June 2003 (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 15th, 2011). Australia also reported that deliberate illegal importation of snails, either for use in the aquarium trade, or for use in small-scale aquaculture, represents a major risk for potential introduction (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 15, 2011).

As for the PRA area, *Pomacea* spp. specimens can at least freely enter Spain -as ornamental species for aquaria.

- Importation of Pomacea insularum for the pet/aquarium trade or for aquatic weed control.

Ampullariids are popular domestic aquarium animals (Perera and Walls, 1996 as cited in Cowie, 2002) and a number of species have been introduced to many parts of the world via the aquarium trade (Cowie, 2002).
Ampullariids are also voracious feeders on aquatic plants. They have therefore been used or suggested to be used for control of aquatic weeds (Cowie, 2002). In Florida and Puerto Rico, *Marisa cornuaretis* has been deliberately introduced in attempts to control aquatic plant nuisances (Simberloff & Stiling, 1996). In Japan, introduced *P. canaliculata* has been suggested as a possible agent for weed control (Okuma *et al.*, 1994; Wada, 1997, both as cited in Cowie, 2002). At least one case of the introduction of applesnails by a landowner into a private pond to control macrophytes was documented in Texas (Howells, 2001b).
To date, *Pomacea* spp. specimens can be freely imported into the PRA area as 'ornamental species for aquaria'.

- Importation of Pomacea insularum as a food item

A number of ampullariids are used as human food in their native ranges. Between 1970 and 1981 a species of *Pomacea*, usually referred to as *P. canaliculata*, was introduced to South-East Asia, initially from Argentina to Taiwan. The purpose of the introduction was both for local consumption and for development for export to the gourmet restaurant trade. The

subsequent spread of this ampullariid in South-East Asia, occurred for the same purposes (Cowie, 2002).
However, consumers did not appreciate this snail and no major trade based on aquaculture operations has developed (Acosta and Pullin, 1991, as cited in Cowie, 2002). In addition, developed nations maintain stringent health regulations that have largely precluded importation of products of *Pomacea* spp. (Anderson, 1993; Naylor, 1996, both as cited in Cowie, 2002).
To our knowledge, *Pomacea* snails are not marketed as food in the EU.

B) Pathways of *Pomacea insularum*.

B.1. Commercial shipments

- Aquatic plants imported for the aquarium trade or as foodstuffs

Besides being a pest of rice, *P. insularum* is also present in natural wetlands.

According to a risk analysis conducted by Australian phytosanitary authorities on the golden apple snail (*P. canaliculata*), immature snails contaminating aquatic plants imported for the aquarium trade or as foodstuffs pose a high risk of accidental introduction (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 15, 2011).

Due to their small size, eggs or juveniles of apple snails may not be noticed during official phytosanitary inspections.

In the USA, the expansion of apple snails' range to new areas has involved the live food trade and the nursery trade -eggs or juveniles attached to live plants (Smith, 2006).
Malaysia blocked the import of *Ipomoea aquatica* from Thailand because of contamination by young golden apple snails (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 28, 2011).

In average, around 95% of the total weight of aquarium plants imported into Spain in 2008-2010 came from countries were *P. insularum* is present (USA, Malasia, Singapur and Thailandia) (Spain official statistics, data not published).

Information on imports of aquatic plants into other EU member states is lacking.

- Importation of live tropical fish

Apple snails can be found as contaminants in shipments of live tropical fish (Smith, 2006).

- Importation of rice

Viable eggs and snails are unlikely to occur as contaminants of imported rice (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 15, 2011).

B.2. Non-commercial shipments

Non-commercial shipments, which mostly refer to articles carried in passenger baggage, might pose a risk of pest introduction.

In the USA expansion of the snail's range to new areas has involved deliberate smuggling of both aquatic plants (for food or aquaria) and apple snails (Smith, 2006).

Hand luggage is not routinely checked in the EU for phytosanitary purposes.

C) Natural spread

Since there are no previous reports on the presence of *Pomacea insularum* in natural environments in Europe, this pathway is not further considered.

1.2. *Select from the relevant pathways, using expert judgement, those which appear most important. If these pathways involve different origins and end uses, it is sufficient to consider only the realistic worst-case pathways. The following group of questions on pathways is then considered for each relevant pathway in turn, as appropriate, starting with the most important.*

All the pathways listed above are not regarded equally important for the introduction and spread of *Ampullariidae* (Smith, 2006). For instance, in the US the rate of introduction of aquatic snails increased in the 1970s, most likely due to expansion of the aquarium trade (McCann *et al*. 1996, Cowie and Robinson 2002, both as cited in Smith, 2006).

Nowadays in Spain, *Pomacea* spp. snails can be found in aquarium shops, and seem to be relatively common species in aquaria. In fact *Pomacea insularum* might have spread into the Ebro Delta area after escaping from an exotic animal facility –the origin of the invasion is being object of a criminal process although the documentation generated by the case is still subject to judicial secrecy.

The use of *Pomacea* snails for aquatic weed control, documented to have been employed in Japan or Texas (see answer to Q. 1.1), is another possibility for this snail to be imported or spread in the EU.

Since apple snails are not marketed as food in Europe 'importation of *Pomacea* snails as a food item' will not be further regarded as a relevant pathway.

Regarding the illegal importation or smuggling of apple snails into the EU for use in aquaria, there are no estimates on its magnitude. However, considering that it can be imported and traded without restrictions, smuggling is not regarded to be comparatively significant.

Since any one deliberate introduction may have a relatively greater chance of establishment than many inadvertent introductions (Joshi *et al*., 2004), the following pathways will not be further considered in this analysis:

- aquatic plants imported for the aquarium trade
- live tropical fish imported for the aquarium trade
- non-commercial shipments of aquatic plants

However, if the conclusion of the present assessment were that *Pomacea 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 life tropical fishes at the EU's ports of entry –in order to reject the entry of consignments infested with the snail.

Therefore, the 'pathway' regarded as more relevant would be:

'Importation of *Pomacea insularum* for the pet/aquarium trade or for aquatic weed control'

Go to 1.3

Probability of the pest being associated with the individual pathway at origin

Since the PRA is being conducted on a pest that is intentionally imported, an assessment of its entry potential is not required. Only questions 1.5, 1.6, 1.10 and 1.13 should be answered (EPPO, 2009).

1.5. *How large is the volume of the movement along the pathway?*

Information on the volume of importation into the EC of *Pomacea insularum* either for the pet/aquarium trade or for aquatic weed control is not available. However, considering the final uses of the snail, that volume is supposed to be minor.

~~Minimal~~ Minor ~~Moderate~~ ~~Major~~ ~~Massive~~

Level of uncertainty: ~~Low~~ Medium ~~High~~

1.6. *How frequent is the movement along the pathway.*

Statistic information on the frequency of importation into the EC of *Pomacea insularum* is also lacking, but it has been rated as moderate, coherently with the answer to Q. 1.5.

~~Minimal~~ ~~Minor~~ Moderate ~~Major~~ ~~Massive~~

Level of uncertainty: ~~Low~~ ~~Medium~~ High

Probability of transfer to a suitable host or habitat

1.10. *In the case of a commodity pathway, how widely is the commodity to be distributed throughout the PRA area?*

Considering *that P. insularum* snails are most likely imported to be sold in aquarium shops, either directly or previous multiplication here in the EU, specimens of *Pomacea* spp. are expected to be moderately widely distributed throughout the PRA area.

~~Very limited~~ ~~Limited~~ Moderately widely ~~Widely~~ ~~Very widely~~

Level of uncertainty: ~~Low~~ Medium ~~High~~

1.13. *In the case of a commodity pathway, how likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?*

There are several possibilities for *Pomacea* snails which are imported for the pet/aquarium trade to be transferred to suitable habitats:

- Intentional release into the environment by aquarium hobbyists -especially in the vicinity of water courses or wetlands, in particular rice fields (Smith, 2006).
- Escape of specimens from outdoor aquaria, water gardens or aquaculture facilities (Smith, 2006)
- Escape of snails from outdoor aquaculture facilities intended for rearing snails for the pet and aquarium trade (Cowie, 2005 as cited by Smith, 2006).

In order to properly assess the likelihood of transfer of the snail to a suitable habitat, it should be also considered that *Pomacea* snails are capable of travelling short distances over land, and crawl out of the water to lay their eggs, but they are still dependent on the aquatic environment for survival. Therefore, proximity of aquaculture facilities to water courses or wetlands would facilitate the transfer of the snail to a suitable habitat. Finally, considering the importance of water availability for aquaculture, and the corresponding typical location of aquaculture facilities, there are chances that *Pomacea* snails would transfer to suitable habitats.

~~N/A~~ ~~Very unlikely~~ ~~Unlikely~~ Moderately likely ~~Likely~~ ~~Very likely~~

Level of uncertainty: ~~Low~~ Medium ~~High~~

Consideration of further pathways

1.14. *Do other pathways need to be considered?*

Answer: *No*.

Go to conclusion on the probability of entry and then to 1.16

Conclusion on the probability of entry

Importation of *Pomacea* snails is so far allowed in the PRA area -at least in Spain, where they have been imported as ornamental species for aquaria. *Pomacea insularum* and other *Pomacea* species are quite popular among aquarists, since they adapt to the warm temperatures required by tropical fish species. For this reason there are aquarium facilities in the PRA area that breed and raise *Pomacea* snails in order to sell them.

Transfer of apple snails into suitable habitats –ricelands and natural wetlands of the PRA area, would be facilitated by a number of factors. According to references in the literature, and considering the likely uses of this snail in the PRA area, the most likely ways of transfer of the snail to suitable habitats would be either intentional release of specimens by aquarium hobbyists or, more importantly, their escape from outdoor aquaculture facilities.

Consequently, the entry of *P. insularum* snails into the EU is regarded as moderately likely.

Probability of Establishment

Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the PRA area

1.15. *Estimate the number of host plant species or suitable habitats in the PRA area (see question 6).*

As previously mentioned, *Pomacea insularum* is a polyphagous species that has shown to be able to feed on many different plant species present in wetlands. As for agriculture, *P. insularum* is regarded a major pest of rice. Crops other than rice which are known to be affected by the snail are not present in the PRA area.

~~Very few~~ ~~Few~~ ~~Moderate number~~ **Many** ~~Very many~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.16. *How widespread are the host plants or suitable habitats in the PRA area? (specify)*

Besides to the presence of host plant species, two main environmental constraints for *Pomacea insularum* have been identified. Firstly, since it is an aquatic snail, presence of water is necessary for this snail to survive and thrive. Secondly, it cannot tolerate low temperatures under certain thresholds –see answer to Q.16. Therefore wetlands with typical Mediterranean mild winters, including many of the rice fields in the EU, are regarded as the suitable habitats for the pest in the PRA area. These habitats can be at least found at different coastal areas by the Mediterranean -from Spain to Greece, as well as at the Guadalquivir Marshes.

~~Very limited~~ ~~Limited~~ Moderately widely ~~Widely~~ ~~Very widely~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

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

N/A ~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ ~~Very likely~~

Suitability of the environment

1.18. *How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?*

P. insularum can be found in areas under diverse temperature regimes (Q. 7), being more damaging under tropical temperature regimes (i.e. Southeast Asia), compared to warm temperate areas (i.e. Texas).

Considering the damage that *P. insularum* has already caused at the Ebro Delta area as well as its continuous spread there, it can be asserted that the climatic conditions in that area – and the temperature regime in particular are adequate for this snail to thrive. Temperature regimes in other rice producing areas and neighbouring wetlands by the Mediterranean are likely to be largely similar compared to the Ebro Delta, and therefore, also adequate for *P. insularum* to establish and cause damage. However the number of generations per year is probably lower by the Mediterranean coast than under warmer climates (Albrecht *et al*. 1999; Wu *et al*. 1995).

~~Not similar~~ ~~Slightly similar~~ Moderately similar ~~Largely similar~~ ~~Completely similar~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

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

First of all, key environments for this aquatic snail to establish and thrive, such as flooded ricefields and natural wetlands, can be found in the PRA.

Salinity may also have an impact on the survival of *Pomacea insularum* specimens (Marfurt and Burks, 2005 in Howells *et al.*, 2006). However, the species shows certain tolerance to salinity (Marfurt and Burks, 2005), and water salinity levels found not only at the Ebro Delta area, but in other rice growing areas of the world, does not hinder the pest's spread and damage.

~~No judgement~~ ~~Not similar~~ ~~Slightly similar~~ ~~Moderately similar~~ Largely similar ~~Completely similar~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.20. *If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?*

Not applicable.

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.21. *How likely is it that establishment will occur despite competition from existing species in the PRA area, and/or despite natural enemies already present in the PRA area?*

Because of its feeding and reproductive characteristics, *P. insularum* is regarded as a highly competitive species, and it has quickly established in many areas of the world outside its natural range. Therefore even if natural enemies were present in those areas, they have proven not to be enough to avoid the establishment of the pest. Potential abilities of various predators of the apple snail were investigated in Japan by Yusa *et al*. (2006). Fish, crustacea, water birds, insects, etc. feed on apple snails, although most of them can attack only small juveniles (Wada, 2006). Animals that can feed on large snails are quite restricted and thus, once the snails grow big, they have a high probability of escaping from natural enemies

(Wada, 2006). Moreover, natural enemy fauna against apple snails are very sparse in rice fields (Wada, 2006).

At the Ebro Delta area, the presence of different species of ducks and birds, among other fauna, has not been able to avoid the establishment and rapid spread of the snail in rice fields in the area.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ Very likely

Level of uncertainty: Low ~~Medium~~ ~~High~~

Cultural practices and control measures

1.22. *To what extent is the managed environment in the PRA area favourable for establishment?*

In the PRA area, rice is generally machine-seeded in flooded fields. Early flooding provides favourable conditions for the establishment of *P. insularum*. According to Cazzaniga (2006), relatively late flooding appears to be important to minimize the economic loss due to apple snails. Moreover, at certain zones of the PRA area the rice fields are usually flooded even sooner for environmental purposes, such as favouring the presence of ducks and other birds and fauna in the area. This would be the case, for instance, of the Ebro Delta area.

On the other hand, tillage seems to have an impact on the extent of damage caused by *Pomacea* snails on rice (Wada, 2006). In the very large rice fields of Argentina (up to 4000 ha), soil plowing with heavy machinery is supposed to kill many buried apple snails (Cazzaniga, 2006). However, machinery used in the much smaller rice fields of the PRA area is not judged to be effective enough in preventing the establishment of *Pomacea insularum*.

Crop rotations, which would help fight the snail (Wada, 2006), are not possible everywhere in the PRA area. For instance, at low saline lands, where either drainage is difficult or salinization occurs if drainage is accomplished, rotation is not possible. This would be the situation of the Ebro Delta area, where agriculture is only possible if plots are maintained flooded with fresh-water. Since rice is the only crop adapted to this management practice, crop rotation is not regarded an option.

Moreover, irrigation and drainage water are likely to favour not only the spread, but also re-infestations of the rice-fields, water channels and even natural wetlands. This is the case at the Ebro Delta area, where drainage water is directed to natural wetlands.

Mechanical harvest would also contribute to both re-infestation and spread of the snail throughout ricefields in the PRA area.

~~Not at all~~ ~~slightly~~ ~~Moderately~~ Highly favourable ~~Very highly favourable~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.23. *How likely is it that existing pest management practice will fail to prevent establishment of the pest?*

Not many pesticides seem to be effective in killing the snail. Therefore, it is unlikely that products used in rice-fields in the PRA area will help prevent the establishment of the pest, which actual establishment of *P. insularum* in the Ebro Delta area confirms.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ **Very likely**

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.24. *Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?*

After Ranamukhaarachchi & Wickramasinghe (2006), eradication at a very early stage might still be possible, but there will be only a very narrow window of opportunity. Accordingly, these authors recommend prevention of its introduction as the primary strategy.

Incursions of *Pomacea* snails are difficult to find and delimit, especially before egg-laying occurs. Moreover, this snail should be eradicated not only from rice-fields, but also from water channels and surrounding wetlands. Finally, both reproductive strategy and feeding habits of this snail contribute to a rapid increase of its population size.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ Likely ~~Very likely~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

Other characteristics of the pest affecting the probability of establishment

1.25. *How likely is the reproductive strategy of the pest and the duration of its cycle to aid establishment?*

High fecundity increases the rate and intensity at which a non-indigenous invader affects its introduced range (Sakai *et al.* 2001, as cited in Barnes *et al.* 2008). In fact, fecundity best indicates invasive potential for molluscs (Burks *et al*, 2010).

In experiments conducted in Texas, Barnes *et al.* (2008) found that *P. insularum*'s clutch size averaged 2064 eggs and clutches exhibited an average of 70% field hatching efficiency (*P. canaliculata*'s clutch size averaged 200 eggs/clutch according to Cowie (2002) and 272 after Teo (2004). Even with a conservative estimate of 1 to 10% survival to adulthood, the average *P. insularum* clutch yields 14 to 144 new applesnails. Moreover, in southeastern US (Texas) adult females can contribute more than 1 clutch/week over an extended growing season (from April to September) (Barnes *et al.,* 2008).
Therefore, compared to other species, the remarkable fecundity of *P. insularum* allows for its quick establishment in new aquatic habitats, an acceleration of detrimental ecologic impacts, and an increased likelihood of becoming a pest (Keller *et al.*, 2007; Conner *et al.*, 2008 both as cited in Burks *et al.*, 2010).

At the Ebro Delta area, the reproductive period of *P. insularum* extends from April/May to October/November (depending on water temperature), egg hatching occurs after two weeks and juveniles reach sexual maturity in 2-3 months.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ Very likely

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.26. *How likely are relatively small populations to become established?*

From the answer to Q.1.25, it can be inferred that it is very likely for small populations to become established. In fact, it seems to have been so at the Ebro Delta area, as well as in other places where the snail has become established.

~~No judgment~~ ~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ Very likely

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.27. *How adaptable is the pest?*

Considering feeding habits (Q.6), environmental requirements (Q.16) and present geographic distribution of *P. insularum* (Q.7), this snail is regarded to be moderately adaptable.

Adaptability is: ~~Very low~~ ~~Low~~ **Moderate** ~~High~~ ~~Very high~~

Level of uncertainty: **Low** ~~Medium~~ ~~High~~

1.28. *How often has the pest been introduced into new areas outside its original area of distribution?*

P. insularum originates from South-America, but during the last decades it has become established in several countries in SE Asia as well as in South Korea, Taiwan and the USA (Texas, Florida, Georgia) (see answer to Q.7). More recently this snail has been introduced into Spain (Ebro Delta area in Catalonia).

~~Never~~ ~~Rarely~~ ~~Sometimes~~ **Often** ~~Very often~~

Level of uncertainty: **Low** ~~Medium~~ ~~High~~

1.29. *If establishment of the pest is very unlikely, how likely are transient populations to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment)?*

Answer: Not applicable.

Conclusion on the probability of establishment

Establishment of *P. insularum* in the PRA area is regarded as very likely, considering the concurrence of a number of circumstances.
Firstly, it is an invasive species, with a high fecundity and highly polyphagous, although known for being mainly a rice pest.
In fact, it has become established in quite a few areas during the last decades, included the Ebro Delta area (NE of the Iberian Peninsula).
Regarding its environmental requirements, the mild winter temperatures in the Mediterranean area together with its ability to burrow in the soil would allow survival of this species over the winter.
Moreover, under these favourable climatic conditions there can be found rice growing areas and wetlands which provide the aquatic environment needed by this snail species.
Although some species present in the area, such as ducks or some fishes, might feed on this snail, this has not prevented the pest from establishing in many areas in the world, included the Ebro Delta.
Several rice cultural practices typical in the area are regarded as favourable to the pest establishment –e.g. rice monoculture together with the long periods during which the rice fields are kept flooded.
Moreover, chemical products used against typical rice pests do not efficiently control *Pomacea* spp. snails.

Probability of spread

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

Spread of *P. insularum* can occur by natural migration -both ways downstream and upstream (Howells and Smith, 2002). Therefore, access to water currents or flooding events -such as those caused by heavy rains, plays a role in dispersing these snails (Tu and Hong 2002, Cowie 2005). Both these situations occur in the PRA area. In particular, heavy rains typically occur under Mediterranean climate conditions.

In addition, individuals of the genus *Pomacea* are capable of travelling short distances over land, and crawl out of the water to lay their eggs, but are still dependent on the aquatic environment for survival.

As a consequence, natural means may be important in spreading the pest within a rice growing zone (Wada, 2006), e.g. within the Ebro Delta area. It could also reach other rice growing zones upstream in Ebro Valley (Navarra, Huesca).

~~Very unlikely~~ ~~Unlikely~~ Moderately likely ~~Likely~~ ~~Very likely~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

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

Natural spread plays a role in the spread of ampullariid snails, but is assisted by different human actions:

- Deliberate movement to outdoor aquaculture facilities (Cowie, 2005) intended either for rearing *Pomacea* snails for the pet and aquarium trade (Cowie, 2005) or for using these specimens as weeders (Wada, 2006). Because of the popularity of *Pomacea* snails among aquarium hobbyists, they are reared in aquaculture facilities in the PRA area.

- Sympathetic release of unwanted pets (Smith, 2006).

- Use of snails as fishing baits -they could be left in ponds and rivers (Wada, 2006).

- Accidental dispersal through boats. For instance, in the Ebro Delta area *Pomacea* snails adhering to boats have been already detected.

- Accidental dispersal on plants intended for propagating (Smith, 2006).

- Soil contamination through agricultural field machinery –e.g harvesters or ploughs. Since harvesters often operate at different rice production areas, they would contribute to spread the snail not only within a rice growing area, but also to distant ones (e.g. from the Ebro Delta to Valencia lagoon rice growing areas).

- Both irrigation and drainage of rice fields may play a role in the spread of the snail.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ **Likely** ~~Very likely~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

1.32. *Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?*

Egypt is the nearest country where environmental conditions seem more appropriate for *Pomacea insularum* to establish- at the Nile Delta area, where rice is an important crop. However, the pest crossing the Mediterranean Sea seems very unlikely.

~~Very unlikely~~ Unlikely ~~Moderately likely~~ ~~Likely~~ ~~Very likely~~

Level of uncertainty: ~~Low~~ Medium ~~High~~

Conclusion on the probability of spread

Spread of *Pomacea insularum* in the PRA area is regarded as likely as a result of the combination of both natural means and the different ways in which human action may contribute to it.

In the spread of *Pomacea insularum* throughout a certain rice growing area or wetland area both natural means and human assistance will likely play a significant role.

In contrast, the spread of the pest to a distant wetland area or rice growing area is also likely to occur, but mainly mediated by human assisstance since:

- *Pomacea* snail's mobility over the land is restricted, and
- Both rice growing areas and wetland areas in the EU are scarce, limited in surface area and usually far from each other.

Conclusion on the probability of introduction and spread

Introduction and spread of *Pomacea insularum* in the Ebro Delta area evidences the susceptibility of Mediterranean ricefields and natural wetlands to this snail, as well as its capacity to rapidly spread.

In this risk assessment it has been detected as well that legal protection against its importation, multiplication, trade, etc. is lacking in the EU, while *Pomacea* snails are highly appreciated among aquarium hobbyists.

Rice is a minor crop in the PRA area and rice growing areas in the EU are disperse. However, there are several ways of spread of *P. insularum* to still non-infested rice growing areas or wetlands in the EU, such as via movement of agricultural machinery –harvesters mainly, or by deliberate movement to outdoor aquaculture facilities.

Therefore, the probability of introduction and spread of *P. insularum* into the PRA area is rated as likely.

Conclusion regarding endangered areas

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

The endangered area corresponds with the rice-growing areas and natural wetlands by the EU's Mediterranean coast, as well as the Guadalquivir Marshes (South Atlantic coast in Spain). The main aspects conditioning this distribution would be the presence of water and host plants, and the existence of adequate temperature conditions -hot in the summer and at least mild during the winter.

2. Assessment of potential economic consequences

Pest effects

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

The damage and economic losses due to apple snails have been enormous (Ranamukhaarachchi & Wickramasinghe, 2006). The snails consume tender tissues at the base of rice seedlings and feed on newly transplanted rice (Halwart 1994a, Wada 1997, both as cited in Ranamukhaarachchi & Wickramasinghe, 2006). Yield losses caused by apple snails can be massive but are variable.

The overall costs related to controlling the snails, replanting, and rice yield losses account for economic loss. Available information on quantitative yield and economic losses is scanty. The Food and Agriculture Organization estimates that apple snail inflicted about US$1 billion in crop losses in the Philippines in the 1980s alone, with global losses ranging from US$55 billion to US$248 billion per year (Zeiger, 2006). In the Philippines between 1987 and 1990, farmers spent US$10 million on pesticides for the control of apple snail (Anderson 1993, as cited in Ranamukhaarachchi & Wickramasinghe 2006).

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.2 *How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?*

Pomacea insularum was first detected in Spain in August 2009, more specifically both on the river shore and in irrigation channels at the left part of the Ebro Delta (Catalonia). Since 2010, the snail can be also found at paddy fields, being the attack extremely virulent at some plots (www.gencat.cat, accessed on February 14, 2011). The pest surveys indicate that the snail has rapidly spread in the Ebro Delta area and that potential reduction in rice yield would be major without any control measures. According to recent official information, 341,213 adult and sub-adult specimens have been manually collected in the area. Although the damage on the rice crops at the Ebro Delta has been minor for the moment, this does not imply that the threat is not serious. In fact, it usually takes this species 3 or 4 years to cause damage from the moment it is detected, but then it becomes catastrophic (R. Joshi, personal communication, December 7, 2010).

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.3 *How easily can the pest be controlled in the PRA area without phytosanitary measures?*

Diverse direct and indirect control methods have been developed intending to fight *Pomacea insularum* and *P. canaliculata*. However, the control of these invasive pests has proven to be very difficult.

In fact, for regions that have not been infested and threatened so far by apple snails, prevention of their introduction must be the primary strategy.

Officials must be aware of the potential problems and be prepared to act quickly if an introduction is detected -eradication may be possible at an early stage of infestation (Ranamukhaarachchi & Wickramasinghe, 2006). Through increased numbers and difficult detection, juvenile apple snails could feasibly consume a greater proportion of plant biomass than adult apple snails and this may partially underlie the success of global apple snail invasions (Boland *et al.*, 2008)

The use of chemicals with molluscicide effect can contribute to diminish the population size of *P. insularum*, but the control of the snail cannot solely rely on this technique, being integrated management approaches preferred instead (Cuong DN, 2006; Ranamukhaarachchi and Wickramasinghe, 2006).

There are no rice varieties resistant to the feeding of apple snails. However, modern high-tillering plant types have better potential to compensate for damaged tillers over time than low and medium-tillering types (Ranamukhaarachchi & Wickramasinghe, 2006).

Various cultural methods of control have been practiced in Asian countries. This includes different types of direct seeding methods. Snail damage is somewhat low in dry-seeded fields, where rice seeds are sown and young plants are raised under dry conditions (Ranamukhaarachchi & Wickramasinghe, 2006). But dry seeding is not a feasible option for every growing area in the EU (see answer to Q. 2.9).

Damage caused by *Pomacea* snails is usually higher among young seedlings than for mature ones. Therefore, transplanting older seedlings would help reduce the snail attack (Ranamukhaarachchi & Wickramasinghe, 2006). However, this technique is not practical in the PRA area, where rice is directly seeded.

In transplanted rice, the mobility of apple snail can be restricted when the water level is maintained at a shallow depth (i.e., 2-3 cm) starting from 3 days after transplanting (Ranamukhaarachchi & Wickramasinghe, 2006). Alternate flooding and drying will greatly reduce the mobility of apple snail and its feeding (Ranamukhaarachchi & Wickramasinghe, 2006). But, again, this control method is not technically possible everywhere in the endangered area.

Crop rotation is a practical way to cope with the snail problem in direct-seeded rice fields as observed by Wada (2004) in Japan. When the soil is drained for the dryland crop, apple snails will find it unsuitable and hence will burrow until the conditions become suitable for them. Two limitations to crop rotation are: (a) there are no research results on the minimum time period during which apple snails can survive buried in the absence of a water environment, and (b) in areas with frequently high water levels or stagnant water, rotation may not be practical (Ranamukhaarachchi & Wickramasinghe, 2006). This would be the case at some of the rice production areas in the EU (e.g. at the Ebro Delta).

The placement of physical barriers or traps and the modification of the water inlets and outlets of the rice plots may be essential in order to avoid both the spread of the snail and new re-infestations, facilitating at the same time the manual collection of specimens. On the other hand, the irrigation and drainage systems in rice producing areas often interconnect different rice plots, irrigation canals and aquatic natural habitats –natural watercourses and others. At the Ebro Delta area, this type of measure has been regarded as essential to fight *P. insularum*, with the following barriers installed in 2010: 200 barrier traps throughout the irrigation channel network, 2 floating containment barriers at the points of invasion of the river habitat and 10 fix barriers at the river banks -in order to prevent the spread of the snail by creeping counter current. However, the installation of additional physical barriers is regarded as necessary, in order to prevent both further spread and re-infestation with the snail.

In addition, disinfestation of harvesters and agricultural machinery in general, before its movement to uninfested areas is regarded necessary.

Removal of snails from the ricefields by handpicking during the period from the final harvest of the preceding crop to the final harrowing for the succeeding crop reduces the snail threat for the next crop (Wada 2004, as cited in Ranamukhaarachchi & Wickramasinghe, 2006). Labour costs associated to handpicking are very high and besides, it is not completely effective. Collecting and destroying egg masses in the field is another method commonly used for controlling apple snail. The egg masses are often very visible, as they are pink and glued on plant stems and sometimes on sticks above the water surface. Both removal of adult and sub-adult snails and destruction of their egg clusters have been already accomplished at the Ebro Delta area -previous clearance of natural vegetation of the river banks was necessary.

The cheapest method of control of apple snails would be the use of natural enemies. Ducks and fish have the greatest potential for reducing the population of apple snails (Ranamukhaarachchi & Wickramasinghe, 2006). However, more research on this issue is needed.

Very easily…..easily…… with some difficulty…..with much difficulty….impossible

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.4 *How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?*

Control costs derived from the pest introduction would be likely major for the rice producing areas of the PRA area.

First of all, early detection of *Pomacea* snails, which is important to get better chances to control it, requires greater surveillance and monitoring effort compared to other pests.

Chemical control can contribute to reduce *P. insularum*'s population, which requires specific products and applications that were not previously necessary. E.g., at the Ebro Delta area, metaldehyde 5% and etofenprox 30% have been applied in 2010, while saponins are foreseen to be employed in 2011.

Unfortunately, crop rotation, an inexpensive and efficient measure, cannot be generally used in the PRA area (see answer to Q. 1.22).

Collection and elimination of adult and sub-adult snails and destruction egg clusters is a typical measure to fight apple snails and has been employed at the Ebro Delta area. However, it is evidently very costly because of its labour requirements.

Both the placement of physical barriers or traps and the modification of the water inlets and outlets of the rice plots have a significant impact on the control costs.

Keeping rice fields dry for a sufficiently long period combined with tilling, may imply not only income losses for farmers but also negative impacts for the environment – since the affected area would cease temporarily to have a wetland character.

At the Ebro Delta, although the surface area with high densities of the snail is still restricted, costs associated to the control of this pest have been already high. Until October 2010, control costs amounted to 110,000 €. Additionally, subsequent drying of the left part of the Delta has been estimated to indirectly cost over 1.12 M€, according to the calculations made by the Agriculture Department of Catalonia's regional administration.

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.5 *How great a reduction in consumer demand is the pest likely to cause in the PRA area?*

Although the pest causes losses in rice production, a reduction in consumer demand is not to be expected.

Minimal ~~Minor~~ ~~Moderate~~ ~~Major~~ ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

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

One of the greatest threats to wetland communities is the spread of invasive species (Zedler & Kercher, 2005; Lacoul & Freedman, 2006, both as cited by Burlakova *et al.*, 2009).

Apple snails (Ampullariidae: *Pomacea* spp.) have become not only agricultural, but also environmental pests widely in southern and eastern Asia and Hawaii (Joshi & Sebastian, 2006; Hayes *et al.*, 2008). More specifically, both *Pomacea canaliculat*a and *P. insularum* have devastated wetlands in Southeast Asia (Morrison & Hay, 2010).

Apple snail densities in natural wetlands may be as high as those found in rice fields, and the snails consume large quantities of many different plant species (macrophytes) besides rice in these areas (Carlsson, 2006). The aquatic plant community is central to many functions in these important ecosystems, where they are the dominant primary producers. Aquatic plants maintain biodiversity by providing varied and structurally complex habitats for macroinvertebrates, zooplankton and juvenile fish (Dielh 1988, 1992; Persson and Crowder 1998, both as cited in Carlsson, 2006). Aquatic plants in these environments also represent food or the substrate for food (periphyton) consumed by macroinvertebrates (James *et al.* 2000, as cited in Carlsson, 2006), fish and waterfowl (Lodge *et al.* 1998, as cited in Carlsson, 2006). In addition, these plants play a key role in nutrient cycling and are important natural 'biofilters' that may ensure minimum water quality (Carlsson, 2006). Wetlands also provide both food for humans and animal fodder (aquatic plants, mollusks, crustaceans, and fish).

Carlsson *et al.* (2004) experimentally demonstrated that invasion by *P. canaliculata* in Asian wetland can dramatically reduce species richness and abundance of macrophytes, originating greater nutrient concentrations and increased phytoplankton biomass. Thus, the system may shift from one of clear water and macrophyte dominance to one that is turbid and dominated by plantonic algae (Carlsson *et al*. 2004). Similar effects can be expected from the invasion of *P. insularum*, given the already commented similarities between this species and *P. canaliculata*.

On the other hand wetlands in Southeast Asia are often located close to or even connected to rice fields, and pesticides that are used in rice fields to kill apple snails are likely to be transported in the opposite direction and to enter the natural environment, with negative consequences for many organisms, including humans (Carlsson, 2006).

Minimal Minor Moderate Major Massive

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.7 *How important is the environmental damage likely to be in the PRA area?*

Feeding, activity, growth, and reproduction of apple snails increase with temperature, and mean temperatures in large parts of Southeast Asia are much higher than those found either in the snail's natural range in South America (Carlsson, 2006) or in Europe. Therefore, both potential agricultural and environmental damages to be caused by *Pomacea insularum* in the PRA area are likely to be lower compared to Southeast Asia. However, many of the reports on damages caused by *Pomacea* snails in Southeast Asia refer to *P. canaliculata* and Boland *et al.* (2008) suggested that *P. insularum* may exhibit greater feeding versatility than *P. canaliculata*. These authors found that *P. insularum* consumed more resource with additional periphyton. In fact, in the presence of additional periphyton, juvenile *P. insularum* consumed nearly 30 times more by mass than juvenile *P.canaliculata*.

Frequently, rice fields in Europe are located at former natural wetlands which have been partially transformed to grow rice. As a consequence, nowadays both rice fields and natural wetlands are often adjacent. Therefore, significant interactions between both environments are likely to occur. This is the case, for instance, of the Camargue region (France), the Ebro Delta area or the Valencia Lagoon ('Albufera'). Moreover, in many cases, rice culture is only possible by permanent field over-flooding with freshwater -in order to keep salt water under the plant root level. Irrigation water returns from paddy fields can significantly contribute to the maintenance of the surrounding natural wetlands and its biodiversity (Canicio *et al.*, 2008). However, they may also clearly contribute to the spread of *Pomacea* snails.

The Ebro Delta area is a wonderful example of the relationships established between diverse ecosystems through the water cycle. By means of an extensive web of irrigation channels, controlled flooding of the rice plots with freshwater from the river is done. Water returns from these plots are collected and subsequently distributed by means of a web of drainage ditches and channels onto natural wetlands, bays and the seashore, fertilizing all these environments and boosting seafood productivity. Nevertheless, the water flow from rice fields to natural wetlands clearly contributes to the spread of *Pomacea* snails throughout the rice fields and natural wetlands in the area. Moreover, chemical control of the snail in irrigation channels or rice-fields implies that part of the employed chemicals and/or their residues would also reach the surrounding natural wetlands.

Considering the contribution of both rice-fields and natural wetland environments to the flora and fauna biodiversity in the area, infestation of these ecosystems with *P. insularum* would be very detrimental to their preservation (see answer to Q. 2.6).

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

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

As previously explained in the answer to Q. 2.1, the damage and economic losses due to apple snails have been overwhelming (Ranamukhaarachchi & Wickramasinghe, 2006).

Crop losses caused by *Pomacea canaliculata* and *P. insularum* have been especially worrying because of the economic and social importance of rice in Southeast Asia, where apple snails have mainly spread for the last decades.

Moreover, *Pomacea* snails have been implicated in the decline of native species of *Pila* in Southeast Asia, with many economic and medicinal or biological values (Acosta and Pullin 1991, Halwart 1994b, both as cited in Ranamukhaarachchi & Wickramasinghe, 2006).

In addition, apple snails pose a serious threat to natural wetland biodiversity (see answer to Q. 2.6).

The use of synthetic pesticides for apple snail control usually pollutes the aerial, soil, and aquatic environments and poses hazards to applicators; farm workers; and non-target organisms such as fish, frogs, and beneficial arthropods (Ranamukhaarachchi & Wickramasinghe, 2006). Significant and long-lasting downstream effects of those pesticides on marine ecosystems can also occur (Ranamukhaarachchi & Wickramasinghe, 2006).

Finally, apple snails are an intermediate host for the rat lungworm (*Angiostrongylus cantonensis*) a nematode that can cause meningitis in humans (Mochida 1991, Halwart 1994b, Naylor 1996). They are also associated with other human health threats, including skin irritations by being an intermediate host of trematodes (Naylor 1996) and digestive tract infections (Mochida 1991, Halwart 1994a, Naylor 1996, all of them as cited in Ranamukhaarachchi & Wickramasinghe, 2006).

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.9 *How important is the social damage likely to be in the PRA area?*

Apple snail could cause enormous damage to rice farmers, since high densities of *P. insularum* can devastate paddy fields, which has already occurred at certain spots of the Ebro Delta area.

Moreover, rice is the only possible crop at most of the EU's rice growing areas, since it can be grown at freshwater flooded fields. This management technique -not tolerated by other crops, is necessary to maintain under the root system the hypersaline phreatic front present at many areas (Canicio *et al.*, 2008).

Answer to Q.2.7 addresses potential environmental damages by the snail in the PRA area.

Finally, as a result of the mentioned direct and indirect environmental damages caused by the snail at rice patches and natural wetlands, both amenity value of recreational areas and revenues from tourism would be negatively affected at some of the rice-producing areas of the EU (e.g. the Ebro Delta, Doñana National Park, Valencia Lagoon or the Camargue). For instance, the recent temporary desiccation of the left part of the Ebro Delta, performed in order to fight the snail, made impossible to hire around 1,000 hunting positions in the area, which meant about 1 M€ income loss for rice growers.

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.10 *How likely is the presence of the pest in the PRA area to cause losses in export markets?*

Viable eggs and snails are unlikely to be present as contaminants of imported rice (http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157, accessed on February 15, 2011). To our knowledge, bans on importation of rice from countries infested with *P. insularum* -or *P. canaliculata*, do not occur.

~~Impossible~~ Very unlikely ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ . ~~Very likely~~ ~~Certain~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.11 *How likely is it that natural enemies, already present in the PRA area, will not reduce populations of the pest below the economic threshold?*

To date, natural enemies present in the areas where *P. insularum* or *P. canaliculata* have been introduced have not been able to keep the snail's population under the economic threshold.

~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ Very likely

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.12 *How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?*

Chemical control of *P. insularum* cannot be recommended as the main technique to fight *P. insularum* because of both insufficient effectiveness to control the snail and the potential deleterious effects of chemicals on the environment and human health. However, since some products may help to fight the snail, chemical control remains as a management option when needed. In fact, at the Ebro Delta area, chemical treatments have been part of the strategy to control the snail, although their use has been mainly restricted to rice plots with the highest density of the snails.

Besides, dessication of rice fields during periods longer than usual in order to fight *P. insularum* would cause a negative impact on the populations of different species of aquatic birds –and particularly on migratory bird species.

On the other hand, because of the impossibility of using herbicides in organic rice farming, weeds may constitute the main difficulty for this kind of management in coastal areas -where crop rotations are not usually an option (Canicio *et al.*, 2008). Apple snails, being polyphagous and voracious plant feeders, might contribute to weed control. However, since they largely feed on rice, they might also cause intolerable yield loss. Moreover, some of the management techniques for controlling weeds in organic rice fields could favour increased infestations with the snail compared to conventional management. For instance, the technique consisting on a rapid over-flooding of the rice field with a 30 cm high water column after sowing, intended for controlling some weed species (Canicio *et al.*, 2008), would at the same time provide a favourable environment for the snail proliferation.

~~Impossible~~ ~~Very unlikely~~ ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ Very likely ~~Certain~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.13 *How important would other costs resulting from introduction be?*

Other pest-related costs could be due to:

- Expert consultancy services in order to control *P. insularum* in the PRA area and prevent it from spreading further.
- Pest surveillance programmes.
- Advice to growers in order to implement effective preventive strategies against the snail.
- Research programmes on the subject.
- Efforts to restore damaged natural environments.

~~Minimal~~ ~~Minor~~ ~~Moderate~~ Major ~~Massive~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.14 *How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?*

It has never been observed to date.

~~Impossible~~ Very unlikely ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ ~~Very likely~~ ~~Certain~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

2.15 *How likely is the pest to cause a significant increase in the economic impact of other pests by acting as a vector or host for these pests?*

It has never been observed to date.

~~Impossible~~ Very unlikely ~~Unlikely~~ ~~Moderately likely~~ ~~Likely~~ ~~Very likely~~ ~~Certain~~

Level of uncertainty: Low ~~Medium~~ ~~High~~

Conclusion of the assessment of economic consequences

Pomacea insularum is regarded as an invasive species that devastates rice fields and natural wetlands. Environmental conditions at these ecosystems in Southern Europe are judged adequate for the pest to establish, as the situation at the Ebro Delta proves.

Usually, damage caused by this snail is limited for the first years after its introduction in a new area. However, later on major rice crop losses are to be expected.

Rice is not a major crop in the EU, although it may be of great economic, social and environmental importance at a local level.

Moreover, *Pomacea insularum* can be also regarded as a threat for Mediterranean natural wetlands, which often host numerous plant and animal species and act as biodiversity reserves.

On the other hand, control of *Pomacea insularum* is complicated and expensive. Rotating rice with any dryland crop would have a significant impact in the pest control while being unexpensive. However this measure cannot be often applied due to salinity problems. Integrated pest management approaches, precise in order to get better chances to control the snail, should include: extensive pest monitoring, manual collection and destruction of snails and egg clusters, placement of barriers and barrier traps, modification of ricefields' water inlets and outlets or chemical treatments, among others.

As a conclusion, the potential economic consequences of the pest establishment in the area can be globally rated as major at the endangered area.

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

The endangered area corresponds with the rice-growing areas and natural wetlands by the EU's Mediterranean coast, as well as the Guadalquivir Marshes (South Atlantic coast in Spain). The main aspects conditioning this distribution would be the presence of water and host plants and the existence of adequate temperature conditions -hot in the summer and at least mild during the winter.

Degree of Uncertainty

The main areas of uncertainty identified in the Pest Risk Assessment are:

- It is unknown the number and distribution of open-air aquaculture facilities in the PRA area breeding *Pomacea insularum* or using it as a weeder.

- There are not any data on how important the trade on *P. insularum* is within the PRA area. As for importations, the situation among the different member states may be different, but at least in Spain there are no registers on the volume and frequency of importation of *P. insularum*, that can be freely imported as an ornamental species for aquaria.

- The range of host plant species for *P. insularum* in the endangered area of the PRA area remains uncertain. There are not any references regarding the plant species on which it would really feed in the Mediterranean area, although there is enough evidence on the polyphagous character of *P. insularum* on macrophytes, and regarding the plant characteristics that influence the palatability of a plant for *P. insularum*.

- The biology of *P. insularum* under the PRA area's conditions is not sufficiently known (tolerance to extreme temperatures, average number of egg clutches per season and female, clutch size, clutch yields and feeding activity).

- The impacts of the control measures for *P. insularum* on existing biological or integrated systems for controlling other rice pests remain uncertain.

- The environmental impact that *P. insularum* may cause in mediterranean natural wetlands of the PRA area remain also uncertain. The reported damages on natural habitats by *P. insularum* mainly correspond to tropical areas. Uncertainties on this matter are closely related to the lack of precise information on the host range and biology of *P. insularum* in the endangered area of the PRA area.

Conclusion of the pest risk assessment

The way which appears as most relevant for the entry of *P. insularum* into the PRA area is the importation of these snails into the EU either for the pet/aquarium trade or for aquatic weed control. Global probability of entry of *P. insularum* in the PRA area has been assessed as moderately likely. The main contributing factors to the entry of the snail into the EU would be the following:

- Importation of this species into the EU is allowed, as well as its multiplication and trade.

- *Pomacea* species are popular among aquarium hobbyists.

- The escape of specimens of *P. insularum* from outdoor aquaculture facilities and, to a lesser extent, its intentional release into the environment would facilitate its transfer to natural or cultivated wetlands –namely ricefields.

On the other hand, the establishment of *P. insularum* in the PRA area has been rated as very likely, considering that:

- *P. insularum* is an invasive species, with a high fecundity and highly polyphagous.

- Environments adequate for the pest to survive and thrive can be found in the PRA area –in particular it threatens both natural wetlands and ricefields at warm temperate areas. In fact, *P. insularum* has already established at the Ebro Delta (NE of the Iberian Peninsula).

- Several rice cultural practices typical in the area are regarded as favourable for the pest to establish –e.g. rice monoculture together with the long periods during which the ricefields are kept flooded.

Spread of *P. insularum* in the PRA area is regarded likely -as a result of the combination of both natural means and the different ways in which human action may contribute to it. Natural spread plays a major role in the pest spread within a rice growing area or natural wetland. However, rice is a minor crop in the PRA area and rice growing areas in the EU are disperse –and the same occurs to natural wetland ecosystems. Therefore, human assistance is regarded decisive in the spread of the snail to still non-infested areas, since *P. insularum* is dependent on the aquatic environment for survival.

Introduction and spread of *P. insularum* in the Ebro Delta area evidences the susceptibility of Mediterranean rice fields and natural wetlands to this snail, as well as its capacity to rapidly spread.

As for the potential economic consequences of the pest establishment, they can be globally rated as major at the endangered area, given that:

- *P. insularum* causes major crop losses after some time from its introduction in an area and it also devastates natural wetlands.

- The control of this pest is complicated and expensive and requires a comprehensive integrated pest management approach.

Therefore, prevention of the introduction of *P. insularum* should be a primary strategy. In fact, current worldwide phytosanitary regulations concerning *P. insularum* rely on import prohibition –USA, Australia.

In contrast, EU legislation in force leaves the door open to the entry of the island apple snail.

Finally, the eradication of the snail at an early stage of infestation may be possible and should be tried at the Ebro Delta area -in order to avoid both any further damage by the snail at the Delta and the snail's further spread in the EU.

Stage 3. Pest Risk Management

3.1 *Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?*

Answer: No.

If no.. Proceed through the risk management scheme

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

Answer: No.

If no.. go to 3.3

3.3 *Is the pathway that is being considered the natural spread of the pest?*

Answer: No.

If no.. go to 3.9

3.9 *Is the pathway that is being considered the entry with human travellers?*

Answer: No.

If no.. go to 3.10

3.10 *Is the pathway that is being considered contaminated machinery or means of transport?*

Answer: No.

Go to 3.12

EXISTING PHYTOSANITARY MEASURES

3.12 *Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?*

Answer: No.

For the moment, legislation in force allows importation of *Pomacea* spp. into the EU.

Go to 3.13

IDENTIFICATION OF APPROPRIATE RISK MANAGEMENT OPTIONS

Option for consignments

Detection of the pest in consignments by inspection or testing & Removal of the pest from consignments (questions 3.13 to 3.15 and 3.16 to 3.18)

Questions 3.13 to 3.18 of the EPPO Guidelines on Pest Risk Analysis, which refer to the 'Detection of the pest in consignments' or the 'Removal of the pest from consignments' do not apply in this case, since the assessed pathway is the importation of *Pomacea insularum* itself.

Go to 3.19

Prevention of establishment by limiting the use of the consignment

3.19 *Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?*

Answer: *No*.

Evidently, limited periods of entry would be of no use in preventing the establishment of the snail. As for a limited distribution of *P. insularum* in the PRA area, it is not regarded as feasible to apply, since once the snail enters into the EU its movement throughout the EU territory is free –and the establishment of protected areas within the EU does not seem feasible to be effectively implemented. Finally, it does not seem feasible either to monitor or control the end use of *P. insularum*.

Go to 3.20

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity & Establishment and maintenance of pest freedom of a crop, place of production or area (questions 3.20 to 3.24 and 3.25 to 3.28)

Questions 3.20 to 3.28 of the EPPO Guidelines on Pest Risk Analysis, which refer to the 'Prevention of infestation of the commodity' or the 'Establishment and maintenance of pest freedom of a crop, place of production or area' do not apply in this case, since the assessed pathway is the importation of *Pomacea insularum* itself.

Consideration of other possible measures

3.29 *Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?*

Answer: *Yes*

In areas of the EU where ecoclimatic conditions are favourable for the pest establishment, as well as nearby the sites where the snail has been reared outdoors, the implementation of surveillance actions is recommended -in order to early detect the presence of the pest and have better chances to eradicate it.

As for the recommendations on surveillance actions at the already infested area of the EU and its surroundings, please see explanation at Q. 3.30.

Regarding eradication of *P. insularum*, it may be possible if early detection occurs. However, eradication is not technically simple and the associated costs and derived impacts –economic, social and environmental, from both introduction and subsequent eradication have been estimated to be high.

Go to 3.30

EVALUATION OF RISK MANAGEMENT OPTIONS[5]

3.30 *Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest into non-infested areas of the endangered area? List them.*

Answer: Yes

[5] According to the recommendations in the EPPO Guidelines, questions 3.29 onwards have been adapted to the peculiarities of the pest.

Since the snail has already entered the PRA area, actions must be taken in order to both:

a) 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.

b) Minimize the snail's population size and associated damages and eventually eradicate it at the Ebro Delta area.

Regarding goal (a), it should be kept in mind that the spread of *P. insularum* in the PRA area could be due either to new introductions of the snail or to the snail spread from the Ebro's Delta -both into natural habitats or cultivated fields.

In order to avoid new introductions of the pest in the PRA area, the following measures should be adopted:

- Legislation changes in order to ban importation of *Pomacea insularum* into the EU.

  This measure has been already adopted by other countries, such as Australia and the USA. Moreover, in the USA, where *P. insularum* is already present, interstate movement has been banned too.

- Banning both breeding and trade of this species within the EU.

Also surveillance actions at both ricefields 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, are recommended (see answer to Q. 3.29)

Moreover, a number of possible measures addressing goal (b) are following listed:

- Collection and destruction of adult and sub-adult snails and destruction of egg clusters of *Pomacea insularum* present in rice fields, water channels and the riverbanks.
  This measure has already been taken at the Ebro Delta area, where about 341,213 adult and sub-adult specimens have been already collected. The majority of the collection took place along the 85 km of channels with the greatest presence of the pest, although egg clusters were located along a total of 130 km of channels in the left hemi-delta.

- Keeping rice fields dry for long periods combined with mechanical labours have been reported to contribute to the snail's destruction.
  This measure, recently applied at the left part of the Delta, has been judged to reduce the snail's population by 80%.

- Modification of the water inlets and drainage outlets of the plots in order to hinder any further spread of the snail in the ricefields.

- Installation of barrier traps throughout the irrigation network. Combining this measure with baiting improves collection of snails.
  At the Ebro Delta area, baiting products are presently being assayed.

- 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-current.

- Chemical treatment in restricted areas of the paddy fields -where the infestation levels are very high, as well as at the irrigation and drainage network of the Delta.

  Most chemicals products with molluscicide effects that can be employed against the inland apple snail have a high environmental impact and even some of them are prohibited in the EU. In addition, trials made on some of them in laboratory (and in some cases also in the field) have shown insufficient effectiveness.

Saponins are the products that seem more adequate to be applied at the Ebro Delta's ricefields, although this kind of treatment is quite new and there is little experience on it at a global scale (Joshi *et al*., 2008; San Martin *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.

- Information actions directed to visitors of the Ebro Natural Park, in order to prevent them from contributing to the pest spread.

- Elimination of apple snails adhering to hulls of boats in the area.

- Elimination of apple snails from tractors, harvesters and agricultural machinery in general, especially before they are moved into a pest free area.

- Design and implementation of research projects in order to prospect for new control techniques and to improve the known ones.
  In this regard, several assays are currently being conducted at the Ebro Delta area.

Go to 3.31

3.31 *Does each of the individual measures identified reduce the risk to an acceptable level?*

Answer: No

Both, banning of the entry of *P. insularum* into the EU as well as its breeding and trade within the EU are regarded as necessary in order to avoid new introductions of the pest into the PRA area.

In addition, a comprehensive integrated management plan is necessary in order to both:
- Avoid the pest spread into non-infested areas, and
- Eradicate the pest in the Ebro Delta area, or at least minimize its presence and impact there.

The integrated management plan should include most, if not all of the measures listed in Q. 3.30 that address goal (b), given the invasive character of the island apple snail.

Go to 3.32

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

Answer: Yes.

See answer to Q. 3.31.

Go to 3.33

3.33 *If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.*

Answer: Not applicable.

Go to 3.34

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

Evidently, prohibition of entry of *P. insularum* implies a maximum interference with international trade in this snail.

Go to 3.35

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

It is regarded essential to apply the necessary measures in order to control the existing infestation of island apple snail at the Ebro Delta area and hopefully eradicate it there, given:

- The risk that the snail poses to the maintenance of the rice production at the Ebro Delta and to the preservation of the valuable and unique natural space of the Delta.

- The importance of preventing the snail from invading other rice producing areas and wetlands in the EU.

Because of that, and although some of the proposed measures (Q. 3.30) may be costly, not applying them would dangerously reduce the opportunities to eradicate the snail. Among such measures there can be cited the following:

- The collection and destruction of snails at ricefields, water channels and riverbanks.

- The modification of water inlets and outlets.

- The installation of different types of barriers

- Keeping ricefields dry for longer than usual (the economic impact of this measure is mainly due to indirect costs, in particular to the loss of income for farmers and the tourist sector in the area derived from a reduction in hunting tourism).

With regards to the environmental impacts that can be derived from certain measures, it must be again kept in mind its necessity in order to efficiently manage this pest.

The main environmental impacts that can result from the proposed actions would be related to:

- The use of chemical products.

  In this regard, saponins seem the less harmful option since they apparently have very little impact on humans and mammals in general while they would be quite effective against the snail.
  However, saponins would have some negative impacts on other fauna, especially on other molluscs, invertebrates and fishes, although there is still little information on this subject. Because of that, at the Ebro Delta area laboratory tests on the specific toxicity of saponins on certain invertebrates and fishes are being carried out. In addition, *in situ* ecotoxicological tests are planned to be carried out. All these facts considered, saponins still seem the most adequate chemicals to be used against *P. insularum*, since they are hydrosoluble, do not bio-accumulate and have relative short degradation times (3-5 days), which would help to reduce the risk of toxic impacts on fauna out of the ricefields. In any case, the proposed battery of physical measures intends to minimize the use of chemical treatments against the snail.

- Desiccation of the ricefields for longer than usual is judged to have a negative environmental impact, especially with regards to aquatic birds –both migratory and permanent in the area.

Finally, the proposed measures are not regarded to have negative social consequences beyond the small economic impact that the prohibition on the importation, breeding and trade of the snail in the EU may have for some aquarium businesses.

Go to 3.36

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

Answer: No.

Go to 3.38

3.38 *Have all major pathways been analyzed?*

Answer: Yes.

Go to 3.41

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

The only 'pathway' analysed is not properly such, but the intentional importation of the pe itself, which as previously explained in this document is by far much more dangerous than any inadvertent importation of the snail.

Go to 3.42

3.42 *All the measures or combination of measures identified as being appropriate for each pathway or for the commodity can be considered for inclusion in phytosanitary regulations in order to offer a choice of different measures to trading partners.*

Answer: Not applicable.

Go to 3.43

3.43 *In addition to the measure(s) selected to be applied by the exporting country, a phytosanitary certificate (PC) may be required for certain commodities. The PC is an attestation by the exporting country that the requirements of the importing country have been fulfilled. In certain circumstances, an additional declaration on the PC may be needed (see EPPO Standard PM 1/1(2): Use of phytosanitary certificates).*

Answer: Not applicable.

Go to 3.44

3.44 *If there are no measures that reduce the risk for a pathway, or if the only effective measure unduly interfere with international trade (e.g. prohibition), are no cost-effective or have undesirable social or environmental consequences, the conclusion of the pest risk management stage may be that introduction cannot be prevented. In the case of pest with a high natural spread capacity, regional communication and collaboration is important.*

Conclusion of Pest Risk Management

Because of the invasive character of *Pomacea insularum* it is essential to prohibit its importation, breeding and trade in the EU, as other countries have already done – USA, Australia.

In addition, and since this snail is already present at the Ebro Delta area in Spain, it is recommended to implement there an Integrated Management Plan in order to control and hopefully eradicate the snail in the area.

Although the economic costs derived from the implementation of such a Plan are expected to be high, they must be assumed in order to avoid incomparably worse economic, social and environmental consequences.

References

Acosta BO, Pullin RSV (1991). Environmental impact of the golden snail (*Pomacea* sp.) on rice farming systems in the Philippines. Freshwater Aquaculture Center, Central Luzon State University, Munoz, Nueva Ecija, and ICLARM, Manila, 34 pp.

Adalla CB, and Morallo-Rejesus B (1989). The golden apple snail, *Pomacea* sp., a serious pest of lowland rice in the Philippines. Pp. 417-422. In: I.F. Henderson (ed) Slugs and snails in world agriculture. British Crop Protection Council Monograph 41.

Aguilar M (2001). Rice situation in Southern Spain. Cahiers Options Méditerranéennes, 50: 123-126.

Albrecht EA, Carreño NB, and Castro-Vasquez A (1999). A quantitative study of environmental factors influencing the seasonal onset of reproductive behaviour in the South American apple-snail *Pomacea canaliculata* (Gastropoda: Ampullariidae). Journal of Molluscan Studies 65: 241-250.

Alonso, AS and Castellanos ZJA (1949). Algunos datos sobre la alimentación de las ampularias. Notas del Museo de La Plata, Zoología 14(115):31-34.

Anderson EA (1993). The Philippine snail disaster. The Ecologist 23, 70-72.

Baoanan G and Pagulayan RC (2006). Taxonomy of golden apple snails (*Ampullariidae*). pp. 25-36. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Barbier EB, Acreman MC, Knowler D (1996).Economic valuation of wetlands: a guide for policy makers and planners. Ramsar Convention Bureau, Gland, Switzerland.

Barnes MA, Fordham RK, Burks RL, Hand JJ (2008). Fecundity of the exotic applesnail, *Pomacea insularum*. J. N. Am. Benthol. Soc, 27(3): 738-745.

Berthold (1991). Vergleichende Anatomie, Phylogenie un historische Biogeographie der Ampullariidae (Mollusca, gastropoda). Abhandlungen des Naturwissenschaftlichen Vereins in Hamburg (nf) 29, 1-256.

Biosecurity Australia (2001). Guidelines for Import Risk Analysis. Draft September 2001 (Available at: www.daff.gov.au/; accessed on February 8, 2011).

Boland BB, Meerhoff M, Fosalba C, Mazzeo N, Barnes MA, Burks RL (2008). Juvenile snails, adult appetites: contrasting resource consumption between two species of applesnails (*Pomacea*). Journal of Molluscan Studies, 74(1): 47-54.

Burks RL, Kyle CH, Trawick MK (2010). Pink eggs and snails: field oviposition patterns of an invasive snail, *Pomacea insularum*, indicate a preference for an invasive macrophyte. Hydrobiologia, 646: 243-251.

Burlakova LE, Karatayev AY, Padilla DK, Cartwright LD, Hollas DN (2009). Wetland restoration and invasive species: apple snail (*Pomacea insularum*) feeding on native and invasive aquatic plants. Restoration ecology, 17 (3): 433-440.

CAB International (2007). Crop Protection Compendium. Wallingford, UK: CAB International.

Canicio A, Catalá M, Escolano M, Fereres A, Galimany G, Moisés J, Rauly T, Reverté V (2008). El cultivo eclógico del arroz en zonas costeras. Departament d'Agricultura, Alimantació i Acció Rural, Generalitat de Catalunya

Carlsson, NOL (2006). Invasive golden apple snails are threatening natural ecosystems in Southeast Asia, pp.61-72. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Carlsson NL, Brönmark C (2006). Size-dependent effects of an invasive herbivorous snail (*Pomacea canaliculata*) on macrophytes and periphyton in Asian wetlands. *Freshwater Biology,* 51: 695-704.

Carlsson N.O.L, Brönmark C, and Hansson L-A (2004). Invading herbivory: The golden apple snail alters ecosystem functioning in Asian wetlands. Ecology 85: 1575-1580.

Carlton, JT (1992). Dispersal of living organisms into aquatic ecosystems as mediated by aquaculture and fisheries activities. Maryland Sea Grant College, College Park, MD.p. 13–46.

Carlton, JT (1996). Pattern, process, and prediction in marine invasion ecology. Biological Conservation 78:97–106.

Cazzaniga, NJ (1990). Predation of *Pomacea canaliculata* (Ampullariidae) on adult Biomphalariaperegrina (Planorbidae). Annals of Tropical Medicine and Parasitology 48(1): 97-100.

Cazzaniga, NJ (2006). *Pomacea canaliculata*: harmless and useless in its natural realm (Argentina), pp. 37-49. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Cazzaniga NJ, and Estebenet AL (1984). Revisión y notas sobre los hábitos alimentarios de los Ampullariidae (Gastropoda). Historia Natural 4: 213-224.

Chataigner J, Mouret J-C (1997). Recherches et production rizicole en France. Cahiers Options Méditerranéennes, 24(2): 117-126.

Cirera JC, Marino G, Morales C, Battello C, Parera A (2010). Informe de la Gira europea de Arroz Ecológico 2010. Alianza del Pastizal, SEO BirdLife, El Faro, 35 pp.

Conner SL; Pomory CM, Darby PC (2008). Density effects of native and exotic snails on growth in juvenile apple snails *Pomacea paludosa* (Gastropoda: ampullariidae): a laboratory experiment. Journal of Molluscan Studies 74: 355-362.

Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community.

Cowie, RH (1995). Identity, distribution and impacts of intorduced Ampullariidae and viviparidae in the Hawaian Islands. *Journal of Medical and Applied Malacology* 5 [1993], 61-67

Cowie, RH (1996). New records of introduced land and freshwater snails in the Hawaiian Islands. Bishop Museum Occasional Papers 46:25-27.

Cowie, RH (2002). Apple snails (Ampullaridae) as agricultural pests: their biology, impacts, and management, pp. 145-192 *in* Baker, GM (ed) Molluscs as crop pests. CABI Publishing, Wallingford, England.

Cowie, RH (2006). Apple snails (Ampullariidae) as agricultural pests: their biology, impacts and management.

Cowie RH, Robinson DG (2002). Pathways of introduction of nonindigenous land and freshwater snails and slugs. http://www.cdfa.ca.gov/phpps/ppd/Entomology/Snails/pathwayspub.htm (accessed July 21, 2005).

Cowie RH, Dillon RT, Robinson DG, and Smith JW (2009). Alien non-marine snails and slugs of priority quarantine importance in the United States: A preliminary risk assessment. Amer. Malac. Bull. 27: 113-132.

Cuong DN (2006). The golden apple snail in Vietnam, pp. 243-254. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Curcó i Masip, A (2001). La vegetación del delta del Ebro (V): las comunidades helofíticas e hidrófilas (clases Phragmiti-Magnocaricetea y Molinio-Arrhenatheretea). Lazaroa 22: 67-81.

Diehl S (1988). Foraging efficiency of three freshwater fish: effects of structural complexity and light. Oikos 53: 203-214.

Elger A, and Lemoine D (2005). Determinants of macrophyte palatability to the pond snail *Lymnaea stagnalis*. Freshwater biology 50: 86-95.

EPPO (2009). Guidelines on Pest Risk Analysis, PM 5/3 (4).

Forés E and Comín FA (1992). Ricefields, a limnological perspective. Limnetica, X: 101-109.

Halwart, M (1994a). The ecology of fish in rice fields. Annals of Tropical Research 10(1):1-15.

Halwart, M (1994b).The golden apple snail *Pomacea canaliculata* in Asian rice farming systems: Present impact and future threat. International Journal of Pest Management 40:199-206.

Hayes KA, Joshi RC, Thiengo SC, Cowie RH (2008). Out of South America: multiple origins of non-native apple snails in Asia. Diversity and Distributions 14, 701-712.

Howells, RG (2001a). Introduced non-native fishes and shellfishes in Texas waters: an updated list and discussion. Management data series. Parks and Wildlife Department (Texas). Austin TX 188.

Howells, R.G. (2001b). History and status of apple snail (*Pomacea* sp.) introductions in Texas. Texas Parks and Wildlife Department, Management Data Series 183:11.

Howells RG, Smith JW (2002). Status of the applesnail *Pomacea canaliculata* in the United States. In Wada, T., Y. Yusa & R. C. Joshi (eds), Proceedings of the Special Working Group on the Golden Apple Snail (*Pomacea* spp.). The Seventh International Congress on Medical and Applied Malacology (7th ICMAM). Los Banos, Laguna, Philippines, SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA): 86–96.

Howells RG, Burlakova LE, Karatayev AY, Marfurt RK, Burks RL (2006). Native and introduced Ampullariidae in North America: history, status and ecology, pp. 73-112. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

James MR, Hawes I, Weatherhead, M (2000). Removal of settled sediments and periphyton from macrophytes by grazing invertebrates in the littoral zone of a large oligotrophic lake. Freshwater Biology 44: 311-326.

Joshi RC, Ponniah AG, Casal C, Hussain NM (2004). Case study on the invasive golden apple snail in ASEAN. Workshop on building capacity to combat impacts of aquatic invasive alien species and associated trans-boundary pathogens in ASEAN countries. Malaysia, July 12-16, 2004. Pp 353-357.

Joshi RC, San Martin R, Saez-Navarrete C, Alarcon J, Sainz J, Antonlin MM, Martin AR, Sebastian LS (2008). Efficacy of quinoa (*Chenopodium quinoa*) saponins against golden apple snail (*Pomacea canaliculata*) in the Philippines under laboratory conditions. Crop Protection 27: 553-557.

Karatayev AY, Burlakova LE, Karatayev VA, Padilla DK (2009). Introduction, distribution, spread and impacts of exotic freshwater gastropods in Texas. Hydrobiologia, 619: 181-194.

Karatayev AY, Burlakova LE, Mastitsky SE & Olenin S (2008). Past, current, and future of the Central European corridor for aquatic invasions in Belarus. Biological Invasions 10: 215-232.

Keller R, Drake J, Lodge D (2007). Fecundity as a basis for risk assessment of nonindigenous freshwater molluscs. Conservation Biology, 21: 191-200.

Lacoul P, and Freedman B (2006). Environmental influences on aquatic plants in fresh water ecosystems. Environmental Reviews, 14: 89-136.

Laup (1991). Golden apple snail and its eradication in Papua New Guinea. In: Kumar, R. (ed.) Proceedings of a Seminar on Pests and diseases of Food Crops – Urgent Problems and practical Solutions. Department of Agriculture and Livestock, Konedobu, pp. 55-62.

Lodge DM, Cronin G, Van Donk E, Froelich AJ (1998). Impact of herbivory on plant standing crop: Comparisons among biomes, between vascular and nonvascular plants, and among freshwater herbivore taxa. Pp. 149-171 in : Jeppesen E, Sondegaard Ma, Sondegaard Mo, Christoffersen K (eds). The structuring role of submerged macrophytes in lakes. Ecological Studies 131, Springer, New York.

Lowe S, Browne M, Boudjelas S, De Poorter M (2000). 100 of the world's worst invasive alien species database. A selection from the global invasive species database. The invasive species specialist group. World conservation union. Hollands Printing Ltd. New Zealand.

Maeda T, Han D, Marshall D, and Thompson KC (2000). Pet supplies: An industry analysis. (BBUS 470). University of Washington. 14 pp.

Marfurt RK & Burks RL. (2005). Invaders from the south: Applesnail (*Pomacea canaliculata*) ecology and life history. Freshwater Mollusk Conservation Society, biennial symposium, St.Paul, Minnesota, 15-18 May 2005

MARM (2010). Anuario de Estadística 2009. Madrid, 1147 pp.

Martin PR, Estebene*t al*, and Cazzaniga NJ (2001). Factors affecting the distribution of *Pomacea canaliculata* (Gastropoda: Ampullariidae) along its southernmost natural limit. Malacologia 43 (1–2):13–23.

McCann JA, Arkin LN, Williams JD (1996). Nonindigenous aquatic and selected terrestrial species of Florida: Status, pathway and time of introduction, present distribution, and significant ecological and economic effects. Center for Aquatic Plants, University of Florida, Gainesville, Florida. http://aquat1.ifas.ufl.edu/mcintro3.html (accessed March 14, 2002; July 22, 2005).

Mitsch WJ, Gosselink, JG (1993). Wetlands, 2nd edition. Van Nostrand Reinhold, New York.

Mochida O. (1991). Spread of freshwater *Pomacea* snails (Pilidae, Molluska) from Argentina to Asia. Micronesica Supplementum 3:51-62.

Morrison WE, Hay ME (2010). Feeding and growth of native, invasive and non-invasive alien apple snails (Ampullariidae) in the United States: Invasive eat more and grow more. Biological Invasions Online publication date: 30-Sep-2010.

Naylor R (1996). Invasions in agriculture: assessing the cost of golden apple snail in Asia. Ambio 25, 443-448.

Neck, RW (1986). A second record of an introduced apple snail, *Pomacea canaliculata*, from the lower Rio Grande valley of Texas. Texas Conchologist 22(3):54–57.

Okuma M, Tanaka K, and Sudo S (1994). Weed control method using apple snail (*Pomacea canaliculata*) in paddy fields. Weed Research, Japan 39, 114-119.

Perera G, Walls JG (1996). Apple Snails in the Aquarium. T.F.H. Publications, Neptune city, new Jersey, 121 pp.

Persson L, Crowder LB (1998). Fish-habitat interactions mediated via ontogenetic niche shifts. Pages 3-23 in: Jeppesen E, Sondegaard Ma, Sondegaard Mo, Christoffersen K (eds). The structuring role of submerged macrophytes in lakes. Ecological Studies 131, Springer, New York.

Ranamukhaarachchi SL, Wickramasinghe S (2006). Golden apple snails in the world: introduction, impact, and control measures. 133-152. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Rawlings TA, Hayes KA, Cowie RH and Collins TM (2007). The identity, distribution, and impacts of non-native apple snails in the continental United States. BMC Evolutionary Biology, 7: 97.

San Martín R, Ndjoko K, Hostettmann K (2008). Novel molluscicide against *Pomacea canaliculata* based on quinoa (*Chenopodium quinoa*) saponins. Crop protection 27: 310-319.

Simberloff D, and Stiling P (1996). Risks of species introduced for biological control. Biological conservation 78, 185-192.

Smith JW (1992). Introduction and dispersal of apple snails (Ampullariidae) on Guam. Pacific Science Association Information Bulletin 44, 12-14.

Smith JW (2006). Ampullariidae pathways, pp.113-120. In Joshi, RC & Sebastian, LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Teo, SS (2004). Biology of the golden apple snail, *Pomacea canaliculata* (Lamarck, 1822), with emphasis on responses to certain environmental conditions in Sabah, Malaysia. Molluscan Research 24: 139-148.

Tu DM, and Hong PDV (2002). National report on the management of invasive alien species. Asean Biodiversity 2(4):38-39. In Joshi, RC & Sebastian, LS (ed.) Global advances in ecology and management *of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Vitousek PM, D'Antonio CM, Loope LL, and Westbrooks R (1996). Biological invasions as global environmental change. American Scientist 84:468-478.

Wada T (1997). Introduction of the apple snail *Pomacea canaliculata* and its impact on rice agriculture. In: Proceedings of an International Workshop on Biological Invasions of Ecosystems by Pests and Beneficial Organisms. National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry and Fisheries, Tsukuba, pp. 170-180.

Wada T (2004). Strategies for controlling the apple snail *Pomacea canaliculata* (Lamarck) (Gastropoda: Ampullariidae) in Japanese direct-sown paddy fields. JARQ 38 (2):75-80.

Wada T (2006). Impact and Control of Introduced Apple Snail, *Pomacea canaliculata* (Lamarck), in Japan, pp. 181-198. In Joshi, RC & Sebastian, LS (ed.) Global advances in ecology and management *of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

Wetzel, RG (1975). Limnology. Saunders, Philadelphia, Pennsylvania.

Wu WL, and Lee YC (2004). The biology and population analysis of the golden apple snail in Taiwan. Pp. 25-33 in: Proceedings of the Symposium on the Management of the Golden Apple Snail, 6-11 September 2004, Pingtung, Taiwan.

Wu ZP, Chen KL, Qing YW, Zhang ZD, Zhang HB, and Li PL (1995). Study on the outbreak and eradication of *Ampullaria canaliculata* Lamark in Sichuan. Plant Quarantine 9(5):266-269.

Yusa Y, Sugiura N, and Wada T (2006). Predatory potential of freshwater animals on an invasive agricultural pest, the apple snail *Pomacea canaliculata* (Gastropoda: *Ampullariidae*) in southern Japan. Biological Invasions 8:137-147.

Zedler JB, and Kercher S (2005). Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30: 39-74.

Zeiger, RS (2006). Forward. In Joshi RC & Sebastian LS (ed.) *Global advances in ecology and management of golden apple snails.* Nueva Ecija: Philippine Rice Research Institute.

www.floraiberica.es (accessed February 18th, 2011).

http://ec.europa.eu/agriculture/markets/rice/index_en.htm (accessed March 3rd, 2011).

www.gencat.cat, accessed on February 14th, 2011

http://www.padil.gov.au/pbt/index.php?q=node/135&pbtID=157 (accesed February 8th, 2011)

http://www.shellfish.uga.edu/invasive%20webitems/meet%20guests/apple%20snail.pdf, accessed February 15th, 2011