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Advancing research on alien species and biological invasions

The Alien to Cyprus Entomofauna (ACE) database: a review of the current status of alien insects (Arthropoda, Insecta) including an updated species checklist, discussion on impacts and recommendations for informing management

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Abstract

Alien insects represent one of the most species rich groups of organisms introduced to Europe, with some responsible for adverse social-economic, human-health, biodiversity and ecosystem impacts. The impacts of invasive alien species, especially on island ecosystems, have been a hot topic of research worldwide. Cyprus is a Mediterranean island at the biogeographic crossroads of Asia, Africa and Europe. This study presents the database of the alien insects of the island of Cyprus as a whole, created through an extensive review including grey literature and online sources. The Alien to Cyprus Entomofauna (ACE) triples the known number of alien insects and adds supplemental information to existing species. Data concerning a total of 349 alien insects are presented alongside an updated checklist and recommendations for informing management. The status of alien insects on the island, their origin, trophic guilds, establishment, pathways of introduction and impacts are discussed. Developing an alien species inventory for the island is challenging due to its geographic position and the increasing movement of people and goods leading to new species introductions. This publication constitutes an important first step towards providing information for effective actions to tackle invasive alien insects on Cyprus. The checklist and accompanying information can underpin understanding of the status and trends of alien species including providing information for risk assessments. ACE will continue to be maintained and updated as new records for Cyprus are made.

Keywords
biological invasions, CyDAS, exotic species, invasive alien species, island invasions, Mediterranean, non-native species

Introduction

The number of alien species across the world is increasing and showing no signs of saturation (Seebens et al. 2017, 2020; Seebens 2019). The present number of documented alien (non-native or exotic) species in Europe is approximately 14,000, one fifth of which are insects (EASIN 2021). A proportion of alien species are categorised as invasive because they threaten native biodiversity and ecosystem services and/or negatively affect human health, society and economy (Mazza and Tricarico 2018; Haubrock et al. 2021). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), invasive alien species have been identified as one of the five main direct drivers of biodiversity change alongside land- and sea-use changes, exploitation of natural resources, climate change and pollution (IPBES 2019; Bellard et al. 2022). The economic cost of biological invasions in Europe, from 1960 to 2020, has been estimated to exceed €116.61 billion euros, despite the evident lack of data for many invasive alien species, urging for a comprehensive appraisal of costs (Haubrock et al. 2021).

The impact of biological invasions on island communities has received considerable attention (Reaser et al. 2007; Russell et al. 2017), with invasive alien species having severe adverse consequences on the evolutionary histories and extinction rates of island species (Mooney and Cleland 2001). Biogeographic research on island biological invasions has highlighted that there are higher numbers of alien species per area unit on islands compared to the mainland (Yamanaka et al. 2015; Dawson et al. 2017) and the number of alien species increases with degree of island isolation in contrast to the number of native species (Moser et al. 2018). It is predicted that there will be an increase in the introduction of alien species during the following decades, mainly driven by social-economic activities (e.g. trade and tourism) facilitating the arrival of stowaways and contaminants (Lenzner et al. 2020; Pergl et al. 2020).

The island of Cyprus is situated at the eastern Mediterranean Sea and bordered by three continents. Its socio-political background has resulted in the classification of the island sometimes as a part of Europe (being part of the European Union) and its geographical position as a Middle Eastern or Western Asian country. The first human-mediated introduction of organisms to the island dates back to 10,500–9000 BC, when the first settlers introduced to Cyprus economically important fauna (i.e. livestock and game animals) as well as horticultural flora (Zeder 2008). The proximity of the island to three continents, the continuous trade over millennia and the global increase in the import of goods and movements of people (Hulme 2009; Demesticha 2019; Seebens 2019), provide opportunities for alien species to arrive in Cyprus (Seebens et al. 2018) and contribute to the challenges for Cyprus in tackling biological invasions.

The alien insect fauna of the island was first documented through DAISIE (2009) and Roques et al. (2010), which reported 114 "confirmed alien" and "cryptogenic" species. In 2020, this number was supplemented by Martinou et al. (2020) reaching a total of 123 species, through the development of the Cyprus Database of Alien Species (CyDAS – www.ris-ky.info/cydas). However, this number was considered to be a significant underestimate, given the species richness of insects. Thus, the need for the compilation and construction of an up-to-date database integrating data from various sources was identified. The Alien to Cyprus Entomofauna (ACE) database provides information on alien insects of the island of Cyprus, subsequently contributing data to the CyDAS.

Materials and methods

Species checklists and databases compiled by DAISIE (2009), Roques et al. (2010), Martinou et al. (2020) and EASIN (2021) were used as a foundation for the database which was extended through a literature survey for records of alien insects in Cyprus. Records of alien species in Cyprus were searched through Google Scholar using the keywords "species name" and "Cyprus". Data were extracted from peer-reviewed journal articles [e.g. Wood (1963); Háva et al. (2010); Collins and Philippou (2016); Salata et al. (2019); Davranoglou et al. (2020, 2021)], reviews [e.g. Greathead (1976)], institutional reports [e.g. FAO (1996); EPPO (1997)], books and book chapters [e.g. Georghiou (1977); Gerber and Schaffner (2016); Sparrow and John (2016)], as well as online sources [e.g. Srour (2013); Fägerström (2021)]. Literature surveys were completed on 31 December 2021.

The status of species was assessed as either "confirmed alien species" or "cryptogenic", with the latter term referring to taxa of unknown origin, neither demonstrably native nor introduced (Carlton 1996). A third category labelled "questionable" was used following EASIN (2021), addressing species whose status should be further investigated. Ten species were added to this category, including species regarded as native to Northern Africa, the Middle East or Western Asia which have not been knowingly introduced to the island such as the beetle *Coccotrypes dactyliperda* (Fabricius, 1801) (Georghiou 1977; Spennemann 2019), the hemipteran *Jacobiasca lybica* (Bergevin & Zanon, 1922) (Georghiou 1977), the dipteran *Pseudodoros nigricollis* Becker, 1903 (van Eck and Makris 2016; André van Eck pers. comm.), the lepidopteran *Dichelia cedricola* (Diakonoff, 1974) (Gatzogiannis et al. 2010) and the hymenopterans *Xylocopa* (*Koptortosoma*) *pubescens* Spinola, 1838 (Varnava et al. 2020), *Aphytis coheni* DeBach, 1960 (Wood 1963), *Diversinervus elegans* Silvestri, 1915 (Orphanides 1988), *Microterys nietneri* (Motschulsky, 1859) (Wood 1963), *Scutellista caerulea* (Fonscolombe, 1832)

(Georghiou 1977; Gerber and Schaffner 2016) and *Vespula germanica* (Fabricius, 1793) (Morris 1937).

Occasional migrants (mainly Lepidoptera and Orthoptera), i.e. lepidopterans *Spoladea recurvalis* (Fabricius, 1775) (De Prins 2005; Lopez-Vaamonde et al. 2010), *Catopsilia florella* (Fabricius, 1775) (John et al. 2019) and *Danaus chrysippus* (Linnaeus, 1758) (Georghiou 1977; Lopez-Vaamonde et al. 2010), as well as orthopterans *Locusta migratoria* (Linnaeus, 1758) and *Schistocerca gregaria* Forsskål, 1775 (Rasplus and Roques 2010; Siedle et al. 2016), were excluded. In addition, species treated by various databases as alien to Europe (Roques et al. 2010; EASIN 2021), but were found to be native to Cyprus, were also excluded. These species were *Acheta domesticus* (Linnaeus, 1758) native to south-western Asia (Rasplus and Roques 2010; Siedle et al. 2016), the northern African aphid *Cinara cedri* Mimeur, 1936 (Coeur d'Acier et al. 2010) represented by the endemic subspecies *Cinara cedri brevifoliae* A.Binazzi, 2017 (Binazzi et al. 2017) and two Asian chalcid wasps, *Aphidius colemani* Viereck, 1912 and *Megastigmus schimitscheki* Novitzky, 1954 (Rasplus et al. 2010; Auger-Rozenberg et al. 2012; Gerber and Schaffner 2016).

The native range of a species was assigned according to biogeographic realms (Udvardy 1975; Snow and Perrins 1998), including species native to tropical and subtropical regions in a category derived verbatim from Roques (2010). In cases of species native to multiple biogeographic realms, all biogeographic realms were documented. Species of "cryptogenic" and "questionable" status were excluded. This treatment was recently applied in a similar publication for the alien insects of Greece (Demetriou et al. 2021). Species were assigned to broad trophic guilds covering phytophagous, detritivorous, parasitic and predatory insects (Roques et al. 2010). Phytophagous insects were subsequently categorised in the following classes considering their main feeding patterns: pollinators, leaf miners, gallers (including leaf- and seed gall-inducers), insects with chewing mouthparts (feeding on flowers, stems, leaves and soft tissues), insects with sucking mouthparts (taxa with sucking mouthparts, feeding on sap) and wood feeders (wood borers and xylem eating insects).

The establishment status was assessed as follows: "Established" (sustaining populations on the island); "Failed to establish" (unintentionally introduced, but failed to establish); "Released, but failed to establish" (intentionally released, but failed to establish); "Eradicated" (confirmed eradication); "Doubtful" (species potentially wrongly identified or records regarded dubious); and "Unknown" (establishment status could not be assigned because of lack of data or species or reported only once). Establishment status was assessed through literature surveys as well as species occurrences by citizen-scientists in the iNaturalist collection project "Alien to Cyprus Entomofauna" (https://www.inaturalist.org/projects/alien-to-cyprus-entomofauna) (iNaturalist 2022), the Global Biodiversity Information Facility (GBIF 2022) and the authors.

Intentional introductions (releases) of biological control agents to the island were catalogued, reporting on their taxonomy, import year, establishment status and recorded impacts on target and non-target species. A preliminary assessment of recorded and inferred impacts of alien insects in Cyprus, was undertaken according to the categories devised by Kenis and Branco (2010). Specifically, we analysed environmental and socio-economic impacts, with the latter category being further divided into alien insects identified as "Outdoor agricultural and horticultural pests", "Pests of protected horticulture", "Stored product and infrastructure pests", "Forestry and urban tree pests", "Arthropods affecting human and animal health", as well as "Arthropods with a positive economic impact". In cases where no impacts were recorded or data were insufficient for a robust classification, species were treated as data deficient. Species which displayed both positive and negative impacts or could be assigned into more than one subcategories of negative socio-economic impact, were assigned accordingly in all applicable impact subcategories.

Results

Biodiversity and species richness

According to the literature search, a total of 349 alien species were identified (Suppl. material 1), distributed within 261 genera and 97 insect families (Fig. 1). The current number of alien insects of Cyprus has tripled (204% increase) since their first treatment (DAISIE 2009; Roques et al. 2010; Martinou et al. 2020). Out of these species, only one can be found in the EPPO A1 list of pests recommended for regulation as quarantine pests, namely *Spodoptera litura* (Fabricius, 1775), while 12 can be found in the EPPO A2 list (Suppl. material 1).

Status

Of the total number of species, most of them are "confirmed alien species" to the island (242 species = 69%), while more than one fourth (97 species = 28%) are "cryptogenic" and ten species (3%) were classified as "questionable" (Fig. 2).

Origin

The largest percentage of "confirmed alien" insect species originates from the Indomalayan biogeographic realm (29%), followed by the Eastern Palearctic (15%). Each of the Afrotropical and Australian realms contribute 14% of "confirmed alien species". Nearly one fifth of "confirmed alien species" originate from the New World, being native to the Neotropical (12%) and Nearctic (10%) realms. Species originating from the tropics and subtropics (4%), as well as "confirmed alien species" within the Western Palearctic (3%), had the lowest representation within the dataset (Table 1).

Trophic guilds

Almost half of the alien insects in Cyprus are classified as phytophagous (48%). Almost one in four are detritivores (24%), while the remaining quarter accounts for parasites, parasitoids (grouped) (17%) and predators (11%) (Fig. 3). Only one species, the ant-

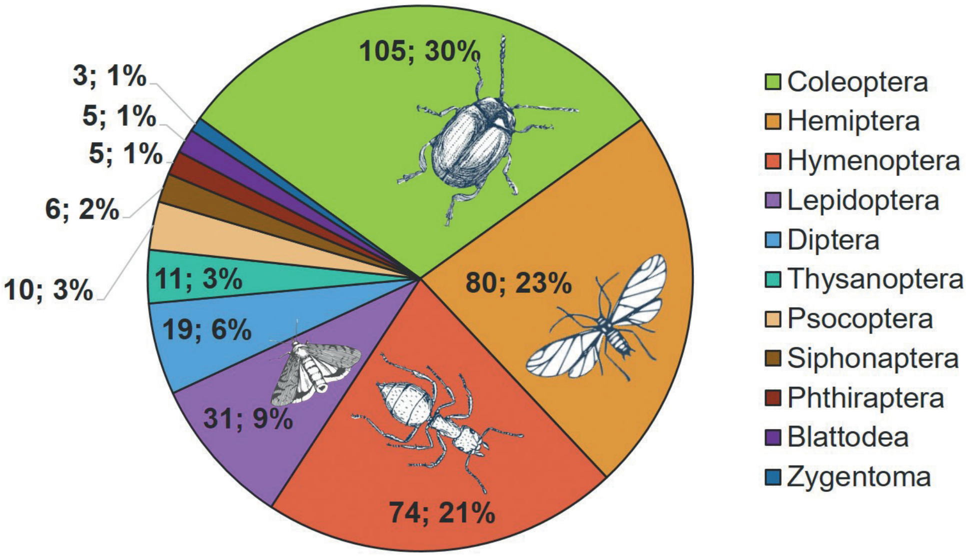

Figure 1. Number and percentage of alien insect species by order detected in Cyprus.

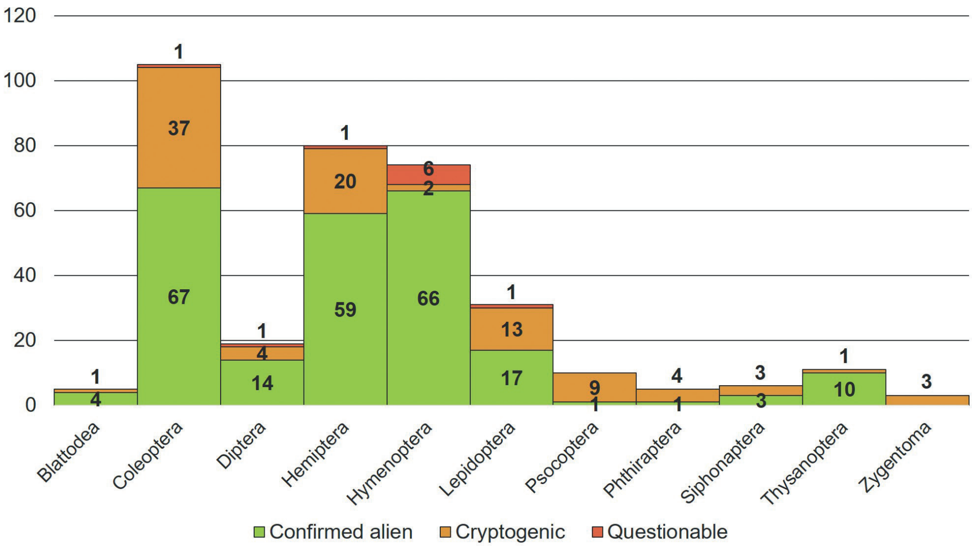

Figure 2. Status of alien insects species by order detected in Cyprus, classified as "confirmed alien" (truly demonstrated to be non-native to Europe and Cyprus), "cryptogenic" (species of unknown origin) and "questionable" (species whose status should be further investigated).

like beetle *Anthicus crinitus* La Ferté-Sénectère, 1849 was recorded as of unknown feeding habits (Denux and Zagatti 2010) and was subsequently excluded from the analysis.

Phytophagous alien insects were further classified into six functional groups (Table 2). Half of the represented phytophagous insects have sucking mouthparts,

Table 1. Origin [regions classified following Udvardy (1975) and Snow et al. (1998)] of orders of alien insects of Cyprus, excluding "cryptogenic" and "questionable" species.

	Western Palearctic	Eastern Palearctic	Afrotropical	Indomalayan	Australian	Nearctic	Neotropical	Tropical / Subtropical
Blattodea	0	1	2	1	0	0	0	0
Coleoptera	3	12	10	22	9	4	9	6
Diptera	0	1	6	0	1	5	1	0
Hemiptera	1	15	6	17	5	9	11	4
Hymenoptera	3	11	12	29	20	6	9	0
Lepidoptera	0	3	2	8	4	1	3	0
Psocoptera	0	0	0	0	0	0	0	1
Phthiraptera	0	0	0	0	0	0	1	0
Siphonaptera	1	0	1	0	0	0	0	1
Thysanoptera	0	0	1	3	1	3	1	1
Zygentoma	0	0	0	0	0	0	0	0
Total	8	43	40	80	40	28	35	13

Table 2. Number of phytophagous alien species (within insect orders) within different functional groups.

	Chewers	Gallers	Leaf miners	Pollinators	Suckers	Wood feeders
Coleoptera	31	0	0	0	0	10
Diptera	6	0	4	0	0	0
Hemiptera	0	0	0	0	78	0
Hymenoptera	1	9	0	5	0	0
Lepidoptera	16	0	4	0	0	1
Thysanoptera	0	0	0	0	7	0
Total	54	9	8	5	85	11
Total (%)	31	5	5	3	50	6

predominantly Hemiptera (92%) and some Thysanoptera (8%). Almost one third chew on leaves, stems and other soft tissues, mostly Coleoptera (57%) and Lepidoptera (30%). All leaf-, seed-gallers and pollinators are hymenopterans, whereas leaf-miners are equally divided between Diptera (Cecidomyidae) and Lepidoptera (Gelechiidae and Gracillariidae). Lastly, the majority of wood-feeding insects were from the order Coleoptera with just one moth from the family Castniidae (Table 2, Fig. 3).

Establishment status

Overall, most of alien insects (70%) seem to have established (producing viable, self-reproducing populations) on the island. Only two species, *Octodonta nipae* (Maulik, 1921) and the yellow fever mosquito *Aedes aegypti* Linnaeus, 1762 are considered to have been eradicated (1%). The Groundnut bruchid *Caryedon serratus* (Olivier, 1790) and the mango seed weevil *Sternochetus mangiferae* (Fabricius, 1775) were unintentionally introduced, but failed to establish (1%). The red scale parasitic wasp *Aphytis holoxanthus* DeBach, 1960 was intentionally released, but failed to establish and nine

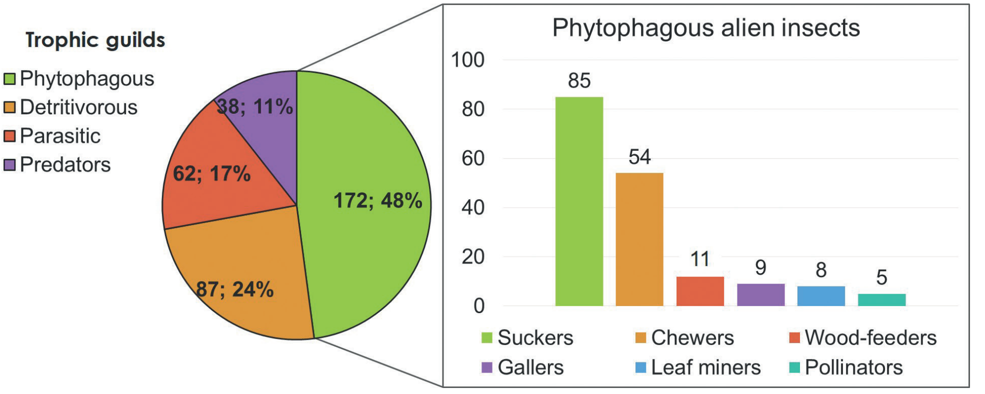

Figure 3. Trophic guilds of alien insects of Cyprus. The number of species and their percentages are shown on the pie chart. Further information on phytophagous insects and their classification is provided in the box depicting the overall number of species in each ecofunctional group.

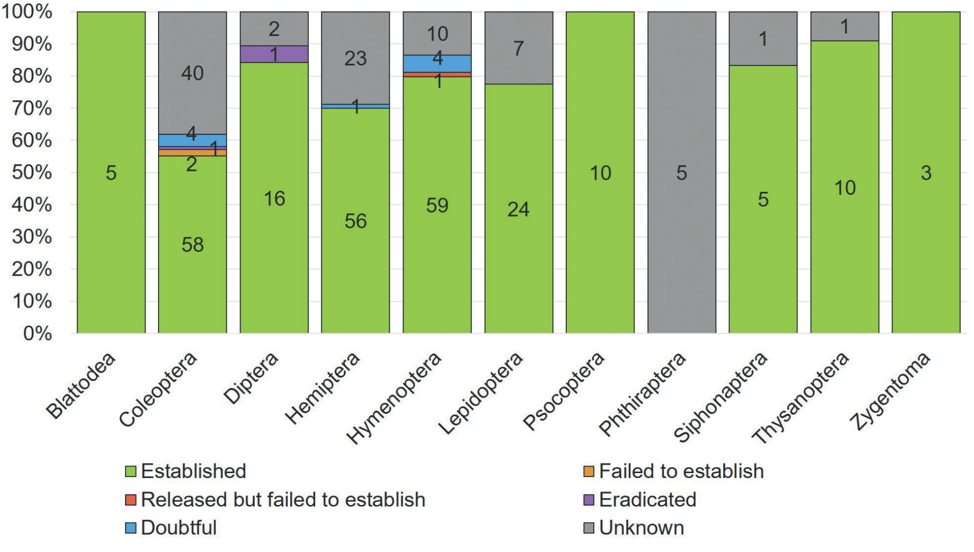

Figure 4. Number and percentage of alien insect species by order detected in Cyprus according to their establishment status, classified as "established" (sustaining populations on the island); "failed to establish" (unintentionally-introduced, but failed to establish); "released, but failed to establish" (intentionally released, but failed to establish); "eradicated" (confirmed eradication); "Doubtful" (species potentially wrongly identified or records regarded dubious); and "Unknown" (establishment status could not be assigned because of lack of data or species or reported only once).

species (3%) are considered doubtful or dubious. More information regarding their establishment status is given below. Nevertheless, information about the establishment of more than one quarter of alien insects (25%) remains unknown (Fig. 4).

Intentional introductions – Biological control agents

Collectively, 32 alien biological control agents of crop pests have been intentionally introduced to Cyprus, accounting for approximately 9% of all alien insects, comprising five alien Coleoptera (16%) and 27 Hymenoptera (84%). Within the Hymenoptera, 17 species (63%) belong to the superfamily Chalcidoidea, nine (33%) to Ichneumonoidea and one species (4%) to the family Vespidae (Suppl. material 2).

Of the total species list, 26 species (81%) have established populations on the island. *Aphytis holoxanthus*, a parasitoid released for the control of scale insects, failed to establish soon after its import and release (Greathead 1976). The establishment status of four species (13%) is unknown. The presence of *Cirrospilus ingenuus* Gahan, 1932, parasitoid of citrus leaf miners, is considered doubtful being catalogued both as established, as well as not established (Gerber and Schaffner 2016).

Most of the introduced biological control agents have been released for control of pests in citrus (59%), potato (30%) and olive (9%) pests (Fig. 5). A single record suggesting the introduction of the yellow jacket *Vespula germanica* to the island (Morris 1937) needs confirmation. Half of these biological control agents were imported to the island during the decade 1951–1960, against potato and citrus pests (Fig. 5). From the

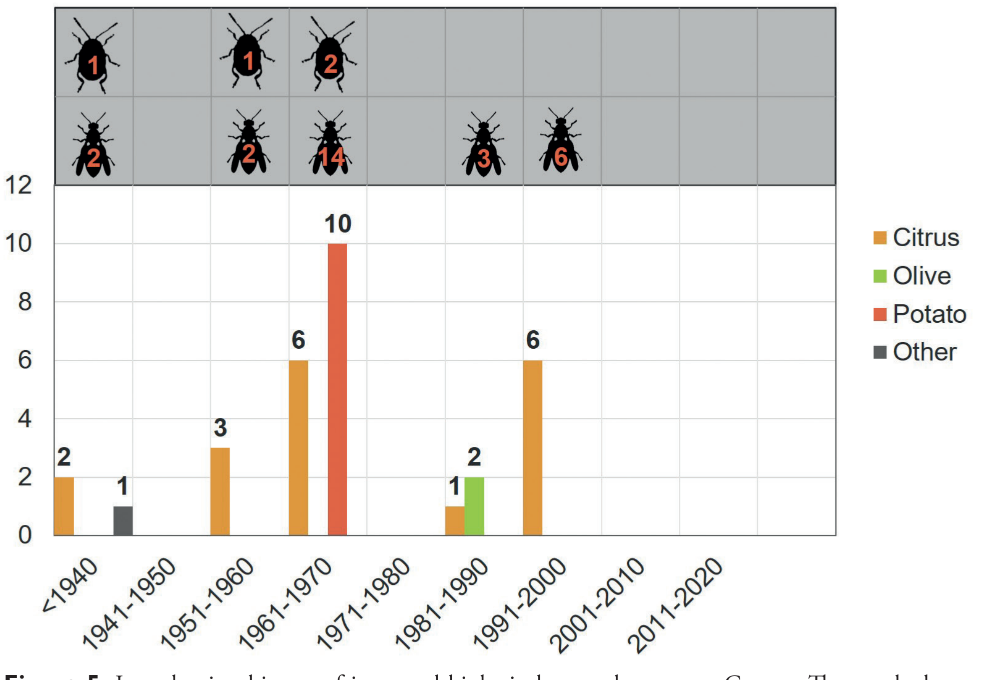

Figure 5. Introduction history of imported biological control agents to Cyprus. The graph shows the number of species per decade released to control citrus, olive, potato and other pests. The number of Coleoptera and Hymenoptera species introduced during each decade are shown in the box over the graph.

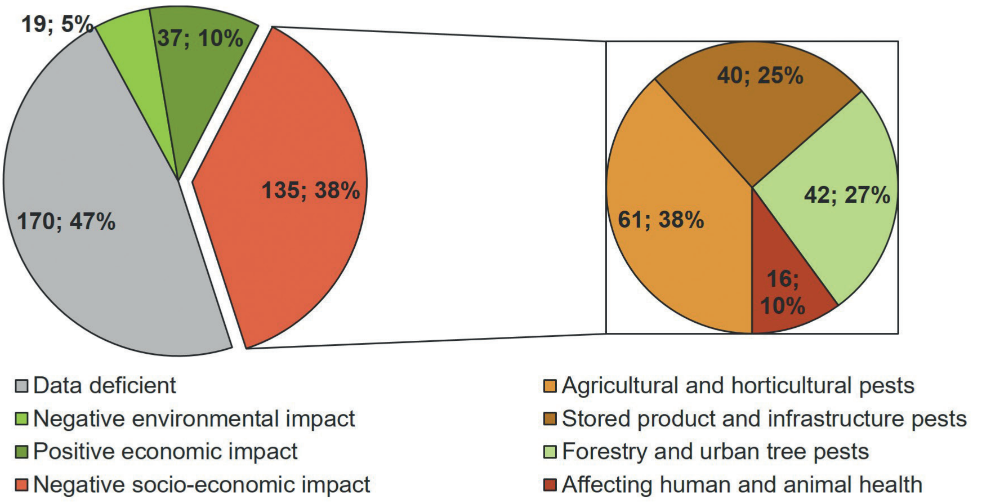

Figure 6. Known registered impacts of alien insects in Cyprus. The number of species classified as data deficient, having positive economic or negative environmental or socio-economic impacts, as well as their percentage are shown in the left pie chart. Negative socio-economic impacts are further divided into alien insects identified as "Outdoor agricultural and horticultural pests", "Pests of protected horticulture", "Stored product and infrastructure pests", "Forestry and urban tree pests" and "Arthropods affecting human and animal health" (right pie chart). The total number of species in this figure does not total to 349 as species displaying both positive and negative impacts or that could be assigned to more than one subcategories of negative socio-economic impacts.

searches conducted to date, it appears that there have been no official records of biological control agents intentionally released into the wild since the beginning of the 21st century. The introduction year of *Rhyzobius forestieri* (Mulsant, 1853), Forestier's ladybird, is unknown. Although Gerber and Schaffner (2016) cite an annual report of the Cyprus Agricultural Research Institute published in 1984, Orphanides (1988) does not mention the species in his article as a biological control agent of *Saissetia oleae* (Olivier, 1791) in Cyprus. Thus, the presence of *R. forestieri* on the island is considered dubious.

Impacts

Only 19 species (5% of total alien insects in Cyprus) were identified as invasive alien species, having negative impacts upon biodiversity and ecosystem functions (Fig. 6). Thirty-seven species (10%) had a positive socio-economic impact, negatively affecting invasive alien host-animal or -plant species, being pollinators or contributing towards the biological control of injurious or alien pest species. The majority of species with recorded negative impacts affected socio-economic parameters (135 species – 38%). These species were predominantly "agricultural and horticultural pests" (61 species – 38%), "forestry and urban tree pests" (42 species – 27%), "stored product and infrastructure pests" (40 species – 25%) and "insects affecting human and animal health" (16 species – 10%) (Fig. 6).

Most of the alien insects of Cyprus (170 species – 47%) were catalogued as data deficient due to the lack of studies addressing their impacts, the lack of observed impacts or the low quality of evidence for impacts (Fig. 6).

Discussion

Biodiversity and species richness

Coleoptera represent the most species-rich order of alien insects on Cyprus comprising more than 100 alien species (Fig. 1). Five families of Coleoptera, namely Nitidulidae (10%), Dermestidae (10%), Chrysomelidae (10%), Ptinidae (10%) and Curculionidae (9%), contain almost half of the alien beetles found in the island. These families include solely detritivores and phytophagous species found in stored products, such as the carpet beetles *Trogoderma granarium* Everts, 1898 and *Trogoderma versicolor* (Creutzer, 1799), the seed beetles *Bruchus rufimanus* Bohemann, 1833 and *Callosobruchus chinensis* (Linnaeus, 1758), as well as representatives of the genus *Sitophilus* Schoenherr, 1838 (Morris 1937; Georghiou 1977). Interestingly, the only references to *Sitophilus sculpturatus* (Gyllenhal, 1838) in Europe concern Cyprus nearly a century ago, when the species was reared from *Eugenia jambolana* (L.) Skeels seeds imported from South Africa (Morris 1937; Georghiou 1977). Nitidulids have been identified both as herbivores and detritivores feeding on ripe and rotten fruit (Georghiou 1977; Jelínek et al. 2016). In addition, these families include some easily detectable major pests of ornamental plants, such as the destructive red palm weevil *Rhynchophorus ferrugineus* (Olivier, 1790) (Kontodimas et al. 2006), but also the leaf beetle *Chrysolina americana* (Linnaeus, 1758), found damaging five aromatic Lamiaceae, including three species native to the island (Hadjiconstantis and Zoumides 2021). Despite the small body size of most species in the aforementioned families, their predominance in the list of alien Coleoptera may well be attributed to their peridomestic lifestyle and negative economic impacts on stored products, crops and ornamentals which reinforce the need for studies addressing their identification and approaches for mitigation of their negative impacts.

As is the case with Greece (Demetriou et al. 2021), Hemiptera are predominantly represented by scale insects (Coccoidea) (44%), followed by aphids (28%) and whiteflies (10%). The high numbers of alien Sternorrhyncha are strongly correlated to their unintentional transport as contaminants on infested plant material (Rabitsch 2010a), but also biological traits facilitating successful biological invasions, such as their minuscule body size, their ability to reproduce both through parthenogenesis and sexual reproduction, as well as their high fecundity (Coeur d'Acier et al. 2010; Pellizzari and Germain 2010). Furthermore, their host plants range includes a wide variety of economically important species increasing detection probabilities (Coeur d'Acier et al. 2010), although their ability to exploit "hidden" microhabitats (e.g. undersides of leaves, shoot and bark crevices) hinder their interception during phytosanitary inspections (Pellizzari and Germain 2010). Improving phytosanitary measures and quarantine inspections, while recognising the challenges, may minimise the import of alien Hemiptera to the island as most species have been associated with common alien ornamental and agricultural plants (Georghiou 1977; Şişman and Ülgentürk 2010; Ülgentürk et al. 2015).

The superfamily Chalcidoidea, holds 71% of all recorded alien hymenopterans. The superfamilies Ichneumonoidea and Formicoidea follow, accounting for 14% and 12% of species, respectively. More than one third of alien Hymenoptera have been intentionally introduced to the island. Introduction pathways of the remaining Hymenoptera are currently unknown and most probably reflect unintentional introduction alongside their hemipteran hosts [e.g. *Psyllaephagus bliteus* Riek, 1962, an Australian parasitoid of the red gum lerp psyllid *Glycaspis brimblecombei* Moore, 1964; (Karaca et al. 2017)] or host plants [e.g. *Pleistodontes imperialis* Saunders, 1882, a mutualistic pollinator of Australian *Ficus rubiginosa* Desf. & Vent.; (Compton et al. 2020a)]. Nine species of alien ants have been collected from Cyprus, including the dubious records (possible misidentifications) of *Cardiocondyla nuda* (Mayr, 1866) (Bernard 1956), *Trichomyrmex destructor* (Jerdon, 1851) and the fire ant *Solenopsis geminata* (Fabricius, 1804) (Georghiou 1977; Collingwood et al. 1997; Salata et al. 2019). According to Salata et al. (2019), the Pharaoh ant *Monomorium pharaonis* (Linnaeus, 1758), *Nylanderia jaegerskioeldi* (Mayr, 1904) and the fire ant *S. geminata* are responsible for the elimination of native species within invaded habitats due to the aggressive behaviour of the invasive ants. Although the fire ant *S. geminata* is only known from an old, possibly erroneous literature record, Cyprus is stated to be within the species' known distribution (Collingwood et al. 1997; Dr Christos Georgiadis, pers. comm.).

All but one of the alien Lepidoptera are moths, with half of species falling under Pyralidae (19%), Gelechiidae (16%) and Tineidae (16%). These families include minute species commonly identified as stored product and household pests, such as the snout moths *Corcyra cephalonica* (Stainton, 1866) and *Ephestia elutella* (Hübner, 1796) and gelechiid moths *Pectinophora gossypiella* (Saunders, 1844) and *Sitotroga cerealella* (Olivier, 1789) (Morris 1937; Georghiou 1977). The sole exception is *Papilio demoleus* Linnaeus, 1758, a large alien butterfly reported only recently from Cyprus, but its impact on native biodiversity is still unknown (John et al. 2021, 2022).

Status

Due to the geographic location of Cyprus, surrounded by Europe, Africa and Asia and the lack of literature data, the status of ten species was treated as "questionable" (Fig. 2). The soldier fly *Pseudodoros nigricollis* is believed to be native to the East Mediterranean and Afrotropics (van Eck and Makris 2016; André van Eck, pers. comm.). The recent discovery of the species on the island and the general lack of knowledge surrounding the distribution of Syrphidae in the Near East pose difficulties in assessing the native or "alien" status of *P. nigricollis* in Cyprus (André van Eck, pers. comm.). In addition, the "cryptogenic" status of its associate host *Hyalopterus pruni* (Geoffroy, 1762) and its observed relationship with both native (*Phragmites australis* and *Prunus* spp.) and alien host plants (*Musa* sp.), further complicate this assessment (André van Eck, pers. comm.). The date stone beetle, *Coccotrypes dactyliperda*, has been regarded as alien to Europe originating from some undetermined tropical or subtropical area (Sauvard et al. 2010). A more recent study characterises this species as of Middle Eastern origin (Spennemann 2019), but its main host plant *Phoenix dactylifera* L. is regarded as introduced to Cyprus (Christofides 2017). The planthopper *Jacobiasca lybica* probably originates from northern Africa, but is widely distributed in the Mediterranean (Mifsud et al. 2010). In Cyprus, the first and only record for the species dates back to 1967 when *J. lybica* was collected on grapes (Georghiou 1977). Previous studies failed to locate the species in the island (Lindberg 1948) and its "alien" status has been regarded as doubtful (Mifsud et al. 2010). The Asian moth *Dichelia cedricola*, has been labelled as alien to Europe (Lopez-Vaamonde et al. 2010). The species is a renowned pest of *Cedrus* spp. causing serious defoliation of *Cedrus libani* A. Rich. in neighbouring Lebanon and Turkey (Nemer et al. 2015). In Cyprus, management of the species in Cedar Valley, where the endemic cedar *C. brevifolia* occurs, was initiated a decade ago (Gatzogiannis et al. 2010). The isolation of Cedar Valley, situated deep within the islands' Troodos mountain range, the reduced available habitat for *D. cedricola* and nativity of similarly perceived alien associate of cedar *C. cedri*, may indicate that, not only *D. cedricola* could be native to Cyprus, but also consist an endemic subspecies.

In relation to Hymenoptera of "questionable" status, six species are presented. The Aphelinidae *Aphytis coheni* has been reported as of both western and south-eastern Asian origin (Avidov et al. 1970; Gerber and Schaffner 2016; EASIN 2021). Despite being intentionally introduced to the island as a biological control agent for *Lepidosaphes beckii* (Newman, 1869), the type-locality of *A. coheni* in neighboring Israel raises doubts about its region of ancestry (Gerber and Schaffner 2016). In Europe, *Scutellista caerulea* was released in France and Greece against *Saissetia oleae* (Olivier, 1791) (Gerber and Schaffner 2016). The species has been collected from Cyprus since 1931 (Wood 1963; Georghiou 1977), but there is no evidence of intentional introduction to the island. A native population of this African species already existed in Crete prior to the species' intentional introduction (Gerber and Schaffner 2016). Taking into account the proximity of both Crete and Cyprus to northern Africa, *S. caerulea* may indeed be native to Cyprus. The same principle applies to both African Encyrtidae *Diversinervus elegans* and *Microterys nietneri* released in Europe as biological control agents, but collected in Cyprus without a recorded history of intentional introductions (Wood 1963; Orphanides 1988; Gerber and Schaffner 2016). Regarding *Vespula germanica*, as stated in Morris (1937) "is said to have been introduced to the island some years ago in hopes of reducing the number of flies". To date, this statement remains unconfirmed. Despite being widespread and common in the Western Palearctic, *V. germanica* has been introduced to various islands, such as Iceland, Madeira and Canary Islands (Rasplus et al. 2010; Beggs et al. 2011). It is, therefore, not possible to confirm the native or "alien" status of *V. germanica* in Cyprus. Nevertheless, this hypothesis could be tested through molecular population genetics. Finally, *Xylocopa pubescens* is perhaps the most common carpenter bee species observed in Cyprus. Despite extensive research on the island's bee fauna conducted during the 1940s and 50s by Georgios Mavromoustakis, the species was not recorded (Mavromoustakis 1949[1948], 1951, 1952). Earliest records of this large and easily identifiable species in Cyprus emerged after the 1990s (Terzo and Rasmont 2014; Varnava et al. 2020). There are no known cases of intentional introduction of *X. pubescens* or other bees on the island (Cyprus Veterinary Services – Ministry of Agriculture, Rural Development and the Environment, pers. comm.). The import of Apoidea from EU countries must be registered in the TRACES platform (https://food.ec.europa.eu/animals/traces_en), while introductions from third countries are mediated by health certificates and inspections upon arrival from custom controls. The Ethiopian ancestral origin of *X. pubescens*, recent detection of the species in 2012 from Athens, Greece (Terzo and Rasmont 2014) and its positive role as a pollinator of greenhouse crops in Israel (Sadeh et al. 2007), may reflect a recent range expansion or perhaps its introduction to the island for agricultural purposes.

Origin

Species originating from biogeographic realms surrounding the island, i.e. the Eastern and Western Palearctic, the Afrotropics and tropical/subtropical regions, account for more than one third (36%) of the "confirmed alien" insects of Cyprus. However, introductions from remote regions seem to have a strong influence on the composition of the island's "confirmed alien" entomofauna, with Indomalaya accounting for more than one fourth (29%) of "confirmed alien species" of insects (Table 1). Asian species, originating from Eastern Palearctic and Indomalaya represent the majority of introduced taxa (44%). This may derive from increased imports from Asian countries, such as China, Israel and Turkey, although the island's largest trading partners correspond to European countries, predominantly Greece and Italy (Trend Economy 2021). Therefore, Greece and Italy may contribute to the introduction of alien species to Cyprus, hidden as stowaways in shipment or avian cargo (Inghilesi et al. 2013; Avtzis et al. 2017; Demetriou et al. 2021).

As trade plays a crucial role in the introduction of alien species (Hulme 2009; Seebens 2019), enhancing biosecurity for regions with high import rates could be advantageous. This could include ongoing effective inspection mechanisms deployed through customs and border controls, at entry points such as airports and harbours, alongside implementation of specialised inspection protocols according to cargo type and origin.

Trophic guilds

The diversity of functional groups represented within each insect order reveals the range of alien insects of Cyprus. Detritivorous species are predominantly beetles (62%). To a lesser extent are Lepidoptera and Psocodea (12% each), followed by Diptera (6%) and common house intruders in the orders Blattodea and Zygentoma (6% and 3%, respectively). The overwhelming majority of parasitic taxa are Hymenoptera (79%), mostly wasps combating agricultural pests of economic significance, such as the Neotropical braconid *Apanteles subandinus* Blanchard, 1947 tackling the common and destructive moth *Phthorimaea operculella* (Zeller, 1873) (Georghiou 1977; Gerber and Schaffner 2016) and others discussed below. These are followed by just a few animal parasites in the orders Siphonaptera and Phthiraptera, as well as some parasitic flies, such as *Trichopoda pictipennis* Bigot, 1876 (Kazilas et al. 2020; Dios et al. 2021). Most of the predatory species belong to Coleoptera (50%) and ants (26%). Predatory behaviour of alien insects has received little to no interest in Cyprus, except from alien Coccinellidae (Wood 1963). Five out of six alien ladybirds found in the island have been intentionally released as biological control agents.

Phytophagous insects are mainly sap-feeding Hemiptera (45%) and Coleoptera (24%) feeding on leaves and stems of plants (Fig. 3; Table 2). Gall formers (gallers) are mostly host-specific to alien ornamental plants, such as *Eucalyptus* spp. infested by the Australian leaf gallers *Leptocybe invasa* Fisher & La Salle, 2004 and *Ophelimus maskelli* (Ashmead, 1900) and alien *Ficus* spp. hosting a wide variety of fig wasps (Compton et al. 2020a; Demetriou et al. 2022; Demetriou et al. in press). Regarding wood-feeding insects, the only exception to Coleoptera is the Neotropical moth *Paysandisia archon* (Burmeister, 1879) (Table 2). The moth was discovered in Paphos and Limassol (Cyprus) boring in *Chamaerops humilis* L., *Phoenix roebelenii* O'Brien and *Washingtonia filifera* (Lindl.) H.Wendl. palms imported from Italy (Vassiliou et al. 2009). The infested plant material was destroyed, but due to the extended biological cycle of the insect, surveys continued until the end of the detection year (Vassiliou et al. 2009). Since then, the palm moth has been sighted once at Zygi (Larnaca) (John and Skule 2016). This demonstrates that wood boring insects can expand into new regions outside their native range even during their immature stages, which can be transported when inside their host plants (later used for planting) or even with timber (Cocquempot and Lindelöw 2010; Demetriou et al. 2021). Thus, in addition to phytosanitary measures reinforced against Hemiptera and species responsible for visually detectable infestation signs (e.g. galls, leaf mines, bite marks), monitoring imported plants and furniture for signs of infestation by wood-feeding insects constructing galleries could be informative for as a biosecurity measure.

Detritivorous species are mainly associated with household commodities and are, thus, probably introduced to the island through international commerce of stored goods. Phytophagous insects may have reached Cyprus through the introduction of their host plants, as indicated for Hemiptera (Rabitsch 2010a), but also Hymenoptera. Although introduction pathways in Cyprus are largely unknown, these assumptions are in accordance with scientific evidence pinpointing the introduction pathways of terrestrial invertebrates in Europe (Peyton et al. 2019, 2020; Pergl et al. 2020). In particular, primary pathways include stowaways and contaminants of food, plants and nursery material (Pergl et al. 2020), while secondary pathways also include the transportation of habitat material, such as soil and vegetation (Pergl et al. 2020). An extended literature survey, not only on a local, but also continental scale, would help identify the main introduction pathways of alien insects to Cyprus. Furthermore, this information could provide information for the design of specific investigation protocols, according to the feeding habits of alien insects and the taxonomic groups present in each feeding guild, to underpin biosecurity.

Establishment status

A total of 245 alien insect species have established viable, reproducing populations on the island (Fig. 4). Species that failed to establish include the seed-beetle *Caryedon serratus*, a species considered unable to establish itself both in the wild and storehouses (Yus-Ramos et al. 2014) and the mango seed weevil *Sternochetus mangiferae* reared once from mango imported from Sri Lanka in 2011 (Biodiversity of Cyprus 2022). As stated earlier, although *Aphytis holoxanthus* was introduced to Cyprus from Israel in 1959 and 1960, it failed to establish and provide any control of *Aonidiella aurantii* (Maskell, 1879) (Gerber and Schaffner 2016).

Although reported as present in Cyprus from Burmeister (1939), the presence of the carabid beetle *Laemostenus complanatus* (Dejean, 1828) is considered unlikely (Austin et al. 2008). Despite their extensive survey work, Austin et al. (2008) failed to detect the species on the island, while it has also been stated that the species is not present in Turkey and the Middle East (Casale 1988). As explained earlier, *Rhyzobius forestieri* is also considered doubtfully present as it has not been mentioned in any literature dealing with the Coccinellidae of Cyprus and their use as biological control agents of scales (Wood 1963; Orphanides 1988; Özden et al. 2006). Lastly, records of *Oligota parva* Kraatz, 1862 and *Nomius pygmaeus* (Dejean, 1831) also seem to be doubtful as the species have been reported only from Baudi di Selve (1870) and Fauvel (1889), respectively. Since then, no records of the species have been found and their presence on the island has not been confirmed (Bordoni 2010). The only dubious record referring to Hemiptera concerns *Ploiaria chilensis* (Philippi, 1862) (Putshkov and Putshkov 1996; Rabitsch 2010b). The remaining four doubtful species are the chalcid wasp *Cirrospilus ingenuus* (mentioned above) and three ant species; *Cardiocondyla nuda*, *Trichomyrmex destructor* and *Solenopsis geminata* (Bernard 1956; Georghiou 1977; Collingwood et al. 1997; Salata et al. 2019). The alien ant fauna of Cyprus will be examined in greater detail during the following years (Demetriou et al. in prep).

Management of alien species is easier and more effective during the initial stages of biological invasion than later in the process (Simberloff et al. 2013). In Cyprus, this was the case with *Octodonta nipae*, a flower beetle which was found on young leaves of ten *Syagrus romanzoffiana* (Cham.) Glassman palms in Limassol and was rapidly eradicated (Vassiliou et al. 2011). Host-plants were potted and maintained as transplants in urban habitats of Germasogeia (Limassol), and infested plants and areas at risk (e.g. gardens, warehouses and production sites) were immediately treated with chemicals and monitored for a period of eight months "due to the long and cryptic life cycle of this palm insect pest" (Vassiliou et al. 2011). Overall, the rapid implementation of measures against *O. nipae* is considered to have resulted in successful eradication of the species on the island. The second invasive alien insect which was considered as eradicated is the yellow fever mosquito *Aedes aegypti*, although it was predicted through horizon scanning to have a high potential for arriving again in the future (Peyton et al. 2019, 2020). However, the species was rediscovered in September 2022 at Dromolaxia, Larnaca District almost one century after it was last reported as present in the country by Aziz (1934). The presence of established populations that might have escaped past eradication efforts or the unintentional re-introduction of the yellow fever mosquito in Cyprus need to be confirmed. Nevertheless, systematic mosquito surveillance in the Akrotiri Peninsula and surrounding regions since 2012 has failed to detect the species thus far (Martinou et al. 2022a). *Aedes albopictus* (Skuse, 1894) has also been recently (October 2022) recorded at six locations in Limassol District (Martinou et al. 2022b; Christou et al. in press). Due to the most recent discovery of these invasive alien mosquito species (exceeding the data collection period), these records are not presented in our checklist, but will be added to the database.

The establishment status of 90 alien insect species (25%) is unknown, due to the collection of single specimens, incomplete record files, as well as data deficiencies in recovered, provided or investigated literature. Thus, further research is necessary to confirm the presence of these insects on the island. Material sampling and identification of alien species in museum and personal collections, as well as communication with experts and digitalisation of grey literature could assist these endeavours. For example, little is known about the establishment status of alien Phthiraptera, where all species were catalogued as "unknown". These data deficiencies could be addressed through the construction and maintenance of databases with observations from veterinarians and municipal veterinary services. Knowledge gaps also appear in Coleoptera, Hemiptera and Lepidoptera where the establishment status was considered as unknown for 38%, 29% and 23% of cases, respectively.

Intentional introductions – Biological control agents

Releases of alien insects as biological control agents in Cyprus reached a peak during the 1960s (Fig. 5; Suppl. material 2). During this decade, half of the released classical biological agents were introduced to the island, to tackle the increased damage caused to cultivations, particularly due to citrus pests, such as the hemipterans *Chrysomphalus aonidum* (Linnaeus, 1758), *Lepidosaphes beckii* and *Planococcus citri* Risso, 1813 (Wood 1963; Gerber and Schaffner 2016). These releases concerned the Asian ladybugs *Chilocorus circumdatus* (Gyllenhall, 1808) and *Chilocorus hauseri* Weise, 1895 whose impacts and establishment are unknown, as well as the import of representatives of the genus *Aphytis* Howard, 1900 (Wood 1963). Although alien Aphelinidae seemed to offer at least partial control of their associated pests, range expansion of *Aphytis melinus* DeBach, 1959 and *A. coheni* led to the competitive exclusion of native-to-Cyprus *Aphytis chrysomphali* (Mercet, 1912) (Orphanides 1984). Ichneumon and braconid releases during the 1960s were aimed at controlling populations of *Phthorimaea operculella* (Gerber and Schaffner 2016). Most species established viable populations on the island although their efficacy as biological control agents remains unknown (Gerber and Schaffner 2016).

Releases during the 1980s included that of *Comperiella bifasciata* Howard, 1906 against the citrus pest *Aonidiella aurantii* (Orphanides 1996), as well as the African species *Metaphycus helvolus* (Compere, 1926) and *Metaphycus lounsburyi* (Howard, 1898) successfully combating the olive grove pest *Saissetia oleae* (Orphanides 1993). In the 1990s, four additional chalcid wasps were recruited against the citrus leaf miner *Phyllocnistis citrella* Stainton, 1856 (Schauff et al. 1998), although their overall impact is rather unknown (Gerber and Schaffner 2016). The reported intentions of rearing and release of the Neotropical chalcid wasp *Cales noacki* Howard, 1907 against *Aleurothrixus floccosus* (Maskell, 1896) have been confirmed (EPPO 1997; Nicos Seraphides pers. comm.). Since the beginning of the 21st century, no data on intentional releases of alien biological control agents were found. Although this may show that alien insects have not been imported to the island during the last two decades, the presented data (Fig. 5) may also indicate the lack of published information in scientific journals.

The history of biological control agents in Cyprus is largely intertwined with commercial potato, olive and citrus crops. Most of the intentionally introduced species have successfully established on the island (81%). However, the efficacy of these releases remains unknown for the vast majority of species (71%). Out of the 19 alien species introduced against citrus pests, only four were reported to offer some degree of control over their hosts (Gerber and Schaffner 2016). Regarding potato crops, out of the ten alien biological control agents introduced to the island, only *Apanteles subandinus* was reported to effectively tackle the common and destructive potato moth *Ph. operculella* (Greathead 1976; Georghiou 1977; Gerber and Schaffner 2016). The inaccessibility of data may be the reason why the percentage of biological control agents considered to be successful in controlling the pest, against which they were released, is seemingly low. For example, in contrast to the only data made available online, stating the intentions of introducing and rearing *C. noacki* (EPPO 1997), the species has not only been introduced and released, but it is also well-established and has provided successful control of *A. floccosus* (Nicos Seraphides pers. comm.).

It could be informative to map the current distribution of historically-known introduced biological control agents to the island, such as *Aphelinus mali* (Haldeman, 1851) or *Copidosoma koehleri* Blanchard, 1940, species for which the presence of established populations is currently unknown (Gerber and Schaffner 2016). The presence, efficacy and non-target effects of biological control agents would be valuable for assessing the benefits of these species, while documenting overall impact towards native biodiversity.

Impacts

Positive impacts of alien insects are largely anecdotal. Out of the 37 species identified, less than half (41%) concerned intentional introductions of biological control agents, as the efficacy of most intentionally introduced species remains unknown. The remaining insects, unintentionally introduced along with their host-plants, reduce the growth of alien invasive plants, such as that of *Leucaena leucocephala* (Lam.) de Wit by its obligate seed-feeding beetle *Acanthoscelides macrophthalmus* (Schaeffer, 1907) (Vassiliou and Papadoulis 2008) or *Ficus microcarpa* L. suppressed by alien non-pollinating fig wasps that inhibit its seed-germination and subsequent spread (Demetriou et al. in press). Although the 37 insect species with registered positive impacts may be presumed as beneficial, the overall lack of studies assessing their integration into natural ecosystems and food-chains may bias such conclusions.

Studies addressing the adverse impacts of alien insects in Cyprus mostly focus on insects of agricultural or horticultural significance (Morris 1937; Georghiou 1977; Kontodimas et al. 2006; Şişman and Ülgentürk 2010; Ülgentürk et al. 2015; Compton et al. 2020b; Hadjiconstantis and Zoumides 2021). The impacts of alien insects on the biodiversity of Cyprus has received minimal attention, evidenced by the small number of alien insects (19 species) classified as invasive (Fig. 6). These species include, *inter alia*, the rosemary beetle *Chrysolina americana* infesting native aromatic plants (Hadjiconstantis and Zoumides 2021), the aphid *Myzus persicae* Sulzer, 1776 (Georghiou 1977; Ioannou and Iordanou 1987), as well as two scale insects *Aspidiotus nerii* Bouché, 1833 and *S. oleae* feeding on native and alien plants (Morris 1937; Georghiou 1977; Orphanides 1993; Şişman and Ülgentürk 2010; Compton et al. 2020b). In addition, four hymenopterans are known to compete with and displace native species (Orphanides 1984; Salata et al. 2019), while another has been found parasitising a native scale insect (Georghiou 1977). Lastly, two alien Siphonaptera, *Ctenocephalides canis* (Curtis, 1826) and *Ctenocephalides felis* (Bouche, 1835) have been found to negatively affect human and animal health as vectors of pathogens (Psaroulaki et al. 2006, 2014) (Suppl. material 2).

The impacts of alien insects in Cyprus are unquestionably in need of a detailed literature investigation covering both published and unpublished literature. Impact assessments, using the protocols and criteria of EICAT and SEICAT (Hawkins et al. 2015; Bacher et al. 2017; IUCN 2020; Kumschick et al. 2020a), to comprehensively assess the impacts of alien insects of Cyprus would be valuable in providing a list of invasive alien species of national concern. Additionally, such impact assessments could be included within risk assessments and should take into account any recorded impacts of alien insects studied in neighboring Mediterranean and Middle-Eastern countries (e.g. Egypt, Greece, Israel and Turkey). Thus, these assessments could act as an early warning system for insects with harmful impacts detected in neighboring regions (Kumschick et al. 2020b), which have been classified as data-deficient in Cyprus, but also species remaining undetected or yet to have reached the island. Nevertheless, the updated checklist of alien-to-Cyprus insect species (Suppl. material 1) constitutes an important first step towards prioritising management decisions and implementing monitoring schemes for invasive alien species on the island.

Horizon scanning for invasive alien species with the potential to threaten biodiversity, human health and the economy of Cyprus (including insects) have been already implemented, addressing species with high likelihood of arrival, establishment and potential impacts (Peyton et al. 2019, 2020). A total of 14 alien insects likely to be imported and established on the island were prioritized. Amongst them, four alien mosquitoes (*Aedes* spp.) with the potential to harm human health and well-being, crop-pests, such as *Leptinotarsa decemlineata* Say, 1824, *Daktulosphaira vitifoliae* (Fitch, 1855) and *Anoplophora* spp., but also invasive alien species, such as *Linepithema humile* (Mayr, 1868) and *Vespa velutina* Lepeletier, 1836 (Peyton et al. 2019, 2020). These species could be included in alert-lists (Peyton et al. 2019). Management measures could benefit from the construction of dynamic, dichotomous identification keys available online for the rapid identification of species in order to support border control and phytosanitary surveillance. In parallel, data availability, usefulness and transparency could be enhanced by data-digitisation of grey literature, following core biodiversity data standards (Groom et al. 2017). In accordance with these recommendations, the updated checklist and data curated by the ACE database are being integrated to the CyDAS, with hopes that they can assist risk assessments on a national and European level.

Lastly, the large percentage of alien insects assessed as data-deficient (47%) (Fig. 6) combined with the high percentage of species whose establishment status is considered unknown or presence is doubtful (25%) (Fig. 4), clearly illustrate the necessity for "more boots in the ground" (Wilson 2017) regarding the study of insects in Cyprus.

Conclusions

Since 2010, the number of documented alien insect species known to inhabit Cyprus has tripled. A total of 349 alien species have been detected while there are already a number of new additions to the checklist. Updated resources including identification keys are needed to raise awareness and support biosecurity strategies.

As introduction pathways of alien insects in Cyprus are largely unknown, stowaways and contaminants of food and plants could be prioritised, since they comprise the most common introduction pathways in Europe (Pergl et al. 2020). Future endeavours include deciphering the biological invasion history, distribution, impacts and species interrelationships of alien insects by utilising classical methods, citizen science and molecular tools. Data and studies focusing on alien insects will be also fed to larger databases, such as the CyDAS, GRIIS and GBIF, to ensure data interoperability (Penev et al. 2021).

Regarding intentional introduction and release of alien biological control agents, educational material and information on the taxonomy, history and efficacy of imported biological control agents could be made available online to the public and scientific community. Such information could be catalogued to register and monitor both importers and providers of biological control agents in order to keep track of alien species intentionally released on the island. The ACE and CyDAS databases can act as data repositories ensuring the accumulation, availability and transparency of data on alien species assisting monitoring and further research efforts, risk assessments, prioritisation of invasive alien species, management strategies and lastly, the establishment of rapid response/early warning systems mitigating further introductions and impacts of invasive alien species.

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Supplementary material 1

Checklist of alien insects of Cyprus

Authors: Jakovos Demetriou, Canella Radea, Jodey M. Peyton, Quentin Groom, Alain Roques, Wolfgang Rabitsch, Nicos Seraphides, Margarita Arianoutsou, Helen E. Roy, Angeliki F. Martinou

Data type: checklist

Explanation note: Checklist of alien insects of Cyprus. Legend: Status = Alien (A), Cryptogenic (C), or Questionable (Q); Establishment status = Established (Es), Failed to establish (Fa), Introduced but failed to establish (In), Eradicated (Er), Doubtful (Do) and Unknown (Un).

Link: https://doi.org/10.3897/neobiota.83.96823.suppl1

Supplementary material 2

Alien biological control agents intentionally introduced to Cyprus

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Data type: database

Explanation note: Data on alien biocontrol agents intentionally introduced to Cyprus including their taxonomy, introduction year/period/decade, origin, establishment status, host (reason of import), impact, and reference(s).

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