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Environmental risk assessment for invasive alien species: A case study of apple snails affecting ecosystem services in Europe

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ABSTRACT

The assessment of the risk posed by invasive alien species (IAS) to the environment is a component of increasing importance for Pest Risk Analysis. Standardized and comprehensive procedures to assess their impacts on ecosystem services have been developed only recently. The invasive apple snails (*Pomacea canaliculata* and *P. maculata*) are used as a case study to demonstrate the application of an innovative procedure assessing the potential impact of these species on shallow freshwater ecosystems with aquatic macrophytes in Europe. The apple snail, *Pomacea maculata*, recently established in the Ebro delta in Spain resulting in a serious threat to rice production and wetlands, having also a high risk to spread to other European wetlands. Here, the population abundance of apple snails is regarded as the main driver of ecosystem change. The effects of ecosystem resistance, resilience and pest management on snail population abundance are estimated for the short (5 years) and the long (30 years) term. Expert judgment was used to evaluate the impacts on selected ecosystem services in a worst-case scenario. Our study shows that the combined effects of apple snails are estimated to have profound effects on the ecosystem services provided by shallow, macrophyte-dominated ecosystems in Europe. This case study illustrates that quantitative estimates of environmental impacts from different IAS are feasible and useful for decision-makers and invasive species managers that have to balance costs of control efforts against environmental and economic impacts of invasive species.

1. Introduction

Biological invasions are frequently considered processes of ecological disturbance (Turner, 2010) disrupting the structure of the community, the population dynamics, and changing the resource availability or the physical environment (Pickett and White, 1985). Disturbances alter the state of an ecosystem and its trajectory; they are key drivers of spatial and temporal heterogeneity (Turner, 2010). However, the effects of a well-established invasive alien species (IAS) in a new territory cannot solely be considered as a disturbance; due to the temporal persistence of the IAS in the receiving environment their presence also represents a driver of ecosystem change. IAS are recognized among the five most important direct or structural drivers of ecosystem change (Henrichs et al., 2010; Tomich et al., 2010) and can affect the provision of ecosystem services significantly.

Ecosystems provide important services to humans. Ecosystems services (ES) are for example the provisioning of freshwater, food production and genetic resources. IAS often disrupt or alter ES. To what extent this might occur depends on the particular species and the ecosystem. Therefore, it remains challenging to estimate the potential impact of IAS on ES.

To make accurate management decisions regarding control of IAS, it is necessary to assess their potential impact both for the short and the long term. In this paper we demonstrate a novel procedure for the

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assessment of environmental impacts caused by IAS to provide required information supporting decision making by the risk managers. The method provides a comprehensive and integrated environmental risk assessment (ERA) that is applicable to any kind of IAS by combining the autecology of the species with the known functions of the invaded ecosystem.

The method was developed according to the guidance document on the ERA of the European Food Safety Authority (EFSA) in which the framework for an ERA was described in detail (EFSA, 2011). The method was further developed and applied in Gilioli et al. (2014). Compared to EFSA (2011) and Gilioli et al. (2014), the approach proposed here represents a substantial improvement towards the applicability of a fully quantitative approach to ERA based on ES. There are two main novelties. First, the causal chain linking the IAS to the impact on ES has been further clarified assigning the role of driving force modifying the ecosystem traits involved in the ES to the population abundance of the IAS and its spatial and temporal variability (Fig. 1). Second, an expert knowledge elicitation (EKE) procedure (EFSA, 2014b) has been successfully applied to the estimation of the probability distributions of the parameters influencing the population pressure and the impact for the selected relevant ES.

The aim of this paper is to illustrate this novel, standardized approach by a case study, assessing the potential impact of apple snails' populations on a selected group of ES that are provided by shallow freshwater ecosystems with aquatic macrophytes.

Apple snails of the genus *Pomacea* have recently established and spread in Spain. Therefore, Europe was chosen as risk assessment area for this study. The method itself is applicable to other regions– it is only necessary to define the area for which the risk is assessed and to have available the climatic conditions and the relevant habitats for this area.

These snails are in the list of the 100 worst IAS in the world (see Global Invasive Species Database, 2015) and are known to devastate shallow freshwater ecosystems which provide important ES (Carlsson, 2006; Morrison and Hay, 2011). Therefore, they represent an ideal case study for testing the ERA framework. We concentrate our assessment on the island apple snail (previously identified as *Pomacea insularum* (d'Orbigny, 1835) and now described as *P. maculata*), and the channelled apple snail *P. canaliculata* (hereinafter referred to as *Pomacea* spp. or the apple snail (s)). These two species are closely related, have often been confounded and their population dynamics pattern and potential impacts are similar (Hayes et al., 2012; Horgan et al., 2014). These two species of apple snails are highly invasive outside their native distribution range in South America. They are serious rice pests (Joshi and Sebastian, 2006) and can have detrimental effects on the flora and fauna of natural freshwater wetlands by causing drastic declines in aquatic macrophytes (Carlsson et al., 2004). This is due to their characteristics, such as diverse diet, high feeding and reproduction rate, and the presence of specific adaptations like their capacity to breathe with both lungs and gills. Furthermore, they can survive adverse conditions by retreating into their shell and closing it firmly with the operculum (Horgan et al., 2014). By this, predators are discouraged and the snails can hibernate or aestivate buried in mud within the protective moisture of their shell for periods of up to eleven months when their habitat dries out (Oya et al., 1987; Yusa et al., 2006).

The apple snail *P. maculata* has been accidentally released in the Ebro delta in Spain (Anon., 2011).There it has established viable populations and is spreading, leading to significant damage to crops (Anon., 2011, EFSA, 2012) and representing a serious threat for ES and biodiversity. After its first outbreak reported in 2009, the snail, that was not known to occur in Europe before, continues its invasion in the Ebro delta and now also in Toll del Vidre, Arnes (Tarragona), despite mechanical and chemical control measures, inundation of rice paddies with saline water and other methods to eradicate or contain it in the rice paddies (Anon., 2011, EFSA, 2012). Currently, the snail is present not only in rice paddies, but also in some nearby wetlands, and it has been found moving upwards along the Ebro river. The import and trade of apple snails were banned by the European Union in 2012, but *P. canaliculata*, and probably also *P. maculata*, are nevertheless still sold online for the aquarium trade within the risk assessment area (Mazza et al., 2015). Hence, there is great concern that the snail might establish in other parts of Europe.

The aim of this paper is to provide a detailed estimation of the potential impact of the apple snail populations on a selected group of ES that

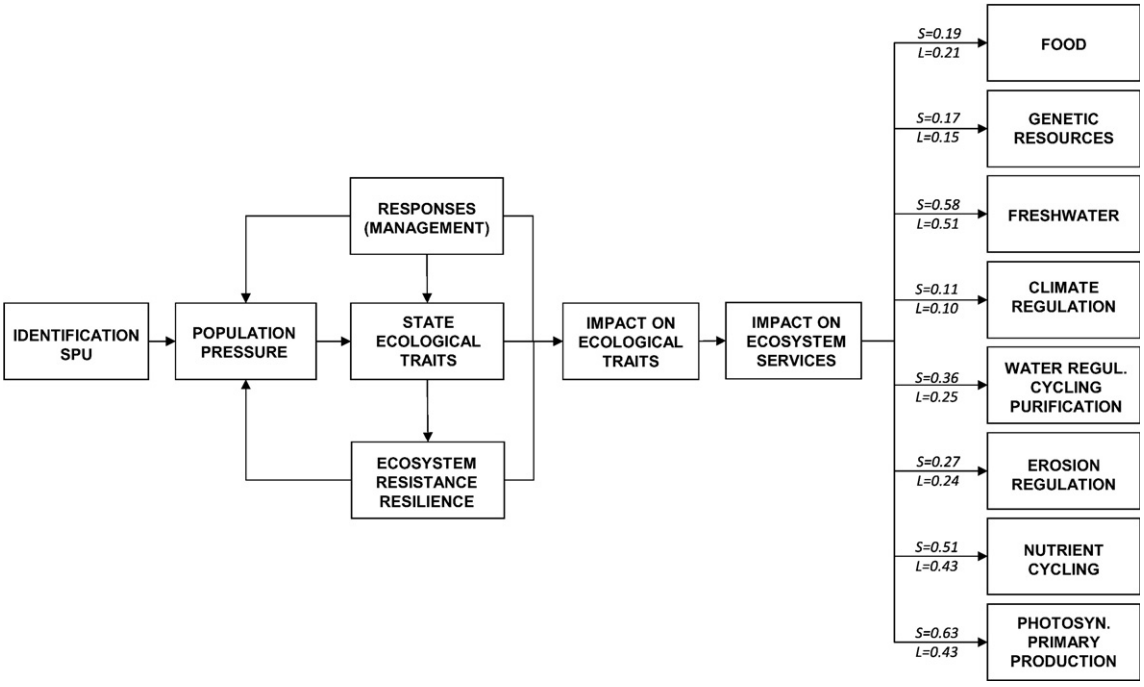

Fig. 1. Causal chain linking the changes in the Service Providing Unit to the impact on Ecosystem Services due to population pressure of the Invasive Alien Species. The risk posed by *Pomacea* spp. to the selected Ecosystem Services in Europe, as described in Section 3.2, in the short term (*S*) and in the long term (*L*), is reported numerically beside each box representing an ecosystem service.