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INVASION NOTE

A preliminary prioritized list of Italian alien terrestrial invertebrate species

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Abstract Invasive alien species (IAS) are considered one of the largest drivers of biodiversity loss worldwide and the negative impacts of IAS can also affect human health and economy. More than 12,000 alien species occur in Europe. Terrestrial invertebrate species are the largest proportion of alien animal species and represents one of the most impacting groups in Europe. The most important European policy against alien species is the EU Regulation 1143/2014, which provides for the development of priority lists of IAS of relevant concern aimed to allow the optimization of intervention measures. Italian policy implemented the EU Regulation with the Legislative Decree No 230/2017 that provides the adoption of a list of IAS of national concern. Aim of this work is to present a preliminary prioritized list of alien terrestrial invertebrate species (ATIS) present in Italy, thus providing an useful tool to identify species to be included in the list of IAS of national concern. We defined criteria for assessing the species and ranking them in a prioritized list on the basis of the magnitude of their potential impact on wild native biodiversity. We identify 233 relevant ATIS, among the 1126 species included in the Italian Alien Terrestrial Invertebrate Database, on which the evaluation process started. After the evaluation process, 109 ATIS with considerable impacts on biodiversity were selected and prioritized. We ranked the species in four priority categories by matching their distribution in Italy with the magnitude of their possible impact on biodiversity.

Keywords Invasive species · EU IAS regulation · Conservation policy implementation · Species of concern · Invasive · Consensus building

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Introduction

Invasive alien species (IAS) represent one of the main drivers for biodiversity loss worldwide, second only to overexploitation, agriculture and urban development (Maxwell et al. 2016). Indeed globalization and human activities such as global trade, tourism and transport, have favoured the movement of species outside their natural range through geographic barriers (Hulme 2009; Bellard et al. 2016). According to Convention on Biological Diversity, IAS are defined as species that are established outside of their natural past or present distribution, whose introduction and/or spread threaten biodiversity (Convention on Biological Diversity 2002). Most of IAS are introduced in new areas accidentally, but some of these are intentionally transported and introduced as biological control agents, pet species, game animals, ornamental and useful species (Hulme et al. 2008). More than 12,000 alien species are reported in Europe by DAISIE project (www.europe-aliens.org). The impact that IAS have on biodiversity and related ecosystem services can occur in a variety of ways including habitat alteration, competition, substitution of native species, disease transmission, predation on and hybridization with native species (Beninde et al. 2015). The negative impacts of IAS can also affect human health and economy (Beninde et al. 2015). However, magnitudes of impacts widely vary in relation to alien taxa or colonized ecosystems. Moreover, in many cases, impacts become evident only in advanced stages of the invasions (Strayer 2012).

Economic evaluation of these impacts remains difficult to assess especially if we consider ecological impacts (Jeschke et al. 2014) and very little is known also about impacts from relevant IAS (Bradshaw et al. 2016). A minimum cost of 12.5 billion euros per year has been calculated in Europe based on documented IAS monetary impacts (Kettunen et al. 2009). Nevertheless, this was an underestimation of real costs, due to a limited recording of costs and limited availability of documents, and the total cost of IAS in Europe can be estimated as 20 billion euros per year (Kettunen et al. 2009). Estimate annual costs for EU policy action against IAS could be around 40–190 million euros per year, ranging from low to high level of investment, respectively (Shine et al. 2010).

Given the high number of alien species present in European countries, it is clear that there is a crucial need to evaluate, compare and predict magnitudes of impacts of different IAS in order to highlight and list priority species for which control or eradication plans need to be developed (Hawkins et al. 2015). In response to this need, the IUCN Species Survival Commission Invasive Species Specialist Group (ISSG) has developed a tool to support the prioritisation process: the Environmental Impact Classification of Alien Taxa (EICAT) (Blackburn et al. 2014; Hawkins et al. 2015). Aim of EICAT is to provide a simple, objective and transparent method for classifying alien taxa in terms of magnitude of their environmental impacts (Hawkins et al. 2015). The method includes five levels of impact categories in which IAS are classified based on magnitude of their impacts on biodiversity (Blackburn et al. 2014).

The question of IAS is very complex and generally poorly understood by society. Communication and synergy among experts, governments, society and international trade industry are therefore necessary to effectively tackle this problem (Courchamp et al. 2017). The European Union (EU) is addressing this issue in terms of legislation. The most important European policy on alien species is the EU Regulation 1143/2014. The focal point of this Regulation provides for the adoption of a list of IAS of Union concern and the relative management measures. Furthermore, Article 12 of the Regulation provides that Member States may establish a national priority list of IAS. With the Legislative Decree No 230/2017 (entered into enforce on 14/02/2018) the Italian policy aims to adapt national legislation to the European provisions. In particular, Article 5 of this Decree requires the adoption and updating of a list of IAS of national concern to which management measures provided for IAS of Union concern must be applied.

More than 20% of the European alien species listed in the DAISIE inventory are terrestrial invertebrates. Although this group includes the majority of alien animal species (Nentwig and Josefsson 2010) and represents one of the most impacting groups in Europe, knowledge about alien terrestrial invertebrate species (ATIS) is still largely limited (Roy et al. 2011). The purpose of this work is to present a preliminary prioritized list of ATIS present in Italy in order to reduce the array of species to be evaluated and to provide a useful tool to identify species to be included in the list of IAS of national concern.

Table 1 List of the assessed Italian ATIS (n = 109)

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Achatina fulica	Mollusca	Gastropoda	Pulmonata	Achatinidae	O	MO	E-PET	2018	AF	4	herm	ph
Aethina tumida	Arthropoda	Insecta	Coleoptera	Nitidulidae	L	MO	C-TIMB	2014	AF	3	amph	o
Ambrosiodmus rubricollis	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	2008	AS	4	amph	ph
Anoplophora chinensis (*)	Arthropoda	Insecta	Coleoptera	Cerambycidae	L	MO	C-TIMB	1994	AS	2	amph	ph
Anoplophora glabripennis (*)	Arthropoda	Insecta	Coleoptera	Cerambycidae	L	MO	C-TIMB	2004	AS	3	amph	ph
Apate monachus	Arthropoda	Insecta	Coleoptera	Bostrichidae	L	MN	C-TIMB	UN	AF	4	amph	ph
Aproceros leucopoda	Arthropoda	Insecta	Hymenoptera	Argidae	D	MO	C-PLANT	2009	AS	2	parth	ph
Arion vulgaris	Mollusca	Gastropoda	Pulmonata	Arionidae	D	MN	C-H_MAT	1965	EU	1	herm	ph
Aromia bungii	Arthropoda	Insecta	Coleoptera	Cerambycidae	L	MN	C-TIMB	2009	AS	1	amph	ph
Ascaridia dissimilis	Nematoda	Secernentea	Ascaridida	Ascaridiidae	L	MN	C-ANIMAL	1973 pub	NA	5	amph	en
Ascaris lumbricoides	Nematoda	Secernentea	Ascaridida	Ascaridiidae	O	MN	C-ANIMAL	2015	OC	5	amph	en
Bactrocera dorsalis (*)	Arthropoda	Insecta	Diptera	Tephritidae	O	MN	C-FOOD	2018	AS	4	amph	ph
Bactrocera zonata	Arthropoda	Insecta	Diptera	Tephritidae	O	MN	C-FOOD	2007 pub	AS	2	amph	ph
Bipalium kewense	Platyhelminthes	Turbellaria	Seriata	Bipaliidae	L	MO	C-H_MAT	1974 pub	AS	5	asex	p
Bruchus pisorum	Arthropoda	Insecta	Coleoptera	Chrysomelidae	D	MN	C-PLANT	1850	AS	5	amph	ph
Bruchus rufimanus	Arthropoda	Insecta	Coleoptera	Chrysomelidae	D	MN	C-PLANT	1850	UN	4	amph	ph
Bursaphelenchus fungivorus	Nematoda	Secernentea	Aphelenchida	Parasitaphelenchidae	O	MO	C-PLANT	2002	UN	3	amph	ph
Bursaphelenchus rainulfi	Nematoda	Secernentea	Aphelenchida	Parasitaphelenchidae	O	MN	C-PLANT	2002	UN	1	amph	ph
Callidiellum rufipenne	Arthropoda	Insecta	Coleoptera	Cerambycidae	D	MN	C-TIMB	1988	AS	3	amph	ph
Camponotus atriceps	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-PLANT	2008 pub	SA	2	amph	o
Cardiocondyla mauritanica	Arthropoda	Insecta	Hymenoptera	Formicidae	L	MO	C-H_MAT	1981	AS	5	amph	o
Cardiocondyla nuda	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-H_MAT	2002	OC	5	amph	ph

Table 1 continued

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Cardiocondyla wroughtonii	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MO	C-H_MAT	2006	AS	4	amph	o
Ceratitis capitata	Arthropoda	Insecta	Diptera	Tephritidae	D	MN	C-FOOD	1863	AF	5	amph	ph
Ceroplastes ceriferus	Arthropoda	Insecta	Hemiptera	Coccidae	D	MN	C-PLANT	2001	UN	5	parth	ph
Ceroplastes japonicus	Arthropoda	Insecta	Hemiptera	Coccidae	D	MN	C-PLANT	1983	AS	2	parth	ph
Ceroplastes rusci	Arthropoda	Insecta	Hemiptera	Coccidae	D	MN	C-PLANT	1918 pub	AF	4	parth	ph
Ceroplastes sinensis	Arthropoda	Insecta	Hemiptera	Coccidae	D	MN	C-PLANT	1900 pub	UN	5	parth	ph
Chymomyza amoena	Arthropoda	Insecta	Diptera	Drosophilidae	L	MN	C-FOOD	1998	NA	2	amph	ph
Cinara cupressi	Arthropoda	Insecta	Hemiptera	Aphididae	D	MR	C-PLANT	1977	NA	4	parth	ph
Colopterus abdominalis	Arthropoda	Insecta	Coleoptera	Nitidulidae	L	MV	C-PLANT	2014	SA	1	amph	ph
Coptotermes gestroi	Arthropoda	Insecta	Isoptera	Rhinotermitidae	O	MN	C-TIMB	2009	AS	3	amph	ph
Corythucha arcuata	Arthropoda	Insecta	Hemiptera	Tingidae	D	MN	C-PLANT	2000	NA	3	amph	ph
Cryptotermes brevis	Arthropoda	Insecta	Isoptera	Kalotermitidae	O	MN	C-TIMB	1978	SA	5	amph	ph
Cyclorhipidion bodoanum	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-TIMB	2007	AS	3	amph	ph
Cydalima perspectalis	Arthropoda	Insecta	Lepidoptera	Tortricidae	D	MO	C-PLANT	2011	AS	2	amph	ph
Cyrtogenius luteus	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	2009	AS	2	amph	ph
Diaspidiotus perniciosus	Arthropoda	Insecta	Hemiptera	Diaspididae	D	MO	C-PLANT	1929	AS	5	amph	ph
Dinoderus japonicus	Arthropoda	Insecta	Coleoptera	Bostrichidae	L	MN	C-TIMB	2013	AS	4	amph	ph
Diversibipalium multilineatum	Platyhelminthes	Turbellaria	Tricladida	Geoplanidae	L	MO	C-H_MAT	2014	AS	2	asex	p
Dreyfusia nordmannianae	Arthropoda	Insecta	Hemiptera	Adelgidae	L	MN	C-PLANT	1983	AS	3	parth	ph
Drosophila suzukii	Arthropoda	Insecta	Diptera	Drosophilidae	D	MN	C-FOOD	1983 pub	AS	3	parth	ph

Table 1 continued

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Dryocosmus kuriphilus (*)	Arthropoda	Insecta	Hymenoptera	Cynipidae	D	MN	C-PLANT	1985	AS	3	parth	ph
Fascioloides magnus	Platyhelminthes	Rhabditophora	Plagiorchiida	Fasciolidae	L	MO	C-ANIMAL	1875 pub	NA	2	asex	en
Frankliniella occidentalis	Arthropoda	Insecta	Thysanoptera	Thripidae	D	MN	C-PLANT	1987	NA	5	parth	ph
Globodera pallida (*)	Nematoda	Secernentea	Tylenchida	Heteroderidae	D	MN	C-PLANT	UN	SA	4	amph	ph
Globodera rostochiensis (*)	Nematoda	Secernentea	Tylenchida	Heteroderidae	D	MN	C-PLANT	UN	SA	5	amph	ph
Gnathotrichus materiarius	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	1998	NA	2	amph	ph
Halyomorpha halys	Arthropoda	Insecta	Hemiptera	Pentatomidae	D	MO	C-PLANT	2013	AS	4	amph	ph
Harmonia axyridis	Arthropoda	Insecta	Coleoptera	Coccinellidae	D	MR	C-PLANT	1964	AS	5	amph	p
Hyalomma aegyptium	Arthropoda	Arachnida	Ixodida	Ixodidae	D	MN	C-ANIMAL	1911	AF	3	amph	ec
Hyphantria cunea	Arthropoda	Insecta	Lepidoptera	Arctiidae	D	MN	C-PLANT	1975	NA	4	amph	ph
Ips duplicatus (*)	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MO	C-PLANT	2009 pub	EU	2	amph	ph
Isodontia mexicana	Arthropoda	Insecta	Hymenoptera	Sphecidae	D	MN	C-H_MAT	1985	NA	2	amph	p
Lasius neglectus	Arthropoda	Insecta	Hymenoptera	Formicidae	D	MR	C-H_MAT	2000	AS	3	amph	o
Leptoglossus occidentalis	Arthropoda	Insecta	Hemiptera	Coreidae	D	MO	C-PLANT	1999	NA	4	amph	ph
Linepithema humile	Arthropoda	Insecta	Hymenoptera	Formicidae	D	MR	C-H_MAT	1921 pub	NA	5	amph	o
Listroderes costirostris	Arthropoda	Insecta	Coleoptera	Curculionidae	O	MN	C-PLANT	2015	SA	5	parth	ph
Macrosiphum euphorbiae	Arthropoda	Insecta	Hemiptera	Aphididae	D	MN	C-PLANT	1863 pub	NA	5	parth	ph
Marchalina hellenica	Arthropoda	Insecta	Hemiptera	Margarodidae	L	MO	C-PLANT	1960	EU	1	parth	ph
Matsucoccus feytaudi (*)	Arthropoda	Insecta	Hemiptera	Margarodidae	D	MO	C-PLANT	1978	AS	3	amph	ph
Megachile disjunctiformis	Arthropoda	Insecta	Hymenoptera	Megachilidae	L	MO	C-TIMB	2011	AS	1	amph	ph
Megachile sculpturalis	Arthropoda	Insecta	Hymenoptera	Megachilidae	D	MO	C-TIMB	2009	AS	2	amph	ph

Table 1 continued

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Megaplatypus mutatus	Arthropoda	Insecta	Coleoptera	Platypodidae	L	MN	C-TIMB	2000	SA	1	amph	ph
Meloidogyne arenaria	Nematoda	Secernentea	Tylenchida	Heteroderidae	L	MN	C-H_MAT	1978 pub	UN	5	parth	ph
Meloidogyne graminicola	Nematoda	Secernentea	Tylenchida	Heteroderidae	L	MO	C-H_MAT	2016	UN	3	parth	ph
Meloidogyne incognita	Nematoda	Secernentea	Tylenchida	Heteroderidae	L	MN	C-H_MAT	1972 pub	UN	5	parth	ph
Meloidogyne luci	Nematoda	Secernentea	Tylenchida	Heteroderidae	L	MN	C-H_MAT	2012 pub	UN	3	parth	ph
Metcalfa pruinosa	Arthropoda	Insecta	Hemiptera	Flatidae	D	MN	C-PLANT	1979	NA	3	amph	ph
Monarthrum mali	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	2007	NA	2	amph	ph
Monomorium pharaonis	Arthropoda	Insecta	Hymenoptera	Formicidae	D	MN	C-H_MAT	1908	AF	5	amph	o
Neoclytus acuminatus	Arthropoda	Insecta	Coleoptera	Cerambycidae	D	MN	C-TIMB	1908 pub	NA	2	amph	ph
Obama nungara	Platyhelminthes	Turbellaria	Tricladida	Geoplanidae	O	MO	C-H_MAT	2012	SA	2	asex	p
Obeliscoides cuniculi	Nematoda	Chromadorea	Rhabditida	Trichostrongylidae	D	MO	C-ANIMAL	2009	NA	2	amph	en
Paratrechina bourbonica	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-H_MAT	2006	AS	4	amph	o
Paratrechina longicornis	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-H_MAT	1979 pub	AF	5	amph	o
Pheidole megacephala	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MV	C-H_MAT	2001	AF	5	amph	o
Phloeotribus liminaris	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	2004	NA	1	amph	ph
Pityophthorus juglandis	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-TIMB	2013	NA	1	amph	ph
Polydrusus inustus	Arthropoda	Insecta	Coleoptera	Curculionidae	O	MO	C-PLANT	1991	AS	1	parth	ph
Popillia japonica (*)	Arthropoda	Insecta	Coleoptera	Scarabaeidae	L	MR	C-PLANT	2014	AS	3	amph	ph
Protopulvinaria pyriformis	Arthropoda	Insecta	Hemiptera	Coccidae	D	MN	C-PLANT	1991	SA	4	parth	ph
Pseudococcus comstocki	Arthropoda	Insecta	Hemiptera	Pseudococcidae	L	MN	C-PLANT	2004	AS	3	amph	ph
Pseudococcus viburni	Arthropoda	Insecta	Hemiptera	Pseudococcidae	D	MN	C-PLANT	1913 pub	SA	5	amph	ph

Table 1 continued

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Reticulitermes flavipes	Arthropoda	Insecta	Isoptera	Rhinotermitidae	O	MN	C-H_MAT	2008	NA	2	amph	ph
Rhagoletis completa (*)	Arthropoda	Insecta	Diptera	Tephritidae	D	MN	C-FOOD	1991	NA	2	amph	ph
Sceliphron caementarium	Arthropoda	Insecta	Hymenoptera	Sphecidae	D	MN	S-CONT	1990	NA	2	amph	p
Strongyloides robustus	Nematoda	Secernentea	Rhabditida	Strongyloididae	D	MN	C-ANIMAL	2012 pub	NA	3	parth	en
Tapinoma melanocephalum	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-FOOD	2007	AS	5	amph	o
Tarsostenus carus	Arthropoda	Insecta	Coleoptera	Cleridae	L	MN	C-TIMB	1999	OC	5	amph	p
Technomyrmex pallipes	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MN	C-FOOD	2002	AF	1	amph	o
Tegolophus califraxini	Arthropoda	Arachnida	Trombidiformes	Eriophyidae	L	MN	C-PLANT	1987	NA	3	amph	ph
Tetramorium bicarinatum	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MO	C-H_MAT	2001	AS	5	amph	o
Tinocallis takachihoensis	Arthropoda	Insecta	Hemiptera	Aphididae	D	MN	C-PLANT	1997 pub	AS	3	parth	ph
Toumeyella parvicornis	Arthropoda	Insecta	Hemiptera	Coccidae	L	MO	C-PLANT	2014	NA	1	amph	ph
Trichoferus campestris	Arthropoda	Insecta	Coleoptera	Cerambycidae	O	MN	C-TIMB	2012	AS	3	amph	ph
Trichopoda pennipes	Arthropoda	Insecta	Diptera	Tachinidae	D	MO	C-PLANT	1988	NA	3	amph	par
Trichostrongylus affinis	Nematoda	Chromadorea	Rhabditida	Trichostrongylidae	D	MO	C-ANIMAL	2010 pub	NA	2	amph	en
Trichostrongylus calcaratus	Nematoda	Chromadorea	Rhabditida	Trichostrongylidae	D	MO	C-ANIMAL	2002	NA	2	amph	en
Trogoderma granarium	Arthropoda	Insecta	Coleoptera	Dermestidae	O	MN	C-FOOD	1941 pub	AS	4	amph	d
Unaspis euonymi	Arthropoda	Insecta	Hemiptera	Diaspididae	D	MN	C-PLANT	1883	AS	3	amph	ph
Varroa destructor	Arthropoda	Arachnida	Mesostigmata	Varroidae	D	MO	C-ANIMAL	1981	AS	5	amph	ec
Wasmannia auropunctata	Arthropoda	Insecta	Hymenoptera	Formicidae	O	MV	C-H_MAT	1996	SA	5	amph	o
Xyleborus atratus	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MN	C-PLANT	2007	AS	2	amph	ph

Table 1 continued

Species	Phylum	Class	Order	Family (subfamily)	Distribution in Italy	Impact on Biodiversity	Main Introduction Pathway	First report in Italy	Native Continet	Number of Colonized Continents	Reproduction Strategy	Diet
Xylosandrus compactus	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MO	C-PLANT	2010	AS	3	amph	ph
Xylosandrus crassiusculus	Arthropoda	Insecta	Coleoptera	Curculionidae (Scolytinae)	L	MO	C-PLANT	2003	AS	5	amph	ph
Xylotrechus stebbingi	Arthropoda	Insecta	Coleoptera	Cerambycidae	D	MN	C-TIMB	1982	AS	3	amph	ph
Zaprionus indianus	Arthropoda	Insecta	Diptera	Drosophilidae	L	MN	C-FOOD	1976	AF	4	amph	ph
Zaprionus tuberculatus	Arthropoda	Insecta	Diptera	Drosophilidae	L	MN	C-FOOD	2013	AF	2	amph	ph

Distribution in Italy: *O* occasional, *L* localized, *D* diffused. Impact on biodiversity: *MN* minor, *MO* moderate, *MR* major, *MV* massive. Main introduction pathway [*E-PET* escape pets (pet/aquarium/terrarium species escapes unintentionally in nature), *C-H_MAT* contaminant on habitat material (unintentional introduction of live organisms as contaminants of habitat material intentionally transferred through international trade e.g. soil…), *C-PLANT* contaminant on plants (unintentional introduction of live organisms as contaminants or parasites on plants or part of plants intentionally transferred through international trade), *C-TIMBER* contaminant on timber (unintentional introduction of live organisms as contaminants in timber trade), *C-ANIMAL* contaminant on animals (unintentional introduction of live organisms as contaminants or parasites of animal intentionally transferred through international trade), *C-FOOD* food contaminant (unintentional introduction of live organisms as contaminants on food intentionally transferred through international trade), *S-CONT* stowaway in containers (unintentional introduction of live organisms stowaway in containers or associated equipment)]. Native continent: *AF* Africa, *AS* Asia, *EU* Europe, *NA* North America, *OC* Oceania, *SA* South America. Reproduction strategy: *amph* amphigony, *parth* parthenogenesis, *asex* asexual reproduction, *hem* hermaphrodite. Diet (referred to the life stage with main impact on biodiversity): *ph* phytophagous, *o* omnivorous, *en* endoparasite, *p* predator, *ec* ectoparasite, *d* detritivore. Species regulated under Directive 2000/29/EC are indicated with an asterisk (*)

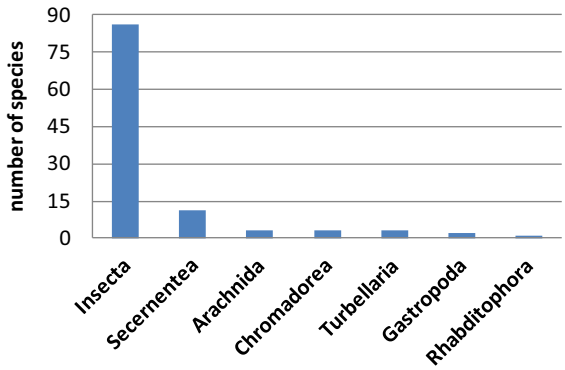

Fig. 1 Number of assessed ATIS for each class. Total number of species: n = 109

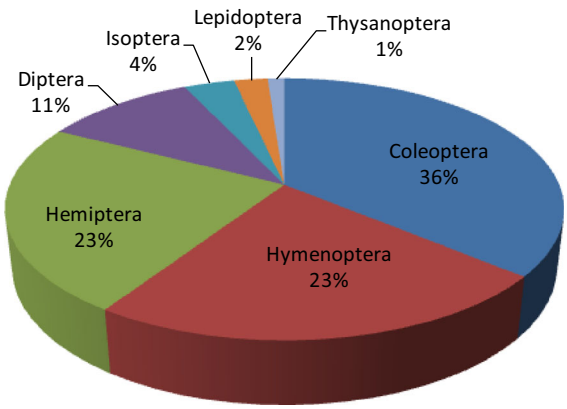

Fig. 2 Orders percentage in Insecta class. Total number of species: n = 85

This work considers only species of terrestrial invertebrates. Terrestrial species with aquatic developmental stages are excluded. Moreover, also IAS of Union concern are not considered (EU Regulation 1143/2014). Even if EU Regulation 1143/2014 does not apply to harmful organisms of phytosanitary concern regulated under Directive 2000/29/EC, species of phytosanitary concern whit remarkable impacts on wild biodiversity are evaluated in this work. We define impact on biodiversity as the impact that alien species could have on native species or on naturalized exotic species introduced before year 1492. The study area is represented by the present Italian political borders.

The selection of Italian ATIS started from the consultation of the Italian Alien Terrestrial Invertebrate Database (IATID) provided by one of the authors of this paper (M. Zapparoli unpublished). This database counts 1126 alien invertebrate species present in Italy, of which 1053 are terrestrial. In order to focus the work on the most harmful species for biodiversity, the list included in the IATID was compared to lists of other international databases as: the Global Invasive Species Database (GISD; www.iucngisd.org), the Delivering Alien Invasive Species Inventories for Europe (DAISIE; www.europe-aliens.org), the Global Register of Introduced and Invasive Species (GRIIS; www.griis.org), the European Alien Species Information Network (EASIN; easin.jrc.ec.europa.eu), the European Network on Invasive Alien Species (NOBANIS; www.nobanis.org), the European and Mediterranean Plant Protection Organization (EPPO) Global Database (gd.eppo.int). Afterwards an expert review was carried out to include in the list possible other relevant species not yet considered. We selected a preliminary list of 233 species on which the evaluation process started.

Criteria for the evaluation of the species were defined in the frame of the first of three workshops (Rome, 14 November 2017) coordinated by the "Italian Institute for Environmental Protection and Research" (ISPRA). The workshops goal was to identify univocal and comparable criteria for the assessment of each species in order to rank those species in a single prioritized list. A group of expert botanists and zoologists with relevant ecological and invasion biology expertise, belong to the most important Italian scientific societies (Unione Zoologica Italiana and Comitato Scientifico per la Fauna d'Italia for the terrestrial invertebrates), attended to the workshops providing information based on their specific knowledge. The experts were divided in five topic groups (terrestrial invertebrates, freshwater invertebrates, vertebrates, marine species and plants) on the basis of their skills. The present paper shows the work performed by the terrestrial invertebrates group.

For each assessed species several data were compiled: in particular, we assigned the magnitude of the potential impact on biodiversity, inspired by the EICAT criteria (Blackburn et al. 2014): minimal concern (MC: the alien species has no effects on the fitness of individuals of native species), minor (MN: the alien species causes a reduction in fitness but not in population density or alteration in the composition of the community of native species), moderate (MO: the alien species causes population decline but not a change in the composition of the community of native

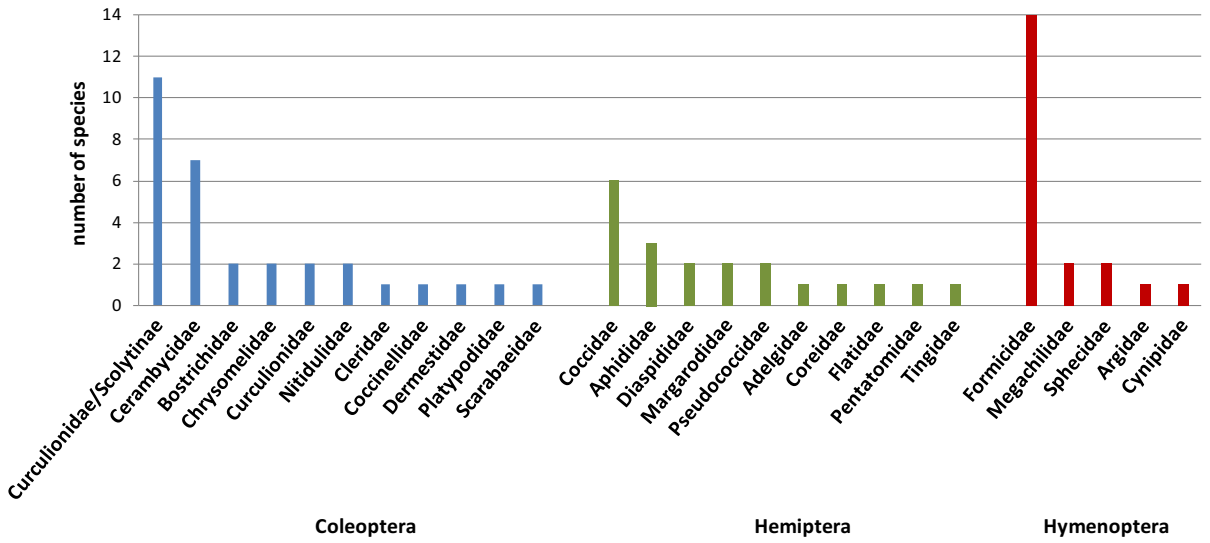

Fig. 3 Number of species for each family among the most representative orders. Coleoptera in blue, Hemiptera in green, Hymenoptera in red. Total number of species: n = 71

species), major (MR: the alien species causes changes in the composition of the community of native species; changes are reversible in case of species eradication), massive (MV: the alien species causes local extinction of population or changes in the composition of the community of native species; changes are irreversible within 10 years after species eradication).

During the second workshop (Rome, 14 March 2018), the assessment of a subset of species was tested among groups in order to standardize assessments according to a consensus-buildings approach (Roy et al. 2014).

The evaluations are based on the experts' opinion, supported (when available) by evidences published in scientific and gray literature, reports on reliable internet forum (www.entomologiitaliani.net; www.naturamediterraneo.com) and consultation of additional specialists. Only species for which sufficient knowledge was available have been considered.

These expert-based assessments have been discussed in the frame of the last workshop (Rome, 7–8 March 2019) to ensure that the evaluation methods were consistent.

Species with potential impact on biodiversity score equal to MC were excluded by the analysis of the present work. For each species the following information are also recorded: taxonomic group (phylum, class, order, family), distribution in Italy (occasional: for species occasionally reported on Italian territory with no evidence of stable population in the wild; localized: for species with a localized distribution in one or more Italian regions; diffused: for species widespread in at least two Italian regions), native area (North America, South America, Europe, Africa, Asia, Oceania), worldwide distribution (number of continents in which the species occur), first record in Italy (refers to the year of first record publication or, when available, to the exact year of introduction), main introduction pathways (following the classification adopted by the Convention on Biological Diversity), reproduction strategies, diet. Due to their peculiar ecology, in this work we analyze separately the subfamily of bark and ambrosia beetles (Curculionidae Scolytinae) from the rest of Curculionidae in order to make the reading of the results more informative and detailed.

To sum up the previous information, we built a matrix "distribution × impact" in which Italian distribution of the species is compared with the magnitude of their potential impact on biodiversity. Through the combination between distribution and magnitude of impact, we ranked the species in four different priority categories: I = low priority, II = moderate priority, III = high priority, IV = very high priority) (Carboneras et al. 2018).

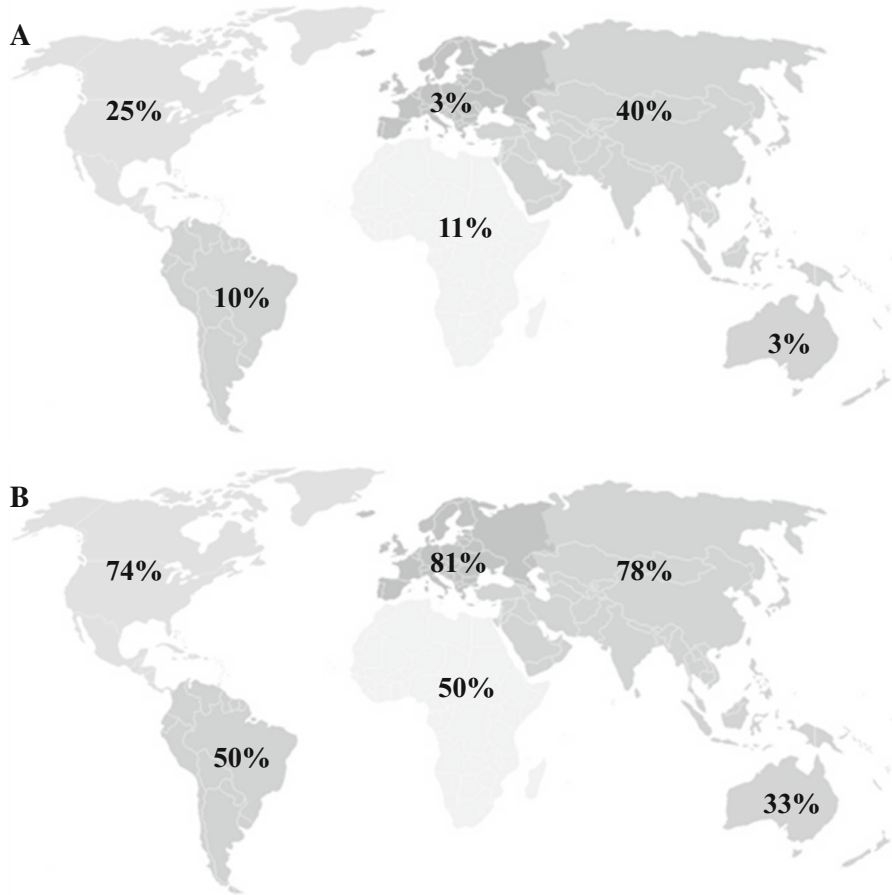

Fig. 4 **a** Percentage of the considered ATIS native to a continent. Native area is unknown in 8% of the species (cryptogenic species). **b** percentage of the considered ATIS present in a continent (both as alien and native; Italian records are excluded from this analysis). Total number of species: n = 109

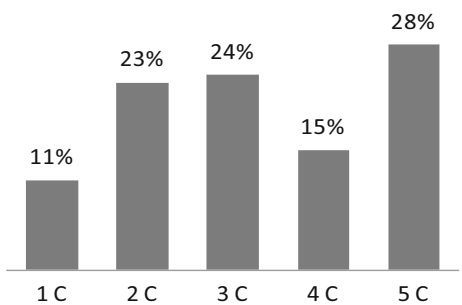

Fig. 5 Percentage of species widespread in one (1C) or more (2C–5C) of the five continents (Europe, Africa, Asia, Oceania, America; Italian records are excluded from this analysis). Total number of species: n = 109

Results

The list of Italian ATIS proposed in our work contains 109 species (Table 1). Ten of these are regulated under Directive 2000/29/EC. The majority of the species belongs to the phylum Arthropoda (82%), followed by Nematoda (13%), Platyhelminthes (4%) and Mollusca (2%). The most representative class is that of Insecta with 86 species (79% of the total) (Fig. 1). Within Insecta, the order Coleoptera represents 36% of the total, followed by Hymenoptera and Hemiptera (both 23%) (Fig. 2). The most abundant families among insects are those of Formicidae (14 species), Curculionidae Scolytinae (11 species) and Cerambycidae (7 species) (Fig. 3).

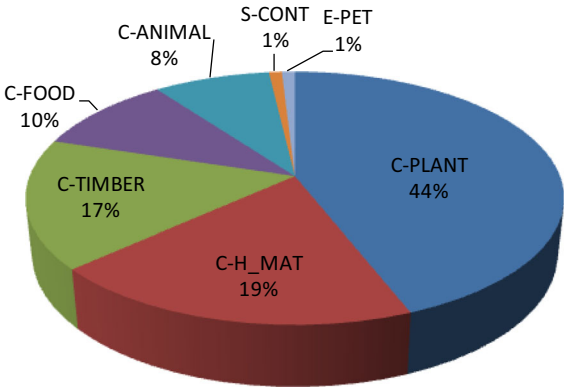

Fig. 6 Probable main introduction pathways of the assessed ATIS [E-PET = escape pets (pet/aquarium/terrarium species escapes unintentionally in nature), C-PLANT = contaminant on plants (unintentional introduction of live organisms as contaminants or parasites on plants or part of plants intentionally transferred through international trade), C-H_MAT = contaminant on habitat material (unintentional introduction of live organisms as contaminants of habitat material intentionally transferred through international trade e.g. soil), C-TIMBER = contaminant on timber (unintentional introduction of live organisms as contaminants in timber trade), C-FOOD = food contaminant (unintentional introduction of live organisms as contaminants on food intentionally transferred through international trade), C-ANIMAL = contaminant on animals (unintentional introduction of live organisms as contaminants or parasites of animal intentionally transferred through international trade), S-CONT = stowaway in containers (unintentional introduction of live organisms stowaway in containers or associated equipment)]. Total number of species: n = 109

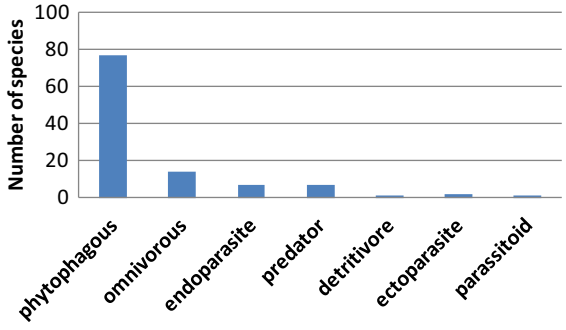

Fig. 7 Diet analysis of the most impacting life stage (larval or imaginal stage) of the species on biodiversity. Total number of species: n = 109

The magnitude of potential impact on biodiversity among assessed species is MN for 69 species, MO for 32 species, MR for 5 species (*Cinara cupressi*, *Harmonia axyridis*, *Lasius neglectus*, *Linepithema humile*, *Popillia japonica*) and MV for 3 species (*Colopterus abdominalis*, *Pheidole megacephala*, *Wasmannia auropunctata*). Species with highest score (MR and MV) belong to Coleoptera, Hymenoptera and Hemiptera.

The considered ATIS are widespread in at least two Italian regions in 42% of cases (D), 36% of the species have a localized distribution in one or more regions (L) and 22% of the species are occasionally reported on Italian territory (O).

Most of the listed species are native from Asia (40%), followed by North America (25%), Africa (11%), South America (10%), Europe (3%) and Oceania (3%) (Fig. 4a). Native range is unknown or uncertain for 8% of the species (cryptogenic species). However, only 11% of the total of ATIS is currently distributed just in its native continent (except for their introduction in Italy). The remaining have been introduced in more than one continent and 28% is widespread in all continents (except Antarctica) (Fig. 5).

Most of the selected ATIS occur in Asia (78% of the species) and North America (74%) (Fig. 4b). Moreover, 81% of the listed species are also reported in at least another European country (Fig. 4b).

More than half of selected species (54%) have been introduced in Italy in the last two decades. Except for the land snail *Achatina fulica*, all have been unintentionally introduced as contaminants in the international trade of organic and inorganic material (e.g. plants or part of plants, habitat material, wood, foods, animals, containers). The probable main pathway of introduction of the selected ATIS is the transport as contaminant on plants or part of plants (44%), followed by contaminant of habitat material (19%) and timber trade (17%) (Fig. 6).

Reproductive strategies of the species vary, in particular 19% of the species can be parthenogenetic and 4% may reproduce asexually.

Based on the diet of the most impacting life stage (adult or immature stage) of the species on biodiversity, we found the following proportions of feeding habits (Fig. 7): 71% phytophagous; 13% omnivorous, 8% parasites (6% vertebrates' endoparasites; 1% vertebrates' ectoparasites; 1% invertebrates' ectoparasites); 6% predators; 1% detritivores; 1% parasitoids (1 species, the tachinid fly *Trichopoda pennipes*).

Comparing the impact on biodiversity with the distribution status of the species in Italy, 49% of them belong to the priority category I, 39% to the category

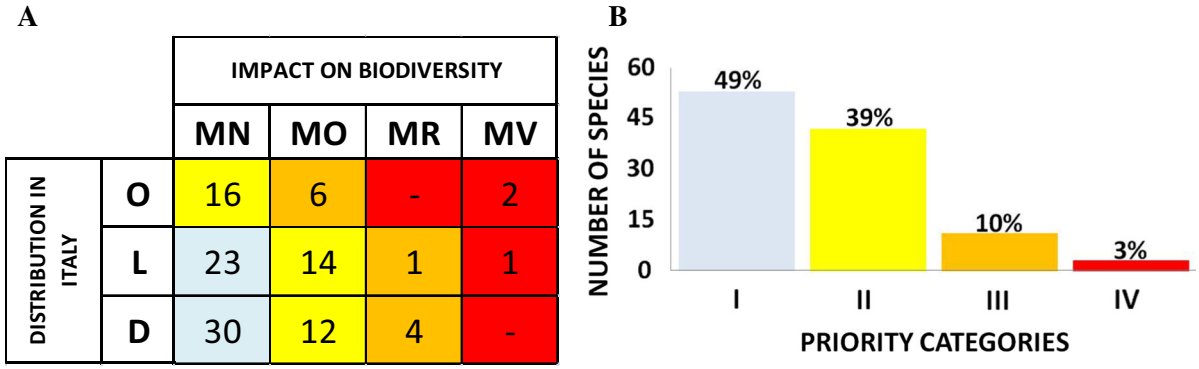

Fig. 8 **a** Matrix "distribution x impact" of the species. The number of species is shown in each box. Each priority category is marked with a different colour: category I (low priority) light blue, category II (moderate priority) yellow, category III (high priority) orange, category IV (very high priority) red [distribution in Italy: O = occasional, L = localized, D = diffused. Impact on biodiversity: MN = minor, MO = moderate, MR = major, MV = massive]. **b** percentage of species by priority category. Total number of species: n = 109

II, 10% to the category III and 3% to the category IV (Fig. 8).

Discussion

The list that we propose contains 109 species of the most relevant ATIS occurring in Italy, all having a possible negative impact on the native biodiversity. This list represents a starting point for the selection of species to be included in the Italian list of IAS of national concern and its future updating. As expected, during our work we have found a lack of information in the scientific literature about the impacts of ATIS on biodiversity (Kenis and Branco 2010): for this reason the collaboration among experts with a consensus-building approach has been essential (Roy et al. 2014; Hawkins et al. 2015; Carboneras et al. 2018).

As expected and highlighted in previous works, the main pathway for the introduction of ATIS is accidental (Roques et al. 2009; Saul et al. 2017). Almost half (44%) of the prioritized species have been introduced as contaminants in the live plants trade, which represents, followed by transport of habitat material and timber trade, the most common pathway of introduction of the listed species. However to define all the vectors of introduction of a species is very complex and in this work we considered the hypothetical main pathway of introduction derived from scientific evidences and species' biology. The number of introduced insect species in Italy (which represent 79% of the selected ATIS) has a linear trend of about 10 new species per year since the Second World War (Inghilesi et al. 2013), but more than a quarter of the considered ATIS have been introduced in Italy during the decade 2008-2018. It is evident that there is the necessity to improve the systems of control to prevent the introduction of species across the borders as aimed by the recent EU policy (Genovesi et al. 2015). Moreover, as a result of globalization, the worldwide presence of 89% of the assessed ATIS is extended to at least two continents, increasing the probability of involuntary reintroduction via global trade (Hulme 2009; Seebens 2019).

When prevention fails, eradication through early warning and rapid response is the best option to avoid the spread of an alien species (Genovesi et al. 2015). For this reason, the EU Regulation 1143/2014 provides for the development of a surveillance system for invasive alien species in order to allow early detection and rapid eradication of these species at an early stage of invasion. This type of approach may be applied in 22% of the selected ATIS which have an occasional or localized distribution in Italy. For the remaining most spread species, according to the Regulation, management measures should be applied in order to eradicate them or at least to avoid their further spread (EU Regulation 1143/2014). In particular we assume that species ranked in III and IV category of priority required urgent risk assessment and management measures, due to their potential impact on biodiversity and distribution in Italy.

The ATIS list here proposed aims to meet the Article 5 of the Legislative Decree No 230/2017,

giving a subset of 109 species out of the total of over thousand alien invertebrate species reported in Italy (Zapparoli unpublished). Such preliminary prioritized list represents a first expert-based reference for the establishment of a list of IAS of Italian concern.

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References

Bellard C, Cassey P, Blackburn TM (2016) Alien species as a driver of recent extinctions. Biol Lett 12:20150623

Beninde J, Fischer ML, Hochkirch A, Zink A (2015) Ambitious advances of the European Union in the legislation of invasive alien species. Conserv Lett 8:199–205

Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Marková Z, Mrugała A, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Wilson JRU, Winter M, Genovesi P, Bacher S (2014) A unified classification of alien species based on the magnitude of their environmental impacts. PLoS Biol 12:e1001850

Bradshaw CJA, Leroy B, Bellard C, Roiz D, Albert C, Fournier A, Barbet-Massin M, Salles J, Simard F, Courchamp F (2016) Massive yet grossly underestimated global costs of invasive insects. Nat Commun 7:12986

Carboneras C, Genovesi P, Vilà M, Blackburn TM, Carrete M, Clavero M, D'hondt B, Orueta JF, Gallardo B, Geraldes P, González-Moreno P, Gregory RD, Nentwig W, Paquet J, Pyšek P, Rabitsch W, Ramírez I, Scalera R, Tella JL, Walton P, Wynde R (2018) A prioritised list of invasive alien species to assist the effective implementation of EU legislation. J Appl Ecol 55:539–547

Convention on Biological Diversity COP 6 Decision VI/23 (2002) Alien species that threaten ecosystems, habitats or species. http://www.cbd.int/decision/cop/?id=7197. Accessed 24 April 2019

Courchamp F, Fournier A, Bellard C, Bertelsmeier C, Bonnaud E, Jeschke JM, Russell JC (2017) Invasion biology: specific problems and possible solutions. Trends Ecol Evol 32:13–22

Genovesi P, Carboneras C, Vila M, Walton P (2015) EU adopts innovative legislation on invasive species: a step towards a global response to biological invasions? Biol Invasions 17:1307–1311

Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilà M, Wilson JRU, Genovesi P, Rabitsch W (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Divers Distrib 21:1360–1363

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. J Appl Ecol 46:10–18

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Solarz W, Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. J Appl Ecol 45:403–414

Inghilesi AF, Mazza G, Cervo R, Gherardi F, Sposimo P, Tricarico E, Zapparoli M (2013) Alien insects in Italy: comparing patterns from the regional to European level. J Insect Sci 13:73

Jeschke JM, Bacher S, Blackburn TM, Dick JTA, Essl F, Evans T, Gaertner M, Hulme PE, Kühn I, Mrugała A, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Winter M, Kumschick S (2014) Defining the impact of non-native species. Conserv Biol 28:1188–1194

Kenis M, Branco M (2010) Chapter 5: impact of alien terrestrial arthropods in Europe. BioRisk 4:51–71. https://doi.org/10.3897/biorisk.4.42

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

Maxwell SL, Fuller RA, Brooks TM, Watson JE (2016) Biodiversity: the ravages of guns, nets and bulldozers. Nat News 536:143–145

Nentwig W, Josefsson M (2010) Introduction. Chapter I. BioRisk 4:5–10. https://doi.org/10.3897/biorisk.4.43

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: DAISIE (ed) Handbook of alien species in Europe, vol 3. Springer, Dordrecht, pp 63–79

Roy HE, Roy DB, Roques A (2011) Inventory of terrestrial alien arthropod predators and parasites established in Europe. Biocontrol 56:477–504

Roy HE, Peyton J, Aldridge DC, Bantock T, Blackburn TM, Britton R, Clark P, Cook E, Dehnen-Schmutz K, Dines T, Dobson M, Edwards F, Harrower C, Harvey MC, Minchin D, Noble DG, Parrott D, Pocock MJO, Preston CD, Roy S, Salisbury A, Schönrogge K, Sewell J, Shaw RH, Stebbing P, Stewart AJA, Walker KJ (2014) Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain. Glob Change Biol 20:3859–3871

Saul WC, Roy HE, Booy O, Carnevali L, Chen HJ, Genovesi P, Harrower CA, Hulme PE, Pagad S, Pergl J, Jeschke JM

(2017) Assessing patterns in introduction pathways of alien species by linking major invasion data bases. J Appl Ecol 54:657–669

Seebens H (2019) Invasion ecology: expanding trade and the dispersal of alien species. Curr Biol 29:120–122

Shine C, Kettunen M, Genovesi P, Essl F, Gollasch S, Rabitsch W, Scalera R, Starfinger U, ten Brink P (2010) Assessment to support continued development of the EU Strategy to combat invasive alien species. Final Report for the European Commission. Institute for European Environmental Policy (IEEP), Brussels

Strayer DL (2012) Eight questions about invasions and ecosystem functioning. Ecol Lett 15:1199–1210