European Commission

JRC TECHNICAL REPORTS

Invasive Alien Species impact on Ecosystem Services

Asian hornet (Vespa velutina nigrithorax) case study

Fedele E., Gervasini E., Cardoso A.C., La Notte A., Vallecillo S., Tsiamis K., Maes J.

2019

Joint Research Centre

EUR 29827 EN

This publication is a Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication.

Contact information
Name: Eugenio Gervasini
Address: Via E. Fermi 2749
Email: eugenio.gervasini@ec.europa.eu
Tel.: +39 0332 783804

JRC Science Hub
https://ec.europa.eu/jrc

JRC 111718

EUR 29827

PRINT	ISBN 978-92-76-09510-1	ISSN 1018-5593	doi:10.2760/646477
PDF	ISBN 978-92-76-09511-8	ISSN 1831-9424	doi:10.2760/134398

Luxembourg: Publication Office of the European Union, 2019

How to cite this report: Fedele E., Gervasini E., Cardoso A.C., La Notte A., Vallecillo S., Tsiamis K., Maes J., *Invasive Alien Species impact on Ecosystem Services - Asian hornet (Vespa velutina nigrithorax) case study*, EUR 29827 EN, Publications Office of the European Union, Luxembourg, 2019. ISBN 978-92-76-09511-8, doi:10.2760/134398, JRC 111718.

Contents

Acknowledgements

The authors would like to thank all EASIN Data Partners, which keep supporting EASIN as single aggregation point for sharing and disseminating information on alien species occurring in Europe, in a harmonized and integrated manner.

Above all, we would like to acknowledge STOPVESPA Project for their active collaboration and the supply of spatial data of *Vespa velutina nigrithorax*, that proved to be essential to this report. We are also grateful to our Colleagues of the EC – JRC Unit D2, Ivan Deriu and Fabio D'Amico for their contribution to this report.

Authors

Fedele E., Gervasini E., Cardoso A.C., La Notte A., Vallecillo S., Tsiamis K., Maes J.

Abstract

Invasive Alien Species (IAS) represent a major threat to the biodiversity in Europe and worldwide, and can cause significant damages to the ecology, economy and livelihood of recipient countries. Recognising the need for a coordinated set of actions for the prevention, early eradication and management of IAS, the European Parliament and the Council adopted the EU Regulation 1143/2014 (hereafter referred as the IAS Regulation). In this context, the EU Member States have given priority to a subset of species (IAS of Union concern) in relation to their potential to cause severe damages, justifying the adoption of dedicated measures at EU level.

Despite the availability of several methodologies for the impact assessment of IAS, there is still a dearth of attention and interest on their effects on socio-economic aspects at EU level. An approach for the assessment of socio-economic impacts of IAS is needed to better perceive the potential damages caused by alien species, in support to the implementation of the IAS Regulation, with particular reference to the enforcement of Art. 5.1, dictating the inclusion in the species' risk assessment of a description of the adverse impact on biodiversity, related ecosystem services (ES), and the cost of damage.

ES can be evaluated and used to estimate the benefits deriving from nature conservation and justify costs of interventions. We argue that the same approach can be followed to estimate the adverse impact of IAS on our society, in relation to biodiversity loss and services decline. With this report we present a novel approach for the assessment of IAS impact on ES in the implementation of the IAS Regulation, which we named 'Classification of Invasive Alien Taxa Impacts on Ecosystem Services' (CATIES).

The approach was applied for evaluating the impact of the Asian hornet, *Vespa velutina nigrithorax,* on pollination service. The first steps include a thorough scientific literature review to retrieve all the available ecological information on the species, and the development of the species-specific framework to analyse the impacts on ES. In a second phase, we produced distribution maps overlapping the species' range with the distribution of ES in the EU. Finally, we measured *V. velutina nigrithorax* related economic loss by means of fruit trees production reduction in response to predation of pollinating insects.

The present work represents a case study on the impact IAS of Union concern may have on the environment's capacity to provide ES, and to quantify the value of the economic losses caused by these species.

1. Introduction

1.1 Background

Invasive Alien Species (IAS) are animal and plant species either intentionally or accidentally introduced into new environments where they do not naturally occur (definition by the Convention on Biological Diversity – CBD). These introductions can lead to negative consequences for ecological and human communities (Millennium Ecosystem Assessment, 2005; Ricciardi et al., 2013; Jeschke et al., 2014). Understanding biological invasions effects is a major challenge, and scientists have only recently started to fully appreciate IAS impacts on recipient ecosystems and community economies (Pyšek et al., 2012; Bellard et al., 2016; Bacher et al., 2017). Ketteunen et al. (2009) estimated that IAS cost €12 billion to the European Union (EU) Member States' economies. However, as the number of unintentional introductions continues to grow (Essl et al., 2015; Roques et al., 2016), so does the cost for their management and the derived economic loss (Hulme, 2009; Scalera, 2010; Silva et al., 2014).

About 14,000 alien species have been recorded so far in Europe (Katsanevakis et al., 2015). The European Alien Species Information Network (EASIN) has been developed by the European Commission's Joint Research Centre to establish a single aggregation point for sharing and disseminating scientific information, and geospatial data, in a harmonized manner, supporting Member States (MS) in the implementation of the EU Regulation 1143/2014 (IAS Regulation) (Katsanevakis et al., 2012, 2013; Deriu et al., 2017) and other EU policies requirements on alien species.

A major challenge is to coordinate actions to prevent, control and mitigate the impact of IAS, as required by the IAS Regulation, which gives priority to a subset of IAS (Art. 4 "the Union list", hereafter IAS of Union concern). The Regulation requires the adoption of dedicated measures at EU level, due to the significant threat these species pose to the ecological stability and the economy in the MS. The Union list, which currently comprises 49 species (EU, 2016; EU, 2017), is updated regularly to prevent, minimise and/or mitigate the adverse impact of IAS in a cost efficient manner (EU, 2014).

In addition, Art 5.1 of the IAS Regulation requires that the IAS risk assessments include a "*description of the adverse impact on biodiversity and related ecosystem services*" and an "*assessment of the potential costs of damage*" of IAS in the EU territory. The term "biodiversity" involves a significant level of complexity but it can be simplified as: "*The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (definition by the Convention on Biological Diversity – CBD).

Decades of ecological research have investigated the implications of biodiversity loss for the maintenance and promotion of ecosystem functions/processes (i.e. the stocks and flows of energy and materials and the roles played by primary producers, consumers and decomposers) (Cardinale et al., 2012). While research into the links between biodiversity and Ecosystem Services (ES) (i.e. ecosystem contributions to human wellbeing) is less developed, there is an increasing evidence that the protection of ES may help halt biodiversity loss (Maes et al., 2012a, 2012b; Ekroos et al., 2014). Furthermore, ES can be evaluated and used to estimate the benefits deriving from nature conservation and justify costs of interventions (EU, 2011; Maes et al., 2012a, 2012b, 2013, 2014, 2016).

We argue that the same approach can be followed to estimate the adverse impact of IAS, in relation to services' decline. With this report we intend to present a novel approach for the assessment of IAS impact on ES with reference to the implementation of the IAS Regulation.

1.2 Ecology of *Vespa velutina nigrithorax*

The Asian hornet, *Vespa velutina nigrithorax*, an IAS of Union concern (EU, 2016), is a predatory species widespread in Asia, and currently invasive in Europe. It has been increasingly reported in continental Europe, where it first appeared in Southern France in 2004 (Villemant et al., 2006). It has then expanded its territory to cover significant areas of west-central Europe (Tsiamis et al. 2017a), including certain regions of Spain, Portugal, Belgium, Germany, Italy, and more recently the United Kingdom (see NNSS: http://www.nonnativespecies.org/home/index.cfm). The only natural enemies of *V. velutina nigrithorax* native to Europe are a nermithid nematode (*Pheromermis vesparum*) and one species of conopid fly (family Conopidae), but their role in controlling the species abundance has yet to be fully understood (Villemant et al., 2015).

Scattered ecological information about the species diet reveals that it has a broad preference for honeybees although this largely depends on the habitat where it is found. The figures presented below (Figure 1) display a rough estimation of the prey preferences of *V. velutina nigrithorax* in relation to different habitats. This information is of great importance while assessing the impact of the species on ES. By feeding predominantly on honeybees, this species can have significant knock on effects on the ecosystem, representing an important obstacle to crop pollination.

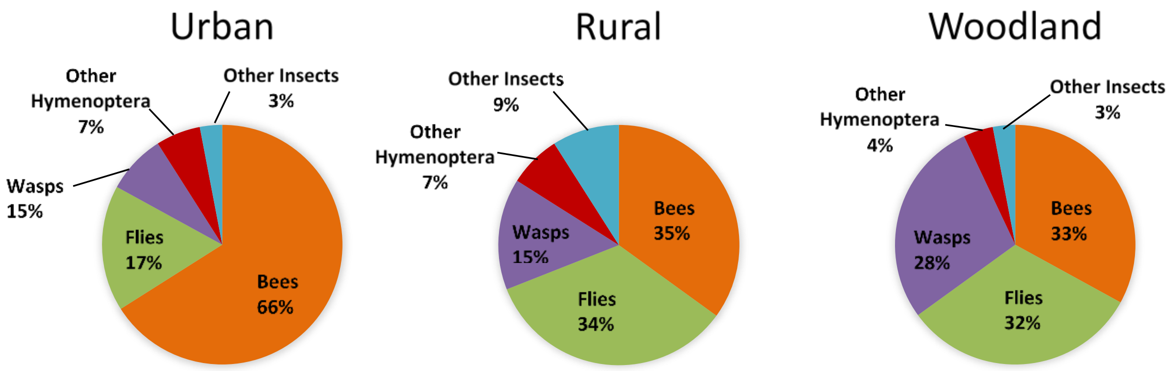

Figure 1. Percentages of prey categories of *V. velutina nigrithorax* in relation to different habitats: Urban, Rural, and Woodland. Adapted from Villemant *et al*. (2011).

A weighted estimate of the damage caused by *V. velutina nigrithorax* to European bee colonies in different environments and with different prey availability, derived from several Authors (Ken et al., 2005; Monceau et al., 2013; Monceau et al., 2014) leads to the assumption that V*. velutina* can be responsible for the loss of 65% of bee colonies in infested areas, as a result of direct predation and weakening of bee colonies. In addition, seasonality is an important factor, since *V. velutina nigrithorax* colonies die out during winter; only the queen survives, and will raise another colony when temperatures increase above a minimum threshold.

1.3 Purpose of this report

Despite the availability of several methodologies for IAS impact assessment, there is still a dearth of attention and interest on the effects on socio-economic aspects at EU level (Vilá et al., 2010; La Maitre et al., 2011; D'Hondt et al., 2015; Hawkins et al., 2015; Bacher et al., 2017, Keller et al., 2017). This can be attributed to the fact that providing a useful basis for estimation and comparison of socio-economic impacts is difficult (Hoagland and Jin, 2006). The approach proposed in this report is built on the estimation of IAS impacts on ES, based on the best available knowledge of ES spectrum and IAS within the EU (Keller et al., 2017; La Notte et al., 2017b).

This report defines an approach for the assessment of IAS impacts on ES and the monetary evaluation at EU level. The approach is applied on a specific case study, the impact of *V. velutina nigrithorax* on pollination service and the economic loss due to the decreased apple production. This work intends to open a debate about the biophysical and economic analysis of the effects of IAS on ES for the assessment of their impact.

2. Methodology

2.1 Framework for Ecosystem Services classification

Efforts to maintain and improve people well-being require understanding of the dynamics of ecosystems and their services (Sandhu and Sandhu, 2014), while recognising the mechanisms underpinning service provision and related threats has become a priority in conservation ecology. In this context, a Common International Classification of Ecosystem Services (hereafter CICES; https://cices.eu/) was developed to highlight and investigate the links between the constituents of human well-being and the corresponding ES, and assess the processes of service flow that make benefits available to humans.

The conceptual framework of CICES is provided by the cascade model describing human well-being dependency on ecosystems, and classify final services as the contributions of living systems to human well-being (Figure 2; La Notte et al., 2017a).

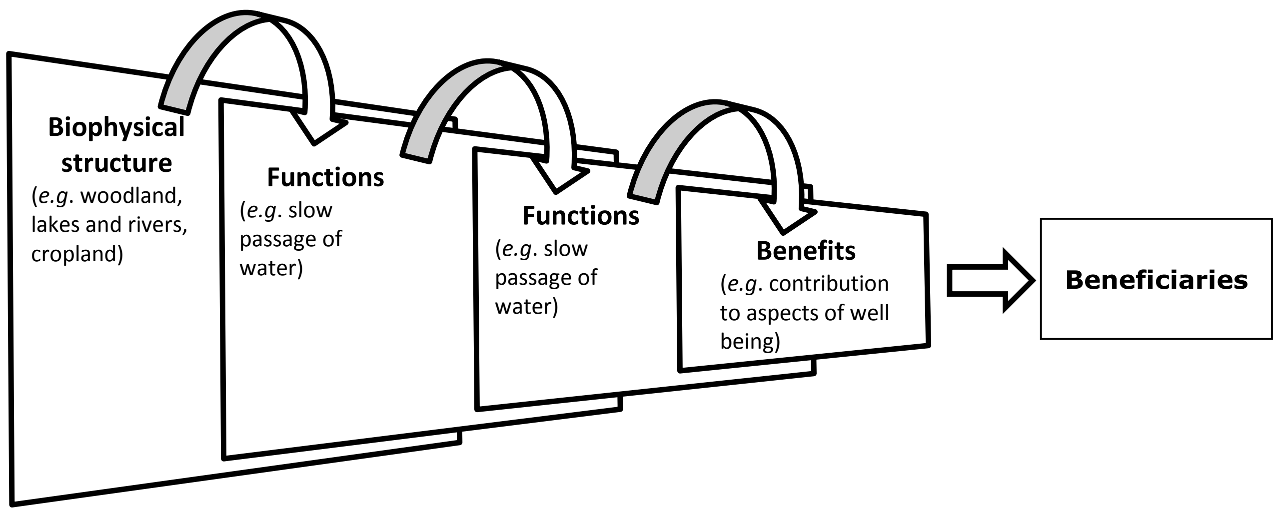

Figure 2. Simplified representation of the ecosystem services cascade model (adapted from La Notte et al., 2017a).

Final ES (benefits) are the result of the flow of services for which there is a demand. In other words, ES are the set of ecosystem functions that contribute to human benefits. According to CICES 5.0 (https://cices.eu/, Haines-Young and Potschin, 2017), there are three major categories of services:

- Provisioning services: include all material, food and biota-dependent energy outputs from ecosystems; they are tangible things that can be exchanged, traded and consumed.
- Regulating and maintenance services: include all the ways in which ecosystems control or modify biotic or abiotic parameters that define the environment where people live; they affect the performance of individuals, communities and populations and their activities.
- Cultural services: include all non-material ecosystem outputs that have symbolic, cultural or intellectual significance.

Our Classification of Alien Taxa Impacts on Ecosystem Services (CATIES) builds on the CICES 5.0, for linking the impact of IAS on ecosystem functions (i.e. on the combination of processes and characteristics that give rise to a service) to the loss of benefits through the ES cascade.

2.2 Framework for assessment of ES

The analysis of IAS impacts on ES was structured on the basis of a methodology to map, assess and determine the value of ecosystems and their services in the EU, developed in the context of the Knowledge Innovation Project on an Integrated system for Natural Capital and ecosystem services Accounting (KIP INCA[1]) (La Notte et al., 2017b).

2.2.1 Ecosystem types and services

The application of classification and assessment frameworks require the identification of the ES relevant to the ecosystem type(s) studied. The following table (Table 1, adapted from La Notte et al., 2017b) presents a matrix of different ecosystem types and services in agreement with the KIP INCA classification metrics. In particular, each ES is assigned to the provisioning ecosystem type it derives from. This aims to supply a framework for the identification of ES and types to be applied in the CATIES framework.

Table 1. Matrix of ecosystem types and service (adapted from La Notte et al., 2017b).

ECOSYSTEM SERVICES	ECOSYSTEM TYPES								
	Urban	Cropland	Grassland	Heathland and shrub	Woodland and forest	Sparsely vegetated land	Wetland	Rivers and lakes	Marine
Arable cropping		x							
Marine fish									x
Outdoor animal husbandry			x						
Timber					x				
Water								x	
Crop pollination		x	x	x	x	x	x		
Erosion control	x*	x	x	x	x		x		
Water purification								x	
Air purification**	x*		x	x	x				
Global climate regulation		x	x	x	x		x	x	x
Flood control		x	x	x	x	x	x		
Outdoor recreation	x*	x	x	x	x	x	x	x	x
TOTAL	3	6	7	6	7	3	5	4	3

** Green urban areas*

*** Only assessed for functional urban areas*

[1] Carried out by the JRC, DG Environment, DG Research and Innovation, Eurostat and the European Environment Agency.

2.2.2 Categories of sectors affected

The factsheet presented in this section (Table 2) identifies the sectors that are most likely to be affected by changes in the flow of ES in response to IAS impacts. These comprise either sectors involved in the transformation process – the process of transforming ES in consumable goods and valuable benefits (users/enable actors) –, or to those that profit from particular goods and benefits – i.e. beneficiaries. This categorisation is the result of a collation of information provided by KIP INCA, CICES V5.0 and the Natural Capital Committee (NCC- www.naturalcapitalcommittee.org).

Table 2. List of sectors most likely to be affected in response to IAS impacts (adapted from KIP INCA and NCC).

Sector	Definition
Agriculture	Cultivation and breeding of animals, plants, and fungi for food, fiber, biofuel, medicinal plants and other products used to sustain and enhance human life.
Forestry	Creation, management, use, conservation, and restoration of forests and associated resources to meet desired goals, needs, and values for human and environment benefits. Forestry is practiced in plantations and natural stands.
Fishery	Raising or harvesting of fish. According to the FAO, a fishery is typically defined in terms of the "people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, purpose of the activities or a combination of the foregoing features".
Households	One or more people who reside in the same dwelling and also share meals or living accommodation, and may consist of a single family or some other grouping of people. The household is the basic unit of analysis in many social, microeconomic and government models, and is important to the fields of economics and inheritance.
Water supply companies	Provision of drinking water and wastewater services (including sewage treatment) to residential, commercial, and industrial sectors of the economy.
Production sites	Sites for the combination of various material inputs and immaterial inputs (plans, know-how) in order to make something for consumption (the output). Production is the act of creating output, a good or service, which has value and contributes to the utility of individuals.
Tourism	Practice of touring, the business of attracting, accommodating, and entertaining tourists, and the business of operating tours. Tourism may be international, or within the traveler's country.
Professional activities	Activities carried out by people who have attained the particular knowledge and skills necessary to perform their specific role, and are subject to strict codes of conduct, enshrining rigorous ethical and moral obligations. Such activities have to meet agreed standards of practice and ethic.
Educational activities	All activities aimed at facilitating learning, or the acquisition of knowledge, skills, values, beliefs, and habits. They include storytelling, discussion, teaching, training, and directed research.
Infrastructure and Transport	This comprises all the fundamental facilities and systems serving a country, city, or other area, including the services and facilities necessary for its economy to function. It typically characterises technical structures such as roads, bridges, tunnels, water supply, sewers, electrical grids, telecommunications (including Internet connectivity and broadband speeds), and can be defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance

	societal living conditions."
Retailing	The process of selling consumer goods or services to customers through multiple channels of distribution to earn profit.
Global	It identifies all possible categories.

2.2.3 Ecosystem services: users, benefits, beneficiaries

The final step of CATIES involves the identification of users/enabling actors, beneficiaries and benefits of ES, as described in table 3 below. This classification, as discussed in La Notte et al. (2017b), clearly defines the transition of services from the ecosystem to beneficiaries, through the production boundary, and eventually the production of benefits. The list of ES in Table 3 has also clear links with the framework of ES flow proposed by SEEA EEA and KIP INCA, which eases comparisons between different frameworks.

Table 3. List of ecosystem services users, benefits and beneficiaries (*adapted from La Notte et al. 2017b*).

ECOSYSTEM SERVICES		USERS / Enabling Actors	BENEFICIARIES	BENEFITS
PROVISIONING	**Arable cropping**	Agriculture Households (own consumption)	Agriculture	Harvested crop
	Marine fish	Fishery Households (own consumption)	Fishery	Caught fish
	Outdoor animal husbandry	Agriculture Households (own consumption)	Agriculture	Animal derived products
	Timber	Forestry Households (own consumption)	Forestry Households (firewood)	Wood and related products
	Water	Global	Global	Natural water effectively used
REGULATING	**Crop pollination**	Agriculture	Agriculture	Increased quality/quantity of crop production
	Erosion control	Agriculture Forestry (quarrying as enabling actors)	Agriculture Forestry Households Production sites	Protection against the risk of landslides
	Water purification (sink-related)	Agriculture Households Production sites	Global	Clean water
	Air purification (sink-related)	Agriculture Production sites Infrastructure & transport	Households	Clean air
	Global climate regulation (sink-related)	Agriculture Forestry Households	Global	Mitigation of climate change effects

		Production sites Infrastructure & transport		
	Flood control	Agriculture Construction	Agriculture Construction Households Production sites	Protection against the risk of flooding
CULTURAL	**Outdoor recreation**	Households	Households Tourism	Components of human well-being and opportunities for business development

2.3 Application of CATIES

In this study we focused on the application of CATIES to the assessment of *V. velutina nigrithorax* (IAS of Union concern; EU, 2016) impacts on pollination, focusing on pollination of apple, pear and peach trees.

Google Scholar was used to query and filter studies on the impacts of *V. velutina nigrithorax* since 2004 (year of first introduction in Europe: Villemant et al., 2006). The keywords that were used for the research query are: "***Vespa velutina nigrithorax*+socio-economic evaluation+invasive species+ecosystem services**". Titles and abstracts (where applicable) were used to select relevant articles. Only peer-reviewed literature was considered in the assessment.

V. velutina nigrithorax has been relatively well-studied due to the severe impact on honeybees and other important pollinators (Villemant et al., 2006, 2011). Consequently, retrieving data on this species has proven relatively straightforward, albeit information (species ecology, distribution and impact on ES) was sometimes sparse and inconsistent.

The information collected and reviewed is summarised in table 4, structured into five columns, including the following information:

1. **Ecosystem factor**: description of the ecosystems which are affected or likely to be affected;
2. **Mechanisms of impact**: description of the impacts on ecological functions and services normally provided by the ecosystem;
3. **Consequences for human well-being**: description of how modifications to ES flow affect human well-being and livelihood;
4. **Categories of people being affected**: description of the group of people being affected;
5. **Citations**: scientific references to case specific articles and reports.

Table 4. CATIES Framework – subset of ecological components, ecological processes, and ecosystem services provided by different ecosystems, the ways these services are affected by *Vespa velutina nigrithorax*, and the negative effects on human-wellbeing.

Ecosystem factor	IAS impact mechanisms	Consequences for human well being	Categories of people being affected	Citations
Urban	(Increased sting risk)	*Communities have to deal with the risk of being stung	*Households	de Haro et al. 2010; Franklin et al. 2017; Monceau et al. 2012;

				Golden et al. 2006; Rome et al. 2011;
Cropland	Reduced pollination through predation	*Loss of crop pollination	*Agriculture *Households Forestry Retailing	Villemant et al. 2006; Tan et al. 2007; Villemant et al. 2011; Rome et al. 2011; Klein et al. 2007; Kevan and Phillips 2001; Southwick et al. 1992; Costanza et al. 1997
Grassland	Reduced pollination through predation	Loss (full or partial) of plant pollination (globally or locally). Reduced service provision	Global	Villemant et al. 2006; Villemant et al. 2011; Rome et al. 2011; Southwick et al. 1992; Costanza et al. 1997
Heathland and shrub	Reduced pollination through predation	Loss (full or partial) of plant pollination (globally or locally). Reduced service provision	Global	Villemant et al. 2006; Villemant et al. 2011; Rome et al. 2011; Southwick et al. 1992; Costanza et al. 1997; Brockerhoff et al. 2017
Woodland	Reduced pollination through predation	Loss (full or partial) of plant pollination (globally or locally). Reduced service provision	Global	Villemant et al. 2006; Rome et al. 2011; Costanza et al. 1997; Brockerhoff et al. 2017
Wetland	Reduced pollination through predation	Loss (full or partial) of plant pollination (globally or locally). Reduced service provision	Global	Villemant et al. 2006; Rome et al. 2011; Costanza et al. 1997
Rivers and lake	Reduced pollination through predation	Loss (full or partial) of plant pollination (globally or locally). Reduced service provision	Global	Villemant et al. 2006; Monceau et al. 2012; Rome et al. 2011; Costanza et al. 1997

2.4 Model crop pollination

Accounting for crop pollination requires the assessment of the ecosystem potential to support wild insect pollinators (pollination potential, extent of service providing areas with different pollination potential) and the demand for pollination, which, is defined as the extent of pollinator-dependent crops.

The spatial overlap between the pollination potential and the demand for pollination is used to estimate the actual flow of the service, i.e. yield production attributable to pollination in overlapping areas between pollination potential and demand. The crop pollination model is described in details in Vallecillo et al. (2018).

Figure 3 depicts the main components of this model, modified to include the effect of *V. velutina nigrithorax,* which decrease pollination potential through predation of insect pollinators, and the consequent negative impact on ecosystem service flow and benefits.

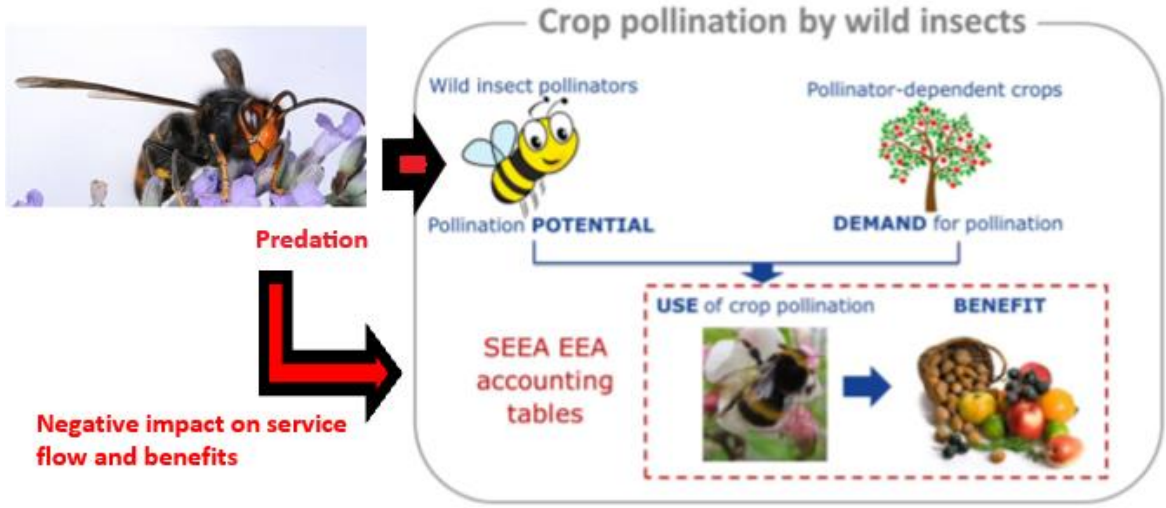

Figure 3. Scheme of the components required for crop pollination accounting, including the impact of *V. velutina nigrithorax* (modified from Vallecillo et al., 2018).

In Vallecillo et al. (2018), the crop pollination assessment uses the following input layers:

- **Crop pollination potential**, an indicator of environment suitability to support wild insect pollinators is used to delineate service providing areas with high, medium, low and none pollination potential. The assessment focused on high and medium potential service areas for 2000 and 2006.
- **Demand for crop pollination** was quantified as the extent of pollinator-dependent crops, following the methodology described in Zulian et al. (2013a). The spatial data derived from the CAPRI model (Britz & Witzke, 2014; Leip et al., 2008; data available for 2004 and 2008) was used to quantify the demand for pollination as the number of hectares per square kilometre, and ten crop types benefiting from insect pollination to different extent. The demand is reported as the number of hectares for the sum of all crops dependent on pollinators.
- The actual **flow of crop pollination** was calculated as the extent of pollinator-dependent crops benefiting pollination inside the delineated service providing areas for 2000 and 2006.

2.5 Assessment of impact of *V. velutina nigrithorax* on crop pollination

The following geospatial data were used in the assessment:

- The **demand area for 2008**[2], extent in hectares (Ha) per square kilometre (Km^2) of fruit trees (i.e. apples, peaches and pears), derived from CAPRI model (Britz and Witzke, 2014; Leip et al., 2008).

[2]Structural transformations in agriculture are relatively slow therefore we can assume that little has changed in terms of fruit trees cultivation over the last decade.

- The **use layer for crop pollination 2006** and the **yield layer for 2008,** derived from Vallecillo et al. (2018)
- The **occurrence of *Vespa velutina nigrithorax*** at grid level 10x10 Km from the EASIN geodatabase (Tsiamis et al., 2017a; EASIN geodatabase, version 4.3, data accessed on 01.12.2017, including data aggregated from Data Partner STOPVESPA project and from EASIN-Lit, Trombetti et al., 2013).

The predation rate of *V. velutina nigrithorax* on pollinators from the scientific literature (65%, see above) was used to estimate the loss of fruit trees production in response to the impacts of *V. velutina nigrithorax* on insect pollination.

Using the ArcMap Raster Calculator tool we estimated the total production of fruit trees (in kg) at regional (or NUTS 2) level by multiplying the demand area layer by the yield layer. Following the same procedure, we calculated the actual flow (kg) of fruit trees pollination by simply multiplying the use layer by the yield layer. We then used the Extract by Mask tool from the toolbox to create a layer displaying the overlapping area of *V. velutina nigrithorax* distribution and the actual flow, which was named as "impacts on pollination layer". With the Zonal Statistics as Table tool, we calculated the extent of the actual flow, total production and impacted flow at NUTS 2 level.

We proceeded by computing two ratios: 1) between the actual flow and the total production to understand the extent of fruit trees production dependency on insect pollination (as reported in Vallecillo et al. 2018), and 2) between the affected flow and the actual flow to measure the proportion of the actual flow being affected by *V. Velutina nigrithorax*. We then multiplied these two ratios by the predation rate of 65% to obtain the overall percentage of production loss for each zone at NUTS 2 level.

This "production loss coefficient" was then applied to the national statistics (with reference to year 2011 for which we could find the maximum amount of information for all the zones being considered in the model) obtained from the national datasets of Spain, Italy and Portugal (excluding France that did not provide information on agricultural production). From Eurostat, we retrieved data on the economic accounts of agriculture for Spain, Portugal and Italy in 2011 (excluding France). We therefore computed the price for fruit trees production in €/kg and multiplied this by the overall zonal total production and the production loss coefficient to obtain the measure of the economic loss at NUTS 2 level.

The data were mapped and processed using ArcGIS version 10.5. Data were classified following the Geometrical Interval classification method, which was designed and added in ArcGIS version 9.2 to work on data that are heavily skewed by a preponderance of duplicate values (Frye, 2007), which is also the case for the data on fruit trees cultivation in the EU. Indeed, this classification identifies classes that best group similar values and that maximize the differences between classes, whose boundaries are set where there are relatively big differences in the data values.

2.6 Scientific and technical issues

A major issue was the lack of informative data on the contribution of honeybees (*Apis mellifera*) to pollination. The analyses in this report refer to the distribution of short flight pollinators excluding honeybees that we know represent a consistent portion of *V. velutina nigrithorax* diet. Data on honeybees must be included in the model as soon as they become available.

Also, ecological data on *V. velutina nigrithorax* are still extremely sparse, additional efforts are urged to provide policy makers and stakeholders with more reliable information on the actual danger posed by this species. In general, we have noticed a lack of experimental research on the effects of *V. velutina nigrithorax* on the ecosystem, and much of the information available in the scientific literature derives from either observational studies or from researches conducted outside the EU.

In addition, major inconsistencies exist in the information provided by the MS about their agricultural production. Some of this information is not available online and must be specifically requested to the national institute of statistics.

3. Results

Building on the cascade model (Figure 2), impacts on ES were linked to consequences for human well-being and categories of people being affected by *V. velutina nigrithorax* (Table 4).

In the following chapters we present the main maps that were created for the assessment of the impact of *V. velutina nigrithorax* on fruit production.

3.1 Total production

The overall total production of apples, pears, and peaches in the EU expressed in kg/km^2.

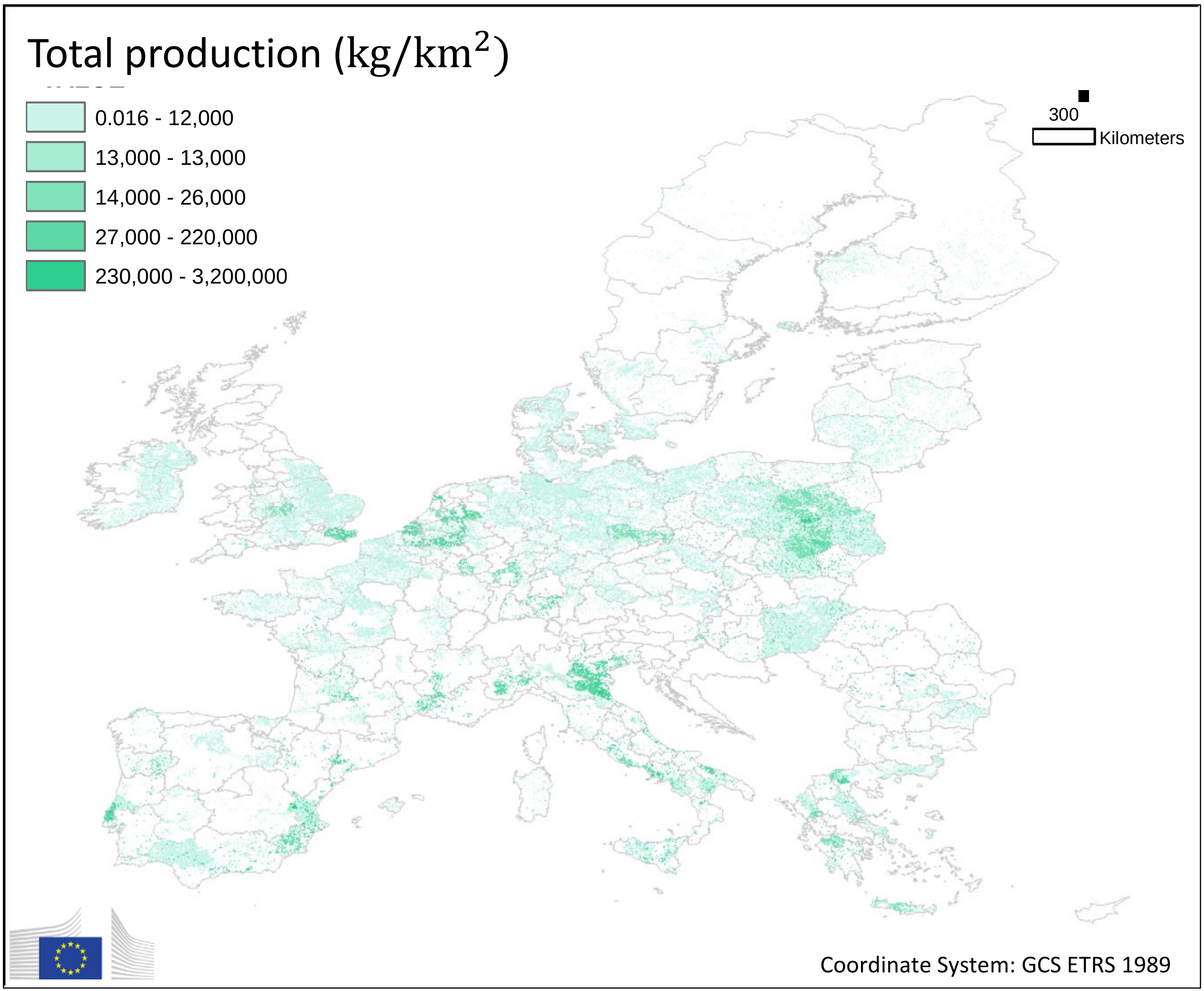

Figure 4. Grid-level (1x1km) Total production: the total production in kg/ km^2 for fruit trees.

3.2 Production flow

In the map below the actual flow of pollination service is shown (i.e. fruit trees production expressed in kg/km^2 dependent on natural pollination).

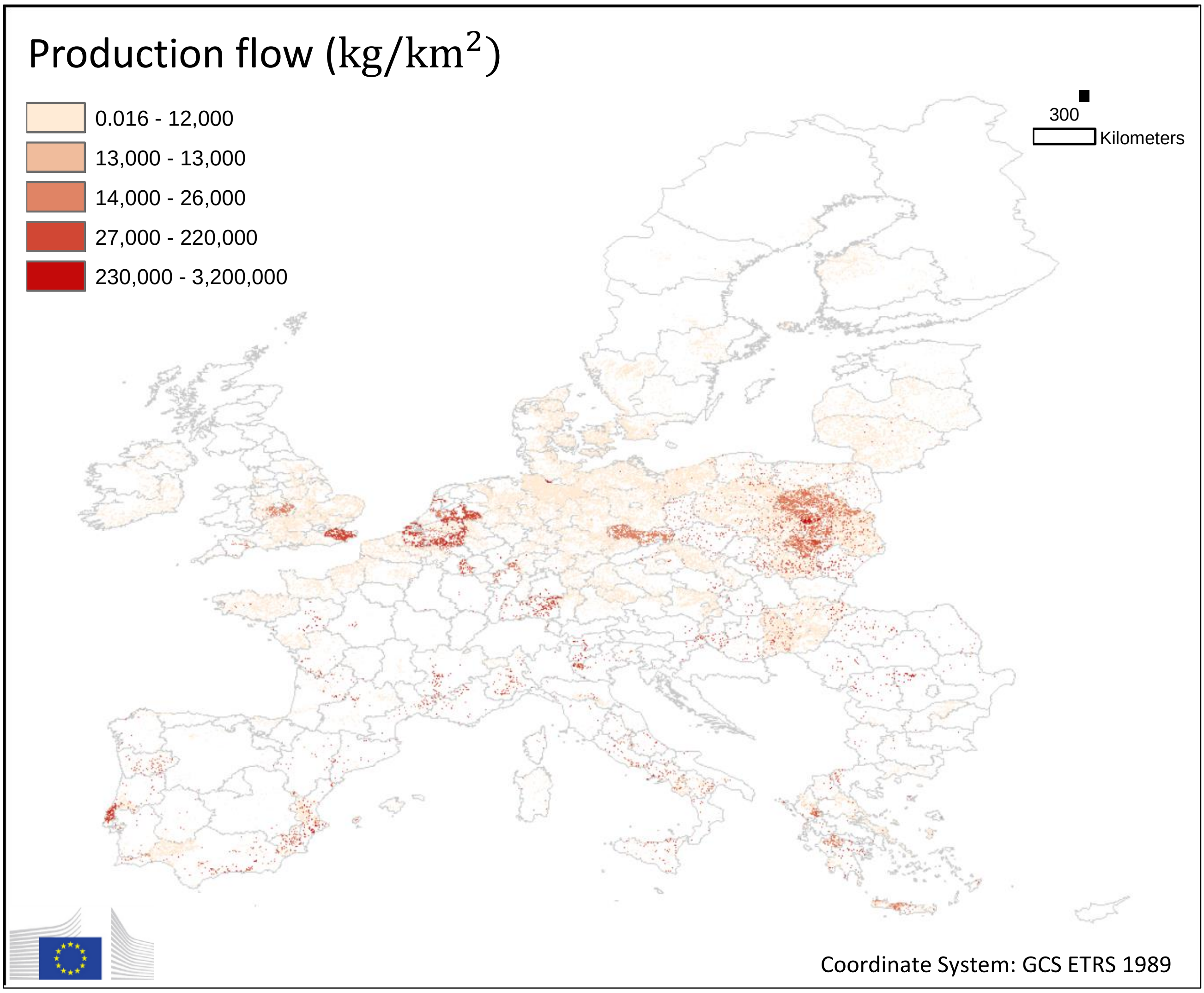

Figure 5. Grid-level (1x1km) production flow: fruit production naturally pollinated in kg/ km^2

3.3 *V. velutina nigrithorax* impacts on pollination service

The distribution of *V. velutina nigrithorax* in the EU (excluding the UK for which data were not yet available) is in figure 6. The taxon has recently been recorded in the UK and eradication measures have been adopted but no georeferenced data are available (Keeling et al., 2017).

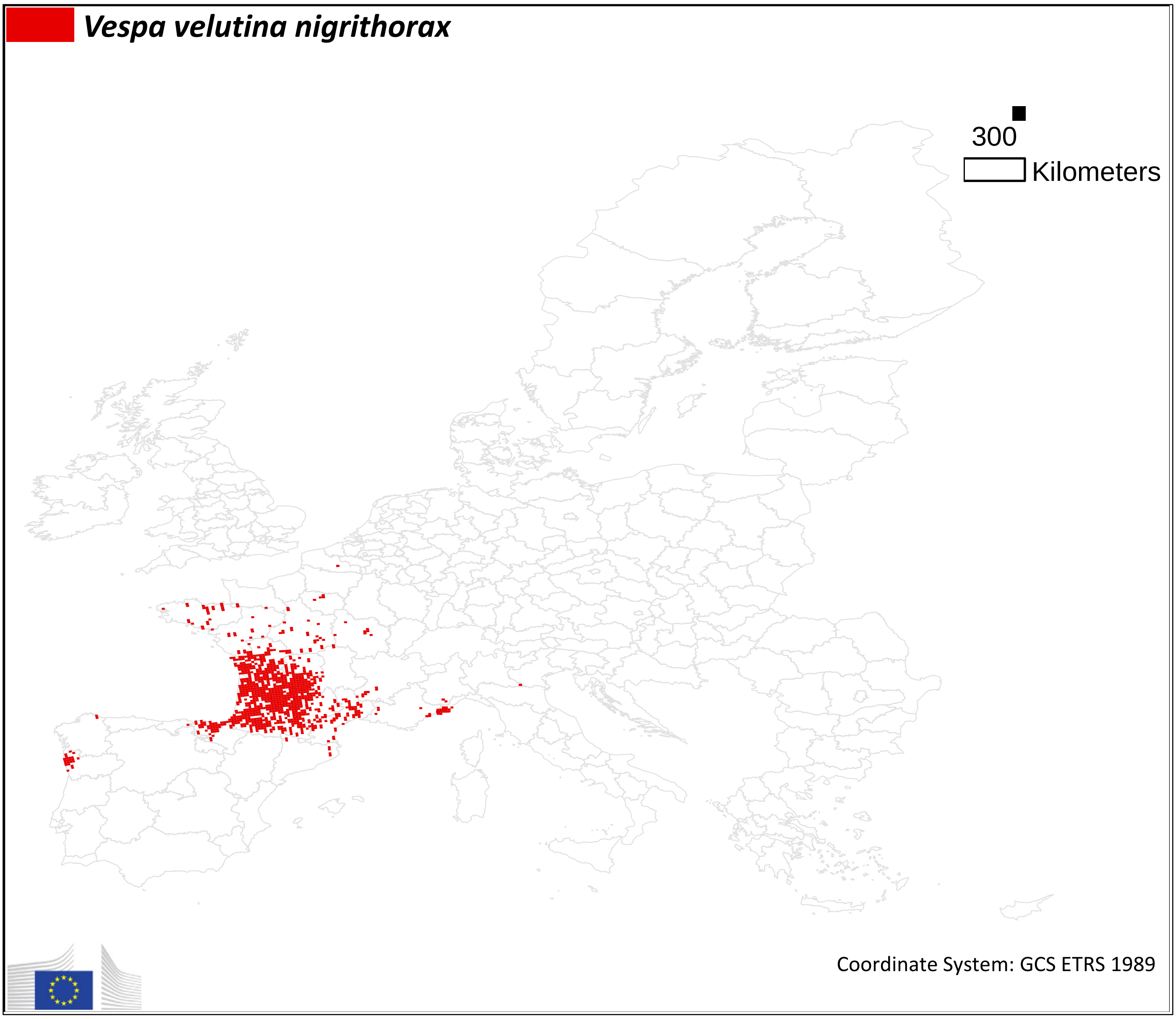

Figure 6. Grid-level (10x10 km) baseline distribution of *Vespa velutina nigrithorax* in EU.

The map in figure 7 displays the area where the Asian hornet range overlaps with the production flow of apples, pears, and peaches naturally pollinated. Note that production flow is represented at grid-level 1x1 km whereas *V. velutina nigrithorax* at grid-level 10x10 km. However, a higher resolution for EASIN grid maps is planned for the future. The result indicates the total flow of production of apples, pears and peaches (expressed in kg/km^2) that is likely to be affected by the Asian hornet.

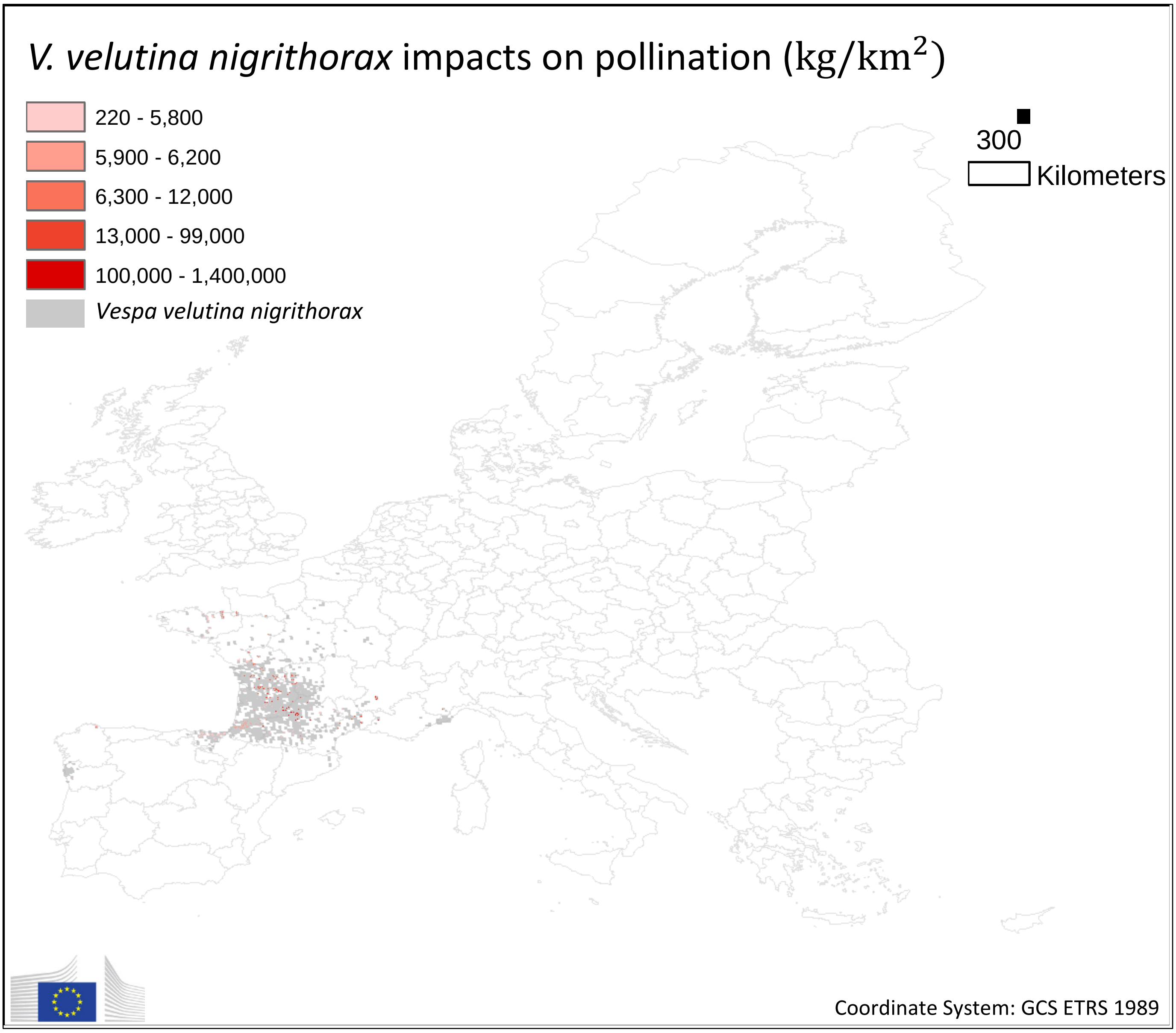

Figure 7. *Vespa velutina nigrithorax* impacts on pollination: impacts on pollination dependent fruit production flow expressed in kg/ km^2 (Grid-level 1x1 km) and distribution of *V. velutina nigrithorax* (Grid level 10x10 km).

3.4 *V. velutina nigrithorax* impacts estimation

With reference to crop pollination service and according to the CATIES framework, (Table 4) the categories of people/economic activities that are being affected by the presence of *V. velutina nigrithorax* in the 21 zones (see Table 5) are agriculture, households and the retailing sector. This is because the decrease in pollinators' abundance reduces the production of fruits and hence lowers the income for the categories mentioned above (references listed in Table 4).

Figure 7 shows that *V. velutina nigrithorax* is documented to be affecting fruit trees pollination in four nations, namely Spain (ES), France (FR), Italy (IT) and Portugal (PT); covering 21 (NUTS 2) zones (Table 5). Its presence has been recorded also in

Germany, but available information fail to identify any overlap between pollination service and the IAS range.

Table 5. NUTS code of the zones where the actual flow is being affected by *V. velutina nigrithorax*.

Nation	NUTS 2	Code
Spain (ES)	Galicia	ES11
	Pais Vasco	ES21
	Cataluña	ES51
France (FR)	Centre	FR24
	Basse-Normandie	FR25
	Bourgogne	FR26
	Nord - Pas-de-Calais	FR30
	Pays de la Loire	FR51
	Bretagne	FR52
	Poitou-Charentes	FR53
	Aquitaine	FR61
	Midi-Pyrénées	FR62
	Limousin	FR63
	Rhône-Alpes	FR71
	Auvergne	FR72
	Languedoc-Roussillon	FR81
	Provence-Alpes-Côte d'Azur	FR82
Italy (IT)	Piemonte	ITC1
	Liguria	ITC3
	Veneto	ITH3
Portugal (PT)	Entre Douro e Minho Trás-os-Montes	PT11

In order to compute the impacts of *V. velutina nigrithorax* on insects' pollination service (and hence fruit trees production), we first computed the production ratio between the actual flow (Figure 5) and total production (Figure 4); this gave us the proportion of fruit trees production dependent on pollination at NUTS 2 level. This ratio was then applied to the national statistics on crop production.

As a second step we computed the flow ratio between affected flow (Figure 6) and the actual flow (Figure 5), this gave us an estimate of fruit trees production dependent on pollination being affected by *V. velutina nigrithorax*.

As a third step, we considered the predation rate of *V. velutina nigrithorax*, this information was retrieved from the scientific literature and was assumed to be equal to 65% (i.e. 65% of pollinators' colonies are killed in areas of occurrence of *V. velutina nigrithorax*). We then multiply all these factors to obtain the percentage of loss at NUTS 2 level.

As a final step, we computed the price per kg (€/kg) of fruit retrieving information from national statistics (production in kg) and Eurostat (production in euro), and multiplied this by the production loss percentages at NUTS 2 level. The result (Table 6) comprises the overall economic loss registered in the area of fruit production being affected by *V. velutina nigrithorax*.

While agricultural production (kg) statistics were retrieved from national datasets, agricultural economic accounts were retrieved from the Eurostat's website. A list of the national institutes from which we derived the information of agricultural production is reported below.

Table 6. List of the main producers of official statistics in Spain, France, Italy and Portugal.

Country	Institute	Website
Spain (ES)	Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente (MAPAMA)	www.mapama.gob.es
France (FR)	Ministére de l"agriculture et de l'Alimentation (AGRESTE)	http://agreste.agriculture.gouv.fr
Italy (IT)	Istituto Nazionale di Statistica (ISTAT)	www.istat.it
Portugal (PT)	Instituto Nacional de Estatística (*INE*)	www.ine.pt
EUROPE (EU)	Eurostat	http://ec.europa.eu/eurostat

Table 7 (below) shows the estimates of production loss calculated for the 21 zones in response to *V. Velutina nigrithorax* impact on pollination. Note that data on crop production are not available for any of the listed zones in France. In addition, information about the climatic restrictions to the species occurrence in Europe would allow to predict the distribution of *V. velutina nigrithorax* in the near future, by simply merging information on pollinators occurrence and climatic variables.

NUTS ID	Actual flow (kg)	Production (kg)	Affected flow (kg)	Production ratio	Flow ratio	Predation rate	Production loss rate	Eurostat (euro)	Eurostat (kg)	Eurostat (€/kg)	Loss (€)
ES11	15778976.3	33133223.18	647395.5474	0.476228232	0.041028995	0.65	0.012700458	354770000	161469000	2.197140008	4505741.45
ES21	1908613.615	4290878.733	1417743.356	0.444807167	0.742813183	0.65	0.214765608	12250000	11463000	1.068655675	2630878.70
ES51	47386152.5	225694827.3	52325.73047	0.20995675	0.001104241	0.65	0.000150698	444380000	814228000	0.545768507	66967.11
FR24	24305754.6	64073853.8	100557.2699	0.379339671	0.00413718	0.65	0.001020108	?	?	?	**?**
FR25	41979990.7	49199563.67	539354.3652	0.853259411	0.012847891	0.65	0.00712568	?	?	?	**?**
FR26	2678804.28	15360137.95	1299.725708	0.174399754	0.000485189	0.65	5.50009E-05	?	?	?	**?**
FR30	3957230.38	6993289.122	11208.1333	0.565861115	0.002832318	0.65	0.001041754	?	?	?	**?**
FR51	83367280.9	131046330.5	1245107.641	0.636166466	0.014935208	0.65	0.006175831	?	?	?	**?**
FR52	46746890.7	47908297.72	3223941.034	0.975757705	0.068965892	0.65	0.043741101	?	?	?	**?**
FR53	20826294.7	43690109.11	10217957.75	0.476682139	0.490627733	0.65	0.15201776	?	?	?	**?**
FR61	141255065	337567998.1	137368024.9	0.418449218	0.972482121	0.65	0.264507349	?	?	?	**?**
FR62	83558378	248352737.3	74773952.24	0.336450401	0.894870796	0.65	0.195701765	?	?	?	**?**
FR63	23198309.4	60945908.34	21702262.91	0.380637684	0.935510539	0.65	0.231458867	?	?	?	**?**
FR71	304253410	514735261.9	11315985.95	0.591087172	0.037192635	0.65	0.014289658	?	?	?	**?**
FR72	4527059.46	6799714.317	17522.91162	0.665772009	0.003870705	0.65	0.001675055	?	?	?	**?**
FR81	70139019.2	282044498.3	10662720.96	0.248680686	0.15202267	0.65	0.024573316	?	?	?	**?**
FR82	128163032	399163870.9	5761131.266	0.321078738	0.044951584	0.65	0.009381449	?	?	?	**?**
ITC1	106431410	301897817.3	1966090.494	0.352541171	0.018472841	0.65	0.004233084	152110000	312115100	0.487352262	643894.41
ITC3	1476071.78	3738834.179	138930.4258	0.394794663	0.094121728	0.65	0.024153191	2210000	2435500	0.907411209	53378.55
ITH3	80014911.5	794669016.4	107738.2891	0.100689608	0.001346478	0.65	8.81246E-05	171180000	344811500	0.496445159	15085.17
PT11	61658145	98494113	3251585	0.626008	0.052736	0.65	0.021458	117030000	97948000	1.194818	2511282.00

Table 7. Estimates of production loss calculated for the 21 zones (in Spain, France, Italy and Portugal) in response to *V. velutina nigrithorax* impact on pollination.

4. Discussion & Conclusions

The approach developed for Classification of Alien Taxa Impacts on Ecosystem Services (CATIES) may play an important role as a tool for supporting the implementation of the IAS Regulation by providing a quantitative biophysical assessment of impact on ecosystem services. However, it should be noted that, at present, ecological data on Invasive Alien Species are, in most cases, extremely sparse and more efforts are needed to fill the current information gaps with particular reference to impacts on ES. The European Alien Species Information Network (EASIN) gives an important contribution in this regard, by providing important aggregated information on IAS distribution in the EU, and facilitating the access to more detailed information available from distributed sources. In addition, a dedicated smartphone application on IAS of Union concern has recently been developed for the general public use, citizen-scientists in particular, by the JRC (Tsiamis et al., 2017b). This application has the potential to act as a powerful tool for monitoring the distribution of IAS of Union concern, and raising public awareness. A constant flow of updated data is crucial for the implementation of the IAS Regulation, including by improving the quality of the data for impact assessment such as CATIES.

Action 5 of the EU Biodiversity Strategy to 2020 requires MS to map and assess the value of ES and promote their integration into accounting and reporting systems at EU and national level by 2020 (EU, 2011; Maes et al. 2012a; Zulian et al., 2013b). The results would provide the knowledge base on which decisions that affect land based resources are made.

A Working Group on Mapping and Assessment on Ecosystems and their Services (MAES) was set to underpin the effective delivery of the EU Biodiversity Strategy to 2020, under the Common Implementation Framework. Recent efforts to map ES in the EU have allowed the authors of this report to assess the impact of *Vespa velutina nigrithorax*, a species of Union concern, on natural pollination at European level. This report intends to provide a preliminary set of guidelines to Member States on possible approaches to assess IAS impact on ES and support MAES efforts towards the assessment and mapping of ES across Europe. EASIN proved to be an excellent source of information on alien species spatial data for compiling the distribution of *V. velutina nigrithorax* and analyse its impacts on pollination service and derived benefits.

Through the monetary evaluation of ES loss in response to IAS impact on the EU environment, CATIES aims to bridge the current gaps between ecological research and policy-making. The economic language clearly plays a central role in efficiently sharing information between different stakeholders and helps increase public awareness on the importance of nature protection and preservation, while promoting sustainable practices.

Finally, it should be noted that although this report intends to provide a standardized tool for the analysis of IAS impact on biodiversity, it builds on previous evaluation of insect pollination service and, because of this, it is case specific. Therefore, it requires to be tailored to the specific service being analyzed.

References

Bacher, S., Blackburn, T.M., Essl, F., Genovesi, P., Heikkilä, J., Juschke, J.M., Jones, G., Keller, R., Kenis, M., Kueffer, C., Martinou, A.F., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Roy, H.E., Saul, W., Scalera, R., Vilà, M., Wilson, J.R.U. and Kumschick, S., 2017. Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution*, pp.1-10.

Bellard, C., Cassey, P. and Blackburn, T.M., 2016. Alien taxa as a driver of recent extinctions. *Biological Letters*, 12.

Britz & Witzke, 2014. CAPRI model documentation 2014, https://www.capri-model.org/docs/capri_documentation.pdf.

Brockerhoff, E.G., Barbaro, L., Castagneyrol, B., Forrester, D.I., Gardiner, B., Gonzalez-Olabarria, J.R., Lyver, P.O.B., Meurisse, N., Oxbrough, A., Taki, H., Thompson, I.A., van der Plas, F. and Jactel H., 2017. Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity Conservation*, pp. 31.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D. A., Kinzig, A.P., Daily, G.C., Loreau, M. and Grace, J.B., 2012. Biodiversity loss and its impact on humanity. *Nature*, Vol.486 (7401), pp. 0–9.

Costanza, R., d'Arge, R., de Groot, R., Faber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 254-260.

de Haro, L., Labadie, M., Chanseau, P., Cabot, C., Blanc-Brisset, I. and Penouil, F., 2010. National Coordination Committee for Toxicovigilance Medical consequences of the Asian black hornet (Vespa velutina) invasion in Southwestern France. Toxicon, 55: 650-652.

Deriu, I., D'Amico, F., Tsiamis, K., Gervasini, E. and Cardoso, A.C., 2017. Handling big data of Alien Species in Europe: The European Alien Species Information Network Geodatabase. *Frontiers in ICT*, 4, pp.4-20.

D'hondt, B., Vanderhoeven, S., Roelandt, R., Mayer, F., Versteirt, V., Adriaens, T., Ducheyne, E., San Martin, G., Grégoire, J., Stiers, I., Quoilin, S., Cigar, J., Heughebaert, A. and Branquart, E., 2015. Harmonia+ and Pandora+: risk screening tools for potentially invasive plants, animals and their pathogens. *Biological Invasions*, 17(6), pp.1869-1883.

Ekroos, J., Olsson, O., Rundlöf, M., Wätzold, F. and Smith, H.G., 2014. Optimizing agri-environment schemes for biodiversity, ecosystem services or both? *Biological Conservation*, 172, pp. 65-71.

Essl, F., Bacher, S., Blackburn, T., Booy, O., Brundu, G., Brunel, S., Cardoso, A.C., Eschen, R., Gallardo, B., Galil, B., García-Berthou, E., Genovesi, P., Groom, Q., Harrower, C., Hulme, P.E., Katsanevakis, S., Kenis, M., Kühn, I., Kumschick, S., Martinou, A.F., Nentwig, W., O'Flynn, C., Pagad, S., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Roques, A., Roy, H.E., Scalera, R., Schindler, S., Seebems, Vanderhoeven, S., Vilà, M., Wilson, J.R.U., Zenetos, A. and Jeschke, J.M., 2015. Crossing frontiers in tackling pathways of biological invasions. *BioScience*, 65(8), pp.769-782.

EU, 2011. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. European Commission. *Com/2011/244, Brussels, Belgium*, pp.1-16.

EU, 2014. Regulation (EU) No 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species. *Official Journal of the European Union* L315, pp.35-55.

EU, 2016. Commission Implementing Regulation (EU) 2016/1141 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. *Official Journal of the European Union* L189/4, pp.4-8.

EU, 2017. Commission Implementing Regulation (EU) 2017/1263 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. *Official Journal of the European Union* L182/37, pp.37-39.

Franklin, D.N., Brown, M.A., Datta, S., Cuthbertson, A.G.S., Budge, G.E. and Keeling, M.J., 2017. Invasion dynamics of Asian hornet, Vespa velutina (Hymenoptera: Vespidae): a case study of a commune in south-west France. Appl Entomol Zool, 52: 221-229.

Frye, C., 2007. About the Geometrical Interval classification method. ESRI. [Online: https://blogs.esri.com/esri/arcgis/2007/10/18/about-the-geometrical-interval-classification-method/] Last accessed on 15/01/2018

Golden, D.B.K., Breisch, N.L., Hamilton, R.G., Guralnick, M.S., Greene, A., Craig, J., Kagey-Sobokta, A., 2006. Clinical and entomological factors influence the outcome of sting challenge studies. Journal of Allergy and Clinical Immunology, 117: 670-675.

Haines-Young, R. and Potschin, M., 2017. *Common International Classification of Ecosystem Services (CICES) V5.0 Guidance on the Application of the Revised Structure.* Fabis Consulting Ltd., pp.26.

Haines-Young, R. and Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being, in Raffaelli, D., Frid, C. (Eds.), Ecosystem Ecology: A New Syshesis, *BES Ecological Reviews Series*, CUP, Cambridge.

Hawkins, C.L., Bacher, S., Essl, F., Hulme, P.E., Jeschke, J.M., Kühn, I., Kumschick, S., Nentwig, W., Pergl, J., Pyšek, P., Rabitsch, W., Richardson, D.M., Vilà, M., Wilson, J.R.U., Genovesi, P. and Blackburn, T.M., 2015. Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification fo Alien Taxa (EICAT). *Diversity and Distributions*, 21(11), pp.1360-1363.

Hoagland, P. and Jin, D., 2006. Science and economics in the management of an invasive species. *BioScience*, 56, 931-935.

Hulme, P.E., 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, 46, pp.10-18.

Jeschke, J.M., Bacher, S., Blackburn, T.M., Dick, J.T.A., Essl, F., Evans, T., Gaertner, M., Hulme, P.E., Kühn, I., Mrugała, A., Pergl, J., Pyšek, P., Rabitsch, W., Ricciardi, A., Richardson, D.M., Sendek, A., Vilà, M., Winter and M., Kumschick, S., 2014. Defining the impact of non-native species. *Conservation Biology*, 28, pp. 1188–1194.

Katsanevakis, S., Bogucarskis, K., Gatto, F., Vandekerkhove, J., Deriu, I. and Cardoso, A.C., 2012. Building the European Alien Species Information Network (EASIN): a novel approach for the exploration of distributed alien species data. *BioInvasions Records*, 2, pp. 235-245.

Katsanevakis, S., Genovesi, P., Gaiji, S., Nyegaard, H., Roy, H., Nunes, A.L., Sánchez Aguado, F., Bogucarskis, K., Debusscher, B., Deriu, I., Harrower, C., Josefsson, M., Lucy, F.E., Marchini, A., Richards, G., Trichkova, T., Vanderhoeven, S., Zenetos, A. and Cardoso, A.C., 2013. Implementing the European policies for alien species – networking, science, and partnership in a complex environment. *Management of Biological Invasions*, 4(1), pp.3-6.

Katsanevakis, S., Deriu, I., D'Amico, F., Nunes, A.L., Sanchez, S.P., Crocetta, F., Arianoutsou, M., Bazos, I., Christopoulou, A., Curto, G., Delipetrou, P., Kokkoris, Y., Panov, V., Rabitsch, W., Roques, A., Scalera, R., Shirley, S.M., Tricarico, E., Vannini, A., Zenetos, A., Zervou, S., Zikos, A. and Cardoso, A.C., 2015. European Alien Species

Information Network (EASIN): supporting European policies and scientific research. *Management of Biological Invasions*, 6(2), pp.147-157.

Keeling, M.J., Franklin, D.N., Datta, S., Brown, M.A., Budge, G.E., 2017. Predicting the spread of the Asian hornet (Vespa velutina) following its incursion into Great Britain. *Scientific Reports, volume 7*, Article number: 6240 (2017).

Keller, R.P., Masoodi, A. and Shacleton, R.T., 2017. The impact of invasive aquatic plants on ecosystem services and human well-being in Wular Lake, India. *Regional Environmental Change*, pp.1-11.

Ken T., Hepburn H. R., Radloff S. E., Yusheng Y., Yiqiu L., Zhou Dany Z., Neumann P., 2005. Heat-balling wasps by honeybees. Naturwissenschaften (2005) 92: 492. https://doi.org/10.1007/s00114-005-0026-5.

Ketteunen, M., Genovesi, P., Gollasch, S., Pagad, S., Starfinger, U., ten Brink, P. and Shine, C., 2009. *Technical support to the EU strategy on invasive species (IAS) – Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission)*. Belgium (Brussels): Institute for European Environmental Policy (IEEP).

Kevan, P.G. and Phillips, T.P., 2001. The economic impacts of pollinator declines: an approach to assessing the consequences. Conservation Ecology, 5(1): 8.

Klein, A.M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. and Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society of London, B: Biological Sciences, 274(1608): 303-313.

La Notte, A., D'Amato D., Mäkinen, H., Paracchini, M.L., Liquete, C., Egoh, B., Geneletti, D. and Crossman, N.D., 2017a. Ecosystem services classification: A systems ecology perspective of the cascade framework. *Ecological Indicators*, 74, pp. 392–402.

La Notte, A., Vallecillo, S., Polce, C., Zulian, G. and Maes, J., 2017b. *Implementing an EU system of accounting for ecosystems and their services. Initial proposals for the implementation of ecosystem services accounts. Report under phase 2 of the knowledge innovation project on an integrated system of natural capital and ecosystem services accounting in the EU*. JRC Technical Report, pp.121.

Le Maitre, D.C., Geartner, M., Marchante, E., Ens, E., Holmes, P.M., Pauchard, A., O'Farrel, P.J., Rogers, A.M., Blanchard, R., Blignaut, J. and Richardson, D.M., 2011. Impacts of invasive Australian acacias: implication for management and restoration. *Divers Distrib*, 17, pp.1015-1029.

Leip, A., Marchi, G., Koeble, R., Kempen, M., Britz, C., Li, C., 2008. Linking an economic model for European agriculture with amechanistic model to estimate nitrogen and carbon losses fromarable soils in Europe. *Biogeosciences*, 5, 73–94.

Maes, J., Liquete, C., Teller, A., Erhard, M., Parracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A.C., Somma, F. and Petersen, J., 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. *Ecosystem Services*, 17, pp.14-23.

Maes, J., Teller, A., Erhard, M., Murphy, P., Paracchini, M.L., Barredo, J.I., Grizzetti, B., Cardoso, A.C., Somma, F., Petersen, J-E., Meiner, A., Gelabert, E.R., Zal, N., Kristensen, P., 2014. *Mapping and Assessment of Ecosystems and their Services. Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*. Publications office of the European Union, Luxembourg. Available at: http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/2ndMAESWorkingPaper.pdf

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M.L., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P.H., Condé, S., Schägner, J.P., San Miguel, J., Estreguil, C., Ostermann, O., Barredo, J.I., Pereira, H.M., Scott, A., Laporte, V., Meiner, A., Olah, B., Royo Gelabert, E., Spyropoulou, R., Petersen, J.E., Maguire, C., Zal, N., Achilleos, E., Rubin, A., Ledoux L., Brown, C., Raes, C., Jacobs, S., Vandewalle, M., Connor, D. and Bidoglio, G., 2013. *Mapping and Assessment of Ecosystem and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy 2020.* Publications office of the European Union, Luxembourg.

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J.P., Grizzetti, B., Drakou, E.G., La Notte, A., Zuliab, G., Bouraoui F., Paracchini M.L., Braat L., Bidoglio G., 2012a. Mapping ecosystem services for policy support and decision making in the European Union. *Ecosystem Services*, 1, pp. 31-39.

Maes, J., Paracchini, M.L., Zulian, G., Dunbar, M.B. and Alkemade, R., 2012b. Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. *Biological Conservation*, 155, pp. 1-12.

Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. USA (Washington DC): World Resources Institute.

Monceau, K., Bonnard, O. and Thiery, D., 2012. Chasing the queens of the alien predator of honeybees: A water drop in the invasiveness ocean. Open Journal of Ecology, 2: 183-191.

Monceau K., Maher N., Bonnard O., Thiéry D., 2013. Predation pressure dynamics study of the recently introduced honeybee killer *Vespa velutina*: learning from the enemy. Apidologie 44:209-221 DOI 10.1007/s13592-012-0172-7.

Monceau K., Bonnard O., Thiéry D., 2014. *Vespa velutina*: A new invasive predator of honeybees in Europe. Journal of Pest Science 87:1-16 DOI: 10.1007/s10340-013-0537-3.

Pyšek, P., Jarošík, V., Hulme, P.E., Pergl, J., Hejda, M., Schaffner, U. and Vilà, M., 2012. A global assessment of invasive plant impacts on resident species, communities and ecosystems: The interaction of impact measures, invading species traits and environment. *Global Change Biology*, 18, pp.1725-1737.

Ricciardi, A., Hoopes, M.F., Marchetti, M.P. and Lockwood, J.L., 2013. Progress towards understanding the ecological impacts of nonnative species. *Ecological Monographs*, 83, pp. 263–282.

Rome, Q., Perrard, A., Muller, F. and Villemant, C., 2011. Monitoring and control modalities of a honeybee predator, the yellow-legged hornet Vespa velutina nigrithorax (Hymenoptera: Vespidae). Aliens, 31: 7-15.

Roques, A., Auger-Rozernberg, M.A., Blackburn, T.M., Garnas, J.R., Pyšek, P., Rabitsch, W., Richardson, D.M., Wingfield, M.J., Liebhold, A.M. and Duncan, R.P., 2016. Temporal and interspecific variation in rates o spread dor insect species invading Europe during the last 200 years. *Biological Invasions*, 18(4), pp.907-920.

Sandhu, H. and Sandhu, S., 2014. Linking ecosystem services with the constituents of human well-being for poverty alleviation in eastern Himalayas. *Ecological Economics*, 107, pp.65-75.

Scalera, R., 2010. How much is Europe spending on invasive alien species?. *Biological Invasions*, 12(1), pp.173-177.

Silva, J.P., Sopeña, A., Silva, J., toland, J., Nottingham, S., Jones, W., Eldbridge, J., Thorpe, E. and Thévignot, C., 2014. *LIFE and invasive alien species*. Luxembourg (Luxembourg): Publications Office of the European Union.

Southwick, E.E. and Southwick, L. Jr, 1992. Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. Journal of Economic Entomology, 85(3): 621-633.

Tan, K., Radloff, S.E., Li, J.J., Hepburn, H.R., Yang, M.X., Zhang, L.J. and Neumann, P., 2007. Bee-hawking by the wasp, *Vespa velutina*, on the honeybees *Apis cerana* and *A. mellifera*. *Naturwissenschaften*, 94(6), pp.469-472.

Trombetti, M., Katsanevakis, S., Deriu, I., Cardoso, A.C., 2013. EASIN-Lit: a geo-database of published alien species records. *Management of Biological Invasions*, 4.7, pp. 261-264, DOI: http://dx.doi.org/10.3391/mbi.2013.4.3.08

Tsiamis, K., Gervasini, E., Deriu, I., D'amico, F., Nunes, A., Addamo, A. and Cardoso, A.C., 2017a. Baseline Distribution of Invasive Alien Species of Union concern. *Ispra (Italy): Publications Office of the European Union;, EUR 28596 EN, doi:10.2760/772692*

Tsiamis, K., Gervasini E., D'amico F., Deriu I., Roglia E., Shade S., Craglia M. and Cardoso A.C., 2017b. Citizen science application. *Ispra (Italy): Publications Office of the European Union; EUR 28441 EN; doi:10.2760/043856*

Vallecillo S., La Notte A., Polce C., Zulian G., Alexandris N., Ferrini S. and Maes J., 2018. Ecosystem services accounting: Part I - Outdoor recreation and crop pollination, EUR 29024 EN; Publications Office of the European Union, Luxembourg, doi: 10.2760/619793, JRC110321

Vilá, M., Basnou, C., Pyšek, P., Josefsson, M., Genovesi, P., Gollasch, S., Nentwig, W., Olenin,S., Roques, A., Roy, D., Hulme, P. and DAISIE partners, 2010. How well do we understand the impacts of alien taxa on ecosystem services? A pan-European, cross-taxa assessment. *Frontiers in Ecology and the Environment*, 8, pp.135-144.

Villemant, C., Zuccon, D., Rome, Q., Muller, F., Poinar, G.O.Jr. and Justine, J-L., 2015. Can parasites halt the invader? Mermithid nematodes parasitizing the yellow-legged Asian hornet in France. *PeerJ*, e947. DOI:10.7717/peerj.947. ISSN 2167-8359

Villemant, C., Muller, F., Haubois, S., Perrard, A., Darroutzet, E. and Rome, Q., 2011. Bilan des travaux (mnhn et irbi) sur l'invasion en france de *Vespa velutina*, le frelon asiatique prédateur d'abeilles. *Journée Scientifique Apicole*, pp.3-12.

Villemant, C., Haxaire, J. and Streito, J.C., 2006. Premier bilan de l'invasion de Vespa velutina Lepeletier en France (Hymenoptera, Vespidae). Bulletin de la Société entomologique de France, 111: 535–538.

Zulian, G., Maes, J., and Paracchini, M.L., 2013a. Linking Land Cover Data and Crop Yield for Mapping and Assessment of Pollination Services in Europe. *Land*, 2, pp.472-492.

Zulian, G., Paracchini, M.L., Maes, J. and Liquete, C., 2013b. ESTIMAP: Ecosystem services mapping at European Scale. *Ispra (Italy): Publications Office of the European Union; EUR 26474 EN; doi: 10.2788/64369*.

List of abbreviations and definitions

AS	Alien species as defined in Art. 3 of EU Regulation 1143/2014
CATIES	Classification of Alien Taxa Impacts on Ecosystem Services
CBD	Convention on Biological Diversity (https://www.cbd.int./)
CIF	Common Implementation Framework
DG ENV	European Commission Directorate General for Environment
EC	European Commission
EEA	European Environmental Agency (http://www.eea.europa.eu/)
EU	European Union
GIS	Geographic Information System
IAS	Invasive Alien Species as defined in Art. 3 of EU Regulation 1143/2014
IUCN	International Union for Conservation of Nature (https://www.iucn.org/)
JRC	Joint Research Centre Directorate of the European Commission
KIP INCA	Knowledge Innovation Project on an Integrated system fir Natural Capital and ecosystem services Accounting (http://ec.europa.eu/environment/nature/capital_accounting/index_en.htm)
MA	Millennium ecosystem Assessment (https://www.millenniumassessment.org/)
MAES	Mapping and Assessment on Ecosystems and their Services (http://biodiversity.europa.eu/maes)
MS	Member States
SEEA EEA	United Nations System of Environmental-Economic Accounting Experimental Ecosystem Accounting (https://unstats.un.org/unsd/envaccounting/eea_project/default.asp)
STOPVESPA	Stop Vespa Asiatica (http://www.vespavelutina.eu/en-us/)

List of Figures

List of Tables

Annex I. Detailed spatial information at grid level 10x10 km as well as original sources are provided for each IAS of Union concern and for each EU country through ArcGIS digital files.

Important Notes: Due to the huge number of ArcGIS files (>350), the information is directly provided through a web-link in the EASIN's website (https://easin.jrc.ec.europa.eu/).

The related information is also available on request by the EASIN team (jrc-easin@ec.europa.eu).

A complete protocol for checking EU baseline distribution of IAS of Union concern is available in Tsiamis et al., 2017 accessible online at: https://easin.jrc.ec.europa.eu/Documentation/Baseline.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: http://europea.eu/contact

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: http://europa.eu/contact

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: http://europa.eu

EU publications
You can download or order free and priced EU publications from EU Bookshop at: http://bookshop.europa.eu. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact).

KJ-NA-29827-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/134398

ISBN 978-92-76-09511-8