National and Kapodistrian University of Athens

Postgraduate Programme

Ecology & Conservation of Biodiversity

Biology Department

Postgraduate Thesis

«Monitoring insect diversity in habitats invaded by *Acacia* in Cyprus – implementation of environmental citizen science / ΠΑΡΑΚΟΛΟΥΘΗΣΗ ΤΗΣ ΕΝΤΟΜΟΠΑΝΙΔΑΣ ΣΕ ΕΝΔΙΑΙΤΗΜΑΤΑ ΣΤΑ ΟΠΟΙΑ ΕΧΕΙ ΕΙΣΒΑΛΛΕΙ Η *ACACIA* ΣΤΗΝ ΚΥΠΡΟ- ΑΝΑΠΤΥΞΗ ΤΗΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΠΟΛΙΤΟΤΗΤΑΣ»

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«Monitoring insect diversity in habitats invaded by *Acacia* in Cyprus – implementation of environmental citizen science/ Παρακολουθηση της εντομοπανιδας σε ενδιαιτηματα στα οποια εχει εισβαλλει η *Acacia* στην Κυπρο- αναπτυξη της περιβαλλοντικης πολιτοτητας»

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ABSTRACT

This study aims at highlighting the importance of insect biodiversity and the services that insects offer. The study is assessing how different habitats affect the biodiversity of insects with different functional traits, by using traditional insect survey methods (pitfall trapping, pan trapping and beat sheet sampling) in the Ramsar wetland of Akrotiri in Cyprus. In addition, this study contributes towards the design and implementation of a citizen-science initiative for monitoring pollinators and other beneficial insects, the Pollinator Monitoring Scheme Kýpros (Poms-ký). Poms-kýwill provide the scientific evidence base for assessing changes in Cyprus pollinators' populations (abundance and distribution) and communities (diversity and composition) and their interactions with native and non-native plants.

The results of this study show that native habitats have in general more positive impacts on insects' diversity and abundance (pollinators, predators and other categories), compared to non-native habitats. Non-native plant species seem to have been integrated in the diets of generalist pollinators' species. The abundance of solitary bees' species (pollinators' specialists) was not significantly different between native and non-native plant species, but this might be the result of a low number of samples. In conclusion, it is necessary to protect and conserve the native habitats of Cyprus such as Thermo-mediterranean riparian galleries and Coastal lagoons, *Sarcopoterium spinosum* phrygana, arborescent matorral with *Juniperus phoenicea* and Mediterranean tall humid grasslands.

Περιληψη

Η παρούσα διπλωματική εργασία έχει ως στόχο να αναδείξει την σημασία της βιοποικιλότητας των εντόμων, όπως επίσης και την σημαντικότητα των υπηρεσιών που αυτά προσφέρουν. Η μελέτη αξιολογεί τον τρόπο με τον οποίο τα διάφορα ενδιαιτήματα επηρεάζουν τη βιοποικιλότητα των εντόμων με διαφορετικά λειτουργικά χαρακτηριστικά, χρησιμοποιώντας παραδοσιακές μεθόδους συλλογής και καταγραφής εντόμων, όπως είναι η δειγματοληψία με παγίδες παρεμβολής (pitfall trapping), η δειγματοληψία με παγίδες πιάτων (pan trapping) και η δειγματοληψία με ράβδο (beat sheet sampling). Τα ενδιαιτήματα στα οποία πραγματοποιήθηκε η μελέτη, αποτελούν τμήματα του υγροτόπου Ramsar στην περιοχή του Ακρωτηρίου, στην Κύπρο. Επιπρόσθετα, η μελέτη αυτή συνετέλεσε στο σχεδιασμό και τη δοκιμή ενός πρωτότυπου για τα κυπριακά δεδομένα, προγράμματος επιστήμης πολιτών, το Pollinator Monitoring Scheme Kýpros (Poms-ký) ή αλλιώς στα ελληνικά ΕΠΙΚΟΝΟΙΑΖΟΜΑΣΤΕ. Το Επικονοιαζόμαστε, αποσκοπεί στην αφύπνιση των πολιτών σχετικά με την σημαντικότητα των εντόμων και στην ενεργή συμμετοχή αυτών με στόχο την ενίσχυση της επιστημονικής έρευνας και συλλογής δεδομένων για τα ωφέλιμα έντομα όπως οι επικονιαστές. Επιπλέον στοχεύει να συμβάλλει στη μελέτη και στην αξιολόγηση των μεταβολών των πληθυσμών (αφθονία και κατανομή) και των κοινοτήτων (σύνθεση και ποικιλότητα) των εντόμων στην Κύπρο, όπως στη μελέτη των αλληλεπιδράσεων των εντόμων με ιθαγενή και ξενικά είδη φυτών.

Τα αποτελέσματα της παρούσας μεταπτυχιακής διατριβής δείχνουν ότι τα φυσικά ενδιαιτήματα ευνοούν τον πλούτο και την αφθονία των εντόμων (επικονιαστές, θηρευτές, όπως και άλλες κατηγορίες εντόμων), σε σύγκριση με ενδιαιτήματα, τα οποία έχουν υποστεί διαταραχές λόγω της εισαγωγής και εξάπλωσης ξενικών φυτών όπως η *Acacia saligna*. Ωστόσο τα ξενικά είδη φυτών, φαίνεται να έχουν ενσωματωθεί στη διατροφή των επικονιαστών. Επιπλέον, τα αποτελέσματα αυτής της μελέτης δεν έδειξαν σημαντική διαφορά στην αφθονία των μοναχικών μελισσών (ιθαγενή είδη επικονιαστών) μεταξύ ιθαγενών και ξενικών φυτών, κάτι που ενδεχομένως να οφείλεται στην περιορισμένη καταγραφή των επικονιαστών αυτών κατά τη διάρκεια της μελέτης.

Διαπιστώθηκε πως είναι απαραίτητη η προστασία και διατήρηση των φυσικών ενδιαιτημάτων της Κύπρου, και πιο συγκεκριμένα η προστασία παραποτάμιων στοών (*Nerio-Tamariceteae*) και των συστάδων του Νότου και των παράκτιων λιμνοθαλασσών, των φρυγάνων της Ανατολικής Μεσογείου (*Cisto-Micromerietea*), των δενδρωδών θαμνώνων με *Juniperus phoenicea, των καλαμιώνων* και των Μεσογειακών λειμώνων με υψηλά αγρωστώδη και βούρλα.

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This thesis was the most demanding project I have done so far in my life. However, I am very satisfied of this experience and I'm ready to continue and turn in practice what I have learnt. Fortunately, I was not alone on this path and that is why these few lines of thanks are necessary.

I would like to collectively express my deep appreciations to my supervisors Professor Margarita Arianoutsou, Professor Anastasios Legakis and Professor Helen Roy, who will examine my thesis, and each one individually for their personal guidance.

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This thesis is dedicated to my family members, who are always next to me and beyond any doubt joint authors of this winning post.

I expressly state that the text of this postgraduate thesis is not a product of partial or total copying, and that the sources used are limited to bibliographic references only.

Ioanna Angelidou

1 INTRODUCTION

1.1 BIODIVERSITY LOSS

Nature is facing many threats, as many species decline rapidly both in distribution and abundance, and biodiversity is getting lost (Millennium Ecosystem Assessment, 2005b; Pocock *et al*., 2016). The main cause for the loss of biodiversity can be attributed to anthropogenic influences on ecosystems globally. According to Brooks *et al*. (2006) and Chivian and Bernstein (2008), human activities are the cause of a biodiversity crisis, with species extinction rates up to 1000 times higher than the natural rate.

Until today, restructuring and managing various ecosystems have resulted to a degradation of 60% of ecosystem services. (Millennium Ecosystem Assessment, 2005b; European Commission, 2015).

The structure and functioning of the world's ecosystems change very rapidly. The effects of ecosystem degradation or elimination, contribute to an accelerating rate of the depletion of Earth' diversity, while the loss of plant and animal species is irreversible (Millennium Ecosystem Assessment, 2005b). As a result, the services that biodiversity provides also get lost (Brooks *et al*., 2006; Pocock *et al.,* 2016).

Threats to ecosystems and by extension to the services that they provide, but also to biodiversity loss, are direct and indirect. The intensification of food production methods, expanded use of irrigation, forest-clearing, contribute to soil erosion, desertification in dryland regions and in waterlogging or salinity of irrigated land and finally raises the potential for serious ecological change (Millennium Ecosystem Assessment, 2005a&b; European Commission, 2015). Moreover habitat loss/fragmentation, climate change, air and land pollution, surface and groundwater contamination and competitive interactions with non-native invasive species, are some more threats of ecosystems and biodiversity that affect the geographical distribution, abundance and behaviour of plants and animals entailing losses in natural resources, change ecosystems' functions and can endanger terrestrial and aquatic ecosystems (Millennium Ecosystem Assessment, 2005a; Sih *et al*., 2011; Oliver *et al.,* 2015a&b; Pocock *et al.,* 2016; Hallmann *et al.,* 2017; Taylor *et al*., 2018; Bonebrake *et al.,* 2019).

1.1.1 INVASIVE ALIEN SPECIES

Anthropogenic activities simplify natural systems and reduce their intrinsic resilience to change, making them unsustainable and likely to lead to irreversible changes or recovery could be slow and costly (Millennium Ecosystem Assessment, 2005b). The majority of species are seeing their population sizes and ranges decline, while genetic diversity has also declined globally (Millennium Ecosystem Assessment, 2005). Additionally, environmental degradation caused by pollution, habitat loss and human-induced disturbance creates favourable conditions for invasive alien species to establish and spread, while the effects of climate change are predicted to aggravate the situation (Kettunen *et al*., 2009).

An “invasive alien species” is defined as a species that is non-native to the ecosystem under consideration. Human actions are the primary means of the introduction of invasive alien species (Roychoudhury *et al*., 2019), which occur in all major taxonomic groups, including animals, plants, fungi and micro-organisms and they have invaded virtually every ecosystem type on the planet, affecting the terrestrial, freshwater and marine environment (Kettunen *et al*., 2009; Roychoudhury *et al*., 2019). Biological invasions by alien species are recognised as a significant component of global environmental change and they have been recognised as the second most important threat to biodiversity at the global level, after direct habitat loss or destruction (Hulme *et al*., 2008; Kettunen *et al*., 2009; Essl *et al*., 2011).

The introduction of invasive alien species, often resulting in a significant loss in the economic value, biological diversity and function of invaded ecosystems (Hulme *et al.,* 2008; Stout and Morales, 2009), and their spread is a serious impediment to conservation and sustainable use of global, regional and local biodiversity, while it has negative impact ecosystem functions and services, socio-economic and cultural heritage values impacts, and human health (Kettunen *et al.,* 2009; European Environment Agency, 2010; Peyton *et al.,* 2019; Roychoudhury *et al*., 2019).

Increased risk of biotic exchange is an inevitable effect of globalization and has increased due to deliberate translocations and accidental introductions related to travel and trade (Millennium Ecosystem Assessment, 2005c; Stout and Morales, 2009; Peyton *et al.,* 2019). In Europe the number of invasive alien species is growing rapidly, affecting, apart from others, the economy, with overall losses estimated to exceed EUR 12 billion annually (European Environment Agency, 2010).

DAISIE (Delivering Alien Invasive Species Inventories in Europe), is the largest European Project on Alien Invasive Species, that funded from European Commission in 2005, and assembled a very comprehensive dataset on alien taxa and generated greater awareness of alien species in Europe. General objects of the programme was the creation of an inventory of alien species that threaten European terrestrial, fresh-water and marine environments, the structuring the inventory to provide the basis for prevention and control of biological invasions and finally, the use distribution data and the experiences of the individual Member States as a framework for considering indicators for early warning (Hulme et al., 2008).

On 1 January 2015, the Regulation (EU) 1143/2014 on invasive alien species (the IAS Regulation), entered into force. The aim of the IAS Regulation is the provision of a set of measures to be taken across the EU in relation to invasive alien species included on the Union list (list of Invasive Alien Species of Union concern). Three distinct types of measures are envisaged (European Commission, official website (b)):

- prevention measures, that aimed at preventing the intentional or unintentional introduction of invasive alien species,
- measures of early detection and rapid eradication, and
- management measures, for invasive alien species that are already established in certain Member States of EU, by prevent them from spreading any further and to minimize the harm they cause.

Horizon scanning is an approach used to prioritise the threat posed by potentially new invasive alien species not yet established within a region (Roy *et al.* 2014; Peyton *et al.,* 2019). The approaches adopted by Roy *et al*. (2014) are starting to be applied more widely within Europe. In the 2017 the island of Cyprus was among the areas where Horizon scanning for IAS was applied. This horizon scanning approach considered the potential threat posed by invasive alien species, predicted to arrive and establish on Cyprus, to biodiversity and ecosystems alongside human health. The prioritised list of invasive alien species had the scale of the entire island but also the SBAs, which have different governance (Peyton *et al.,* 2019).

1.1.1.1 Invasive plants

The number of plant introductions has climbed steadily since the late eighteenth century. Their invasions are common in virtually every terrestrial habitat on earth (Stout and Morales, 2009) and they are widely considered to have an adverse effect on the ecosystems they invade, resulting in biodiversity loss and changes in ecosystem functioning (Stout and Tiedeken, 2016). However, impacts are likely to be strongly context dependent and vary according to the traits of the invaders and the invaded community (Stout and Tiedeken, 2016).

Invasive alien plants disrupt both floral and faunal communities of the invaded regions, as they can displace native and endemic plant species and they can bring changes on interactions between invasive alien plants and native fauna (Millennium Ecosystem Assessment, 2005; Samways, 2007; Sunny *et al.,* 2015). That reduces local diversity and negatively impacts entire ecosystems and can even, affect local hydrology, and ecosystem services (Millennium Ecosystem Assessment, 2005; Samways, 2007).

Invasions of introduced plants result in severe ecological damage and economic losses worldwide (Roychoudhury *et al.,* 2019). Thus, over the past 18 years, particular focus has been placed on understanding the ecological role of invasive plants through interactions with native insect communities, especially pollinators (Sunny *et al.,* 2015; Stout and Tiedeken, 2016).

The control of invasive alien plants requires difficult, costly and time-consuming programmes (Wilson *et al.*, 2011). Therefore, identifying future invasions of invasive alien species is pivotal to mitigating the negative effects of introduced species and has been seen as an essential component for the management of those species with demonstrated net economic and ecological benefits (Peyton *et al.,* 2019).

1.1.1.1.1 INTERACTIONS BETWEEN INVASIVE PLANTS AND INSECTS

Plants are essential components terrestrial food webs and insects depend on them greatly. The nutritional quality of plant tissues, as well as their morphological characteristics, may significantly affect the feeding behaviour and growth of native herbivores. Insect herbivores discriminate between suitable and unsuitable plants for their own nutrition and/or that of their progeny. Thus invasive plants, as a new resource, can affect native insect herbivores and their natural enemies directly (Bezemer *et al.,* 2014; Sunny *et al*., 2015).

Secondary chemical compounds present in the invasive plants can either be toxic, causing decline in native insect populations, or be attractive to native insects, helping their survival (Sunny *et al.,* 2015). Moreover, invasive alien plants can provide shelter when there otherwise might not be, and alien water weeds can provide increased habitat for some insects, but only for already geographically wide spread and generalist species (Samways, 2007). As a result, there is no clear consensus regarding how well native herbivores perform on invasive plant species (Bezemer *et al.,* 2014).

It is interesting that the impacts of alien (non-native) plants are not always negative (Samways, 2007). Some studies show that invasive plants are highly suitable as hosts and insects achieve high potential fitness, (Samways, 2007; Bezemer *et al*., 2014).

1.1.1.1.2 INTERACTIONS BETWEEN INVASIVE PLANTS AND POLLINATING INSECTS

Whilst interactions with native pollinators may be beneficial for invasive plants, the opposite is thought to be true for impacts of invasive plants on native pollinators. This could be because large stands of invasive alien plants occupy space, displacing native plants, which may be assumed to be more likely to provide a suitable resource. In addition, invasive alien plant species can be integrated in generalist pollinators' diet and alter their behaviour, resulting in additional indirect impacts of invasive plants on some specificity pollinators' species (Stout & Tiedeken, 2016).

Studies which have examined the effects of invasive plants on the abundance of pollinators have come to contrasting conclusions. Some studies have reported positive impacts of invasive plants on the abundance of some species (generalist butterflies and bees), whilst others have found invasive plants associated with decreased abundance of butterflies, bees and indeed entire pollinator communities. On the other hand, some studies have reported no impact on pollinator abundance (bees, hoverflies) (Stout & Tiedeken, 2016).

1.1.2 INSECTS AND THEIR IMPORTANCE

Based on their inherent and ecological values, insects and related invertebrates should be protected (Kim, 1993; Samways, 2005). Their importance for the functioning of ecosystems is huge, as they are contributing to fundamental ecosystem processes including soil turnover, decomposition and nutrient cycling, while they also play key roles in local food webs (Gill *et al.*, 2016; Díaz *et al.,* 2018; Oberprieler *et al.,* 2019).

Insects have an intricate ecological role in ecosystem processes (Kim, 1993). Due to that the loss of a species can affect the interactions of the remaining species (Kim, 1993). The pollinator species, many of which are specific to particular types of flowering plants, directly affect the survival of their host plants. The loss of many decomposers, such as blowflies and house flies, will dramatically reduce rates of decay and recycling, which will result in accumulations of slowly decomposing animal carcasses and vegetable matter (Kim, 1993; Hallmann *et al.*, 2017).

Terms used such as keystone, umbrella, flagship and vulnerable species are used in order to measure the effects of anthropogenic stress on biodiversity and environment (Kim, 1993). For example, pollination, which is a key ecosystem service, as it is essential for agricultural production and for the reproduction and evolution of wild plants is, are influenced by a series of environmental changes as habitat fragmentation/ loss, excessive land use and land use change, pesticide use, various pathogens and parasites, biological invasions, climate change, etc. The decline of pollination can easily be documented through historical time-series (Petanidou *et al.*, 2013).

In conclusion insect biodiversity loss is more than just using a collection of species (Sánchez-Bayo and Wyckhuys, 2019) and as E.O. Wilson said:

"Without insects the rest of life, including humanity", "would mostly disappear from the land, within a few months" (Wilson after Leahy, 2019).

1.1.3 INSECT POPULATION DECLINING

Insects and related arthropods are a dynamic group of organisms with a long evolutionary history, which have appeared first in the Devonian (400 million years ago) and have diversified very successfully (Kim, 1993). Over the last 400 million years the diversity of insects has been increasing at the family level (with about 600 families living today) (Kim, 1993; Samways, 2007), showing an astonishing taxonomic diversity. They are abundant in almost all environments across the globe, and it is considered that their global number to higher than 4 million species, however our present knowledge is limited to about 1 million species (Kim, 1993; Gill *et al*., 2016).

Insects are now facing the most menacing extinction driver of all, that caused by the human species (Samways, 2007). The insect decline has been described as the "Insect apocalypse" or "Insect Armageddon" (Lawton, 2018; Cardoso *et al*., 2019; Leahy, 2019). A global analysis of 452 species in 2014 showed that insect abundance has declined 45% over 40 years (Leahy, 2019). In 2017, Hallmann *et al.* (2017) revealed that there was a shocking decline (76%) in flying insects' biomass at several of Germany's protected areas. One year later Lister and Garcia (2018) reported biomass losses between 98% and 78% for ground-foraging and canopy-dwelling arthropods in rainforests of Puerto Rico. Sánchez-Bayo and Wyckhuys (2019) stated that "unless we change our ways of producing food, insects as a whole will go down the path of extinction in a few decades". As insects comprise about two thirds of all terrestrial species on Earth, the above trends confirm that the sixth major extinction event is under way (Sánchez-Bayo and Wyckhuys, 2019).

Our understanding of the extent and underlying causes of this decline is based on the abundance of single species or certain taxonomic groups (Lister *et al*., 2018). The main drivers of insect declines are: i) habitat loss and conversion to intensive agriculture and urbanisation; ii) pollution, mainly that by pesticides and fertilisers; iii) biological factors, including pathogens and introduced species; and iv) climate change (Kim, 1993; Samways, 2007; Oliver *et al*., 2015a&b; Hallmann *et al.,* 2017; Sánchez-Bayo and Wyckhuys, 2019).

Despite their importance, insects and other arthropods have not been taken seriously for conservation by policy-makers and the conservation community at large (Kim, 1993; Samways, 2005; Sánchez-Bayoa and Wyckhuys, 2019). They are often ignored in conservation planning due to the difficulty and lack of knowledge regarding their identification and taxonomy and the poor understanding of their patterns of diversity and distribution, as well as the impracticability associated to carrying out comprehensive sampling (Taylor *et al*. 2018; Tzirkalli *et al*., 2019). These factors help maintain ignorance about insects' diversity and distribution (New *et al.,* 1995; Samways, 2007; Oberprieler *et al.,* 2019). According to that, there are likely to be more extinction, even of species that have never and will never be described. Description of all those unknown species before they become extinct is the taxonomic challenge, as only 10% of all insects have scientific names. Moreover, many taxonomic revisions are still required (Samways, 2007).

In more recent years, arthropods have begun to gain the attention of the conservation community as the importance of preserving ecosystems and sustaining the dynamics of ecological processes has been recognized (Kim, 1993; Samways, 2005). However, the time and monetary constraints create a gap between the optimal monitoring methods and the practical needs in conservation (Hegland *et al.*, 2010).

The science of insect conservation takes account of the scale, population structure, rapid dynamics of these organisms, as well as their sensibility to environmental change (New *et al.,* 1995). Moreover, insect conservation focuses strongly on the variety and differences among insects, and links these to landscape and other large-scale conservation initiatives, without ignoring special cases where a particular insect species requires particular conservation attention (Samways, 2005).

1.2 INSECT CONSERVATION

It is difficult to recognise insect extinction, and insect conservation requires major efforts. Some of the critical factors which pose difficulty in insect conservation are the huge species diversity and the level of their taxonomy which is still inadequate. In addition, the size of their populations and biomass, that are extremely large, the geographical populations that are highly variable, as well as their functional roles. Finally, habitats and niche requirements that are so diverse and variable, and that ecological information about them is scarce, are some additional factors (Kim, 1993).

Insect conservation must take multiple approaches to cover all the fronts, targeted at different scales, such as population, species or guilds at a certain habitat. The species of insects and related arthropods that are eminently endangered and threatened must be protected immediately with specific conservation measures such as the establishment of protected areas, in situ and ex situ, culture and release, and habitat restoration (Soulr, 1991; Kim, 1993).

Ultimately, however, insects' conservation efforts should be focussed on preserving the dynamics of ecosystem processes by protecting the ecosystem structure and function and on reducing anthropogenic impacts on the ecosystems and landscapes to minimize extinction (Kim, 1993). There are many ways to combine targeted sites or reserve areas. However, the outcome must be flexible enough for practical conservation management, including making allowances for climate change (Samways, 2007).

Furthermore, it is essential to include irreplaceability, as some sites may be common but others may be rare or even unique, as there is a possibility to be lost. Finally, it is essential to include not only areas that are endemic hotspots, but also areas that are typical, areas that are zones of ecological transition, and areas that have evolutionary potential (Samways, 2007).

These reserve selection procedures are a coarse-filter or landscape approach, and for that reason these should ideally be complemented with a fine filter of species (threatened species and species of special conservation status). A shortcoming of systematic conservation planning for insect conservation is that there are often taxonomic errors, poor distributional data, and a bias toward certain species (Samways, 2007).

Understanding patterns of biodiversity is essential to developing conservation strategies and monitoring conservation goals. Species surrogates (higher taxa, species richness, endemism, threat status, and/or alternative taxa) are often cited as major indices for explaining diversity patterns. Species richness, in particular, remains a central component of most priority-setting studies (Samways, 2007, Xu *et al.,* 2008). Other types of surrogates include vegetation types, land systems or classes, and environmental domains. However, none of these surrogates is perfect, and the risk of using them is that important or even critical aspects of regional insect diversity may be overlooked (Samways, 2007).

When different types of taxa are compared, there may not be concordance, leading to biases depending on which taxa are used. While the use of environmental surrogates can embrace a range of taxonomic diversity, this broad-scale approach can overlook critical small-scale habitats and special features essential to small animals such as insects (Samways, 2007).

Therefore, it is best to combine both environmental and species surrogates for systematic conservation planning. The first studies in this field suggest that insects and plants are most of the time, concordant and are represented by many environmental surrogates. However, there will not be always a perfect match (Samways, 2007).

There are six fundamental principles that are interrelated and together provide guidelines for conservation management of insects. Those principles are interrelated and together provide guidelines for synthetic conservation management of insects, and through that biodiversity conservation (Inamke *et al*., 1997; Samways, 2007):

1. **Maintain as much quality landscape heterogeneity as possible** (vegetation and ground heterogeneity - management activities must focus on the wider landscape and not simply on individual patches).

2. **Maintain reserves as source habitats, particularly for specialists** (reserves must be large enough to retain specialist organisms in the long term and not lose them to ecological relaxation and global warming).
3. **Reduce contrast between remnant natural patches and neighbouring disturbed areas**.
4. **Maintain as much undisturbed or minimally disturbed habitat as possible** (land sparing-outside reserves).
5. **Simulate natural conditions and disturbance as much as possible, in transformed landscapes** (the management and restoration targets require knowledge of the character of the focal ecosystem at different times in the past and aim to simulate some time bracket).
6. **Connect like patches of quality habitat as much as possible** (corridors' roles: movement corridor, habitat, filter, barrier, source, and sink - short-term and long-term evolutionary scale of movement).

Running throughout all these principles is the necessity for healthy population levels, which usually require the combined support of the metapopulation trio of large patch (habitat) size, good patch quality, and reduced patch isolation. Furthermore, in addition to those six principles, there is an overlay of the fine filter, species approach, in which particular species in specific areas require focused attention. (Samways, 2007).

To begin with insect conservation, the target area for conservation must be clearly defined and inventory survey plans developed. Those areas may be defined by the needs or reasons for taxonomy, ecology and particular species. Unfortunately, the kinds of information used to set priorities for vertebrates and vascular plants are not available for most insect and arachnid species. Moreover, at local level, a specific biodiversity conservation plan should be developed on the basis of the local faunal knowledge and the cultural definition of ecological and economic values of species (Kim, 1993).

1.2.1 INVENTORY AND MONITORING THE CHANGES IN INSECT'S COMMUNITIES

Inventory and assessment of biodiversity provide the bases for developing practical, cost- effective preservation and monitoring programmes (Kim, 1993). Insect monitoring is used to obtain information on population size, density, and composition and to detect variations in insect abundance, to provide decision support regarding management of the area that the sampling occurs (Krüger and Fiore 2018). To do this, it is important to have robust survey techniques of insect populations (Shrestha *et al.* 2019).

It is unlikely that a single sampling method is sufficient. Often two or three methods have to be used together if there is little prior knowledge concerning the insect fauna. Commonly used methods to collect insects include sweep netting, beat sampling, pan traps, pitfall traps, vacuum sampling, light traps and malaise traps. The choice of method is determined by the insect taxon, by live stage of concern, by the purpose of the study and the cost. Ground surveys can be either qualitative or quantitative, depending on the objective (Krüger and Fiore 2018).

There are two primary types of ground faunal surveys: (1) taxonomic survey, which produce comprehensive, authoritative catalogues and monographs for specific taxa, but usually involves a long turn-around time, (2) environmental survey, which assesses the status of environmental heterogeneity (habitats and their biotic components in the local target site), is the most common type of biodiversity survey for target sites, and is commonly used in environmental impact assessment programmes. Therefore, the data collected by the environmental surveys, are superficial and often based on misidentification and gross taxonomy. For that reason, they usually fail to supply sufficient information on the composition and habitats of resident species for effective conservation action (Kim, 1993).

Before a ground survey is undertaken, there must be completed taxonomic and faunistic assessment of the target area, which can provide information on species, and their distribution, habitat requirements, host- substratum associations and seasonality, and aid in formulating a survey plan and predicting the biodiversity structure. Furthermore, there must be complete habitat classification and description (through the use of a remote sensing database, maps and other published information on soil, landforms-physiography, vegetation and other parameters of habitat heterogeneity), and establishment of a database management system, which must accommodate taxonomic and faunistic information, habitat description and classification, as well as data on field collection, collection management, species identification and the biodiversity profile (Kim, 1993).

1.3 CYPRUS

Cyprus is a Mediterranean island of high diversity (Medail and Diadema, 2009) a result of its geographical position and size (9251 km2), the varied geology and geomorphology, climatic conditions, habitat diversity (Tsintides *et al.*, 2007) and a long history of human presence, dating back to 12,000 years ago (Simmons 1999; Christodoulou *et al.,* 2018). It is located at the South Eastern corner of Europe, South of Turkey and about 500 km from the coast of Egypt, west of Syria and Lebanon (Lentini, 2015).

Situated at a biogeographic crossroad, Cyprus creates regions of rapid turnover (or high beta diversity) of species and habitats, leading to exceptionally high levels of species richness (Spector, 2002). It is considered as biodiversity "hotspot" area, as it is the only centre of birds' endemism in Europe and the Middle East. Also six out of its 11 wild mammals are endemic and sub-endemic (Médail & Quézel, 1997; Department of Environment, 2010; Hewitt, 2011; Tzirkalli *et al*., 2019).

The flora of Cyprus is comprised of 1700 plant native and non - native taxa. Of those being native 8.2% are endemic (Médail & Quézel, 1997; Tsintides *et al*., 2007; Zomeni and Bruggeman 2013; Tzirkalli *et al*., 2019). Insect diversity of Cyprus is also considered high as more than 7000 species are estimated to be present on the island and more than 10% are endemic (Tzirkalli *et al.,* 2019). Therefore it is necessary to do more researches to collect data about the insects' biodiversity.

1.3.1 INSECT CONSERVATION IN CYPRUS

There are many countries, that have well-documented insect faunas and they are far ahead with regard to invertebrate conservation; they often have long-term datasets that can highlight diversity hotspots and reveal declines or changes in insect species composition, relative abundance or geographic range (Taylor *et al*., 2018).

The availability of such comprehensive datasets means that insects can be included in conservation decisions, something that hasn't been adopted yet in Cyprus. A broad-scale national inventory is thus required to determine what Cyprus's insect biodiversity assets are and how they are distributed spatially (diversity hotspots, centres of endemism, evolutionary refugia etc.) to inform reserve design and optimisation of resources for conservation management.

The Natura 2000 network of protected areas almost covers 18% of the EU territory (Nieto *et al.,* 2014). Until now, in Cyprus, a total of 40 Sites of Community Importance (SCI) and 30 Special Protection Areas (SPA) have been identified. In addition, 39 management plans have been prepared, including measures and actions for the conservation of natural habitats, species and the habitats of species (http://www.moa.gov.cy/moa/environment/environmentnew.nsf/page12_en/page12_en?OpenDocument).

Even though, many rare and scarce species have been lost from the wider landscapes, protected areas provide an essential tool in conservation even if these sites were never designated based on the presence of particular insect species (Nieto *et al.,* 2014).

In Cyprus there have been prepared management plans for the species *Euplagia quadripunctaria* and *Propomacrus cypriacus* (Department of Environment 2013). The conservation action aims to the creation of micro reserves for those species, through the protection and restoration of selected habitats, as well as the creation of new ones. The action objective is the construction of small ponds which will secure the availability of suitable habitat for *Euplagia quadripunctaria* in dry years, the protection of groups of aging trees which contain rotting stems that are known to provide habitat for *Promomacrus cypriacus*, as well as the planting of 2000 plants that are used by the targeted species throughout their biological cycle

(http://www.moa.gov.cy/moa/icostacy/icostacy.nsf/All/86C57CD6C7759B0FC22578DC002C4420?OpenDocument&print). In 2017, Sfenthourakis *et al*. suggested a taxonomic change of *Promomacrus cypriacus,* however they suggested conservation of the species as an endemic subspecies of *P. bimucronatus* (*Propomacrus bimucronatus cypriacus*).

Thymelicus acteon (VU), *Pseudophilotes vicrama* (VU) (Van Swaay and Warren, 1999), *Chelostoma comosum* (EN) (Nieto *et al.,* 2014), *Bucephaloptera cypria* (EN), *Pezotettix cypria* (LC), *Pyrgomorpha cypria* (LC), *Eupholidoptera cypria* (NT) (Hochkirch *et al.,* 2016) and *Ischnura intermedia* (NT) (De Knijf *et al.,* 2016; https://www.iucnredlist.org/) are some of the species that are threatened with extinction, according to the IUCN regional Red Listing guidelines, in Cyprus. However, the Natura 2000 network has underperformance for insect conservation. For that reason, it stresses the need for new complementary European and national policies, targeting the conservation of endemics and red listed insect species (ICOSTACY, 2011).

1.3.2 AKROTIRI WETLAND-STUDY AREA

The Akrotiri peninsula is located south-west of the southern port town of Limassol. It is bounded roughly by northing 34º 34' and 34º 39' and easting 33º 03' and 32º 54'. Most part of it is situated within the British Western Sovereign Base Area (WSBA), an area governed by the United Kingdom under an arrangement that dates from the establishment of the Republic of Cyprus in 1960 (Austin *et al.,* 2011; SBA Administration, 2012).

The climate at Akrotiri is Mediterranean with dry summers and mild winters. The warm season covers the period mid-June to late September, when precipitation is low. The cold season is from early December to late March, when precipitation is relatively high (average annual precipitation 370 mm, with a slightly increasing trend). The air humidity of the area is quite high, especially during the summer. The winds are typically light to moderate and the prevailing directions are from the west (SBA Administration, 2012).

The peninsula includes military installations such as RAF1 Station Akrotiri and satellite communication sites, the built-up area of Akrotiri village, agricultural plantations, forest, but also an internationally important wetland complex. The latter comprises Akrotiri Salt Lake and a number of adjacent internationally important saline and freshwater habitat types, including salt marsh, permanent and seasonal saline lagoons, sand flats, freshwater and saline reed beds and freshwater marsh. Moreover Akrotiri peninsula is the largest aquatic system in Cyprus, and one of the very few major Salt Lakes within the eastern Mediterranean in semi-natural condition that exhibits a wide range of saline and freshwater influences (SBA Administration, 2012).

This area has huge ecological value and is important for maintaining the biological diversity of the eastern Mediterranean biogeographic region, as it supports an appreciable number of rare, vulnerable or endangered species or subspecies of plant or animal (Akrotiri Peninsula Environmental Management Plan, 2012). A large part (2171 ha) of the peninsula is a classified RAMSAR site, an Important Bird Area (IBA) and a Special Protection Area (SPA), equivalent to the EU designation, according to the mirror law (26/2007) in the Cyprus Sovereign Base Areas (SBAs) and is also a candidate Special Area of Conservation (SAC) for habitats and species of wild flora and fauna (SBA Administration, 2012; http://www.akrotirimarsh.org/en/home).

Akrotiri hosts one of the largest, most pristine and ecologically complex examples of coastal ecosystems in Cyprus. This ecological complex hosts a diverse habitat mosaic, which has European interest and according to the provisions of the Protection and Management of Nature and Wildlife Ordinance 2007, includes priority habitats that are required protection through the designation of Special Areas of Conservation (SBA Administration, 2012). Under the Habitat Directive (Art. 3 and 4), those Special Areas of Conservation can ensure the favourable conservation status of each habitat type and species that are living in this habitat type, as they are received the necessary management or restoration measures of sites (European Commission, official website (a)).

It is one of the most important botanical hotspots in Cyprus, with estimates of more than 800 indigenous plant taxa. Fourteen of the thirty-five endangered plant species included in Cyprus Plants Red Data Book occur only at Akrotiri Peninsula (SBA Administration, 2012). The fauna includes more than 300 bird species out of which more than 90 are included in Schedule 1 to the Game and Wild Birds Directive (species of birds for whose protection Special Protection Areas are prescribed) and a rich herpetofauna as well as invertebrate and fish fauna (SBA Administration, 2012).

Habitats, plants and birds at the peninsula are well studied but the rest of the interest, particularly invertebrates, reptiles, mammals, amphibians and fish require further work, including at the baseline level (SBA Administration, 2012).

1.3.2.1 THREATS TO BIODIVERSITY IN AKROTIRI WETLAND – INVASIVE ALIEN SPECIES –*ACACIA SALIGNA*

Anthropogenic threats are the more significant source of the deterioration, destruction and loss for ecosystems (habitats and species) in Cyprus. Impacts are mainly generated by ecosystem changes due to humane activities (land use change, pollution of surface runoff, habitat fragmentation, use of biocides hormones and chemical products), together with natural system modification. Introduction of alien species is also responsible for habitat deterioration and local species extinction being thus a potential major threat (Christodoulou, 2003; Samways, 2007; Department of Environment, 2010; SBA Administration, 2012; Ministry of Agriculture, Natural Resources and Environment, 2014; Peyton *et al*., 2019).

The introduction of alien plants and animals to new regions has generated much concern among biologists. Invasive alien plants can displace indigenous ones and overrun ecosystems, even affecting local hydrology. Such impacts inevitably reduce local insect diversity, which can return when the alien plants are removed (Samways, 2007). Moreover, there are also enormous economic losses incurred due to the impacts of invasive alien species (Howarth and Ramsay, 1991; Hadjikyriakou and Hadjisterkotis, 2002; Bezemer *et al.,* 2014).

It has been well documented that invasive alien species are one of the greatest threats to biological diversity globally, often stated as second after habitat loss, and the highest threat on many island ecosystems, like Cyprus (Howarth and Ramsay, 1991; Hadjikyriakou and Hadjisterkotis, 2002; Christodoulou, 2003; Bezemer *et al*., 2014; Peyton *et al.,* 2019). The islands' vulnerability to biological invasions, is due to the limited habitat availability and to the small populations with restricted genetic diversity (Peyton *et al.*, 2019).

Acacia saligna, an invasive alien plant species introduced in Cyprus last century, is the biggest threat of biodiversity, in Akrotiri peninsula, as it has been spreading rapidly, displacing indigenous species of flora and promoting monocultures of acacia, causing damage to biodiversity (Wilson *et al.,* 2011; Akrotiri Peninsula Environmental Management Plan, 2012; Pescott *et al*., 2018). The plantations of *Acacia saligna* at Akrotiri salt lake began in 1896 in order to dry up the marshland around the salt lake and improve the climate of the neighbouring villages (Christodoulou, 2003).

In October 2015 and March 2017, a team from the Centre for Ecology and Hydrology (CEH), Wallingford, UK together with British Forces Joint Services Health Unit (JSHU) undertook surveys for alien species in Cyprus. The surveys were directed within four key areas: the Akrotiri Forest, phrygana within both the Akrotiri and Dhekelia Sovereign Base Areas (SBAs), and the Fassouri marsh. The aim of the project was to characterise the plant communities associated with invasive and non-invasive woody alien plants. The main focuses for the surveys were *Acacia saligna, Casuarina cunninghamiana, Eucalyptus camaldulensis* and *E. gomphocephala,* and *Symphyotrichum squamatum* (syn. *Aster squamatum*) (Pescott *et al.,* 2017; Peyton *et al.,* 2017).

According to the surveys of invasive aliens that took place in Akrotiri, phrygana and maquis at Akrotiri SBAs appeared much less invaded than the salt marsh surrounding the Akrotiri forest north of the salt lake. In addition, richness was considerably higher in the phrygana sites compared to the Akrotiri forest and salt marsh. On the other hand, no richness difference was found between Acacia-invaded plots and plots containing native woody species (Peyton *et al.,* 2017).

Invasive alien species are notoriously difficult and expensive to control or eradicate, and it is important to try to find the most efficient management strategies. Prevention is usually more cost-effective than post-entry eradication or containment (Taylor and Hastings, 2004), but obviously it is already too late to use this option for *Acacia saligna* in Cyprus. So, the management of acacia needs to be based on a long-term strategy and appropriate methods, as the species is very persistent and forms a very viable seed-bank (Akrotiri Peninsula Environmental Management Plan, 2012).

Acacia management needs to make use of an integrated control strategy within a dedicated management plan, which may be required by different control measures. Moreover management should be site-specific and include measures for the restoration of the natural vegetation and the reduction of disturbance (Brundu *et a*l., 2018).

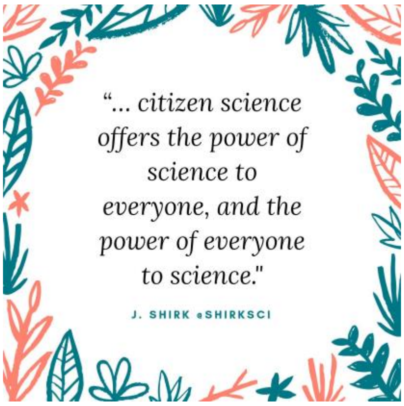
Acacia management can be at different points in their life cycle (seedlings and adult plants). Plants can be managed through hand pulling and grazing (seedlings), herbicide treatment, fire or mechanical control, or limiting recruitment opportunities by changing land management, etc. Moreover, reducing seed production (e.g. biological control, hormonal control to reduce seed set or flowering, etc.) can limit both spread rates and the build-up of seed banks (Wilson *et al.,* 2011; Brundu *et al*., 2018).

Eradicating *A. saligna* from Cyprus is under investigation by the Cyprus Forest department (Wilson *et al.,* 2011). The eradication project of *A. saligna* has been initiated from two Natura 2000 sites (Department of Environment, 2010), in Cyprus Cape Greko National Forest Park and in the mist netting hotspot of Cape Pyla (ΚΥΚΠΕΕ; Shialis *et al*., 2016). However, removal programme in the mist netting hotspot of Cape Pyla was put on hold. (Shialis *et al*., 2016). Moreover in 2012, a LIFE project proceeded to the removal of invasive species (mostly acacias) in wetland of Oroklini Lake (Department of Forests, 2012). Finally, in 2019, the Department of Forests proceeded to the removal *A. saligna* in Gila and Mavralis National Forests (Department of Forests, 2019).

Some more invasive alien species that have already arrived, established and threaten biodiversity, ecosystems and human well-being in Akrotiri peninsula include *Oxalis pes-caprae* (Bermuda buttercup), *Gambusia holbrooki* (Eastern Mosquitofish), *Pterois miles* (Lionfish) and *Fistularia commersonii* (Cornetfish) (https://www.ris-ky.eu/cydas).

1.4 CITIZEN SCIENCE

A major challenge faced by ecologists is effectively communicating the reliance of humanity on nature, raising the importance of nature in public and political agendas, and thus influencing individuals and decision-makers (Pocock *et al.,* 2016). Moreover, citizen science projects strive to help participants understanding of and support for science, the environment, and Earth stewardship, to learn about the organisms they are observing and to experience the process by which scientific investigations are conducted (Bonney *et al.,* 2009; Dickinson *et al.,* 2012).



Citizen science projects have been remarkably successful in advancing scientific knowledge, and contributions from citizen scientists now provide a vast quantity of data about species occurrence and distribution around the world. Developing and implementing public data-collection projects that yield both scientific and educational outcomes requires significant effort (Bonney *et al.,* 2009, Schröter *et al.,* 2017).

There are three benefits of integrating citizen scientists into ecological monitoring networks. Those are the extension of spatial and temporal sampling effort, the reduction of costs (lowest expense per observation), and the educational and recreational benefits for citizens (Bonney *et al.,* 2009; Kremen *et al.,* 2011; Dickinson *et al*., 2012; Carvell et al., 2016). Moreover, with recent reductions in research funding and increases in the scale and severity of environmental issues, interest in the application of citizen science is now greater than ever (Bonney *et al*., 2009).

Citizen science, however, clearly differs from traditional science, which is carried out by professional scientists. Citizen science' data are collected by volunteers and for that reason their concerns are exist that data quality will be poor. Also, particular concern cause errors due to misidentification of species, as could have important implications for conservation policy and decision making (Kremen *et al.,* 2011; Gardiner *et al.,* 2012). However, this can be avoided by the participation of scientists for the verification of the citizens or by ongoing training the citizens (Gardiner *et al.,* 2012).

Citizen science is a quite new sector in Cyprus. Some of citizen science projects relevant to insects that take place in Cyprus are:

- The Three Mosquiteers, which is a pilot citizen scientist initiative aimed at raising awareness regarding vector borne diseases, vector ecology and management of native and non-native mosquitoes in Cyprus that educate children of all ages but also adults regarding vectors of disease such as mosquitoes (https://scistarter.org/the-three-mosquiteers),
- The Cyprus Butterfly Study Group formed to encourage conservation of the island's butterflies. It complements a very active Butterfly Recording Scheme for Cyprus, thereby building a valuable database for current and future conservation projects by the Cypriot authorities (http://www.cyprusbutterflies.co.uk/),
- Cyprus Dragonfly Study Group is a third age citizen science programme. The aim of this programme is to monitor selected dragonfly sites on a regular basis, and to build up a picture of their flight seasons, and health of populations (http://paphos3rdage.org/dragonfly-study-group),

1.4.1 POLLINATORS MONITORING SCHEME - KÝPROS: FLOWER-INSECT TIMED COUNT (FIT COUNTS)

Monitoring pollinators and other beneficial insects is more challenging than for some already monitored taxa such as birds, because: i) there are many more species; ii) most of these cannot be identified to species in the field so capture/collection of specimens becomes necessary; iii) there are comparatively few volunteer recorders or citizen science initiatives focussed on pollinating insects; and iv) identification of collected specimens is time-consuming and requires specialist skills. Therefore, the sampling design, taxonomic resolution and range of species or groups to be monitored, levels of volunteer and professional involvement, data handling and support tools will all be critical to the success of any long-term pollinator monitoring framework (Carvell *et al.,* 2016; Schröter *et al.,* 2017).

Pollinator Monitoring scheme of Cyprus (Poms-ký), is a programme designed for citizen scientists by a Research Team in the UK and modified by RIS-Ký project team, to enable us to provide much-needed data on the state of the Cyprus's insect pollinators, especially wild bees and hoverflies, the role they fulfil in supporting farming and wildlife, and their interactions with native and non-native plants (http://www.ris-ky.eu/poms-ky; BWARS). Also, this new monitoring scheme can be implemented by professionals and volunteers and is the first scheme in Cyprus for monitoring pollination services to crops or wild plants.

1.5 AIM OF THIS STUDY

This study examines the diversity of the insect fauna of Akrotiri in relation to habitat characetristics, and evaluates how insect diversity and abundance varies among six different habitat types in Akrotiri peninsula, five dominated by native species and conserved by the EU Habitats Directive (Dir. 92/43/EEC): (1) Thermo-mediterranean riparian galleries and Coastal lagoons, (2) arborescent matorral with *Juniperus phoenicea*, (3) the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, (4) the Mediterranean tall humid grasslands, (5) the *Sarcopoterium spinosum* phryganas and (6) the *Acacia saligna-Eucalyptus* spp. plantations (non-native forest).

Our hypothesis is, that few errand-less abundant insect species would be found in man - made habitats, as invasive plants would affect the plant communities, making those habitats less suitable for native, specialised insects.

An additional aim of this project was to design and test a national pollinator monitoring scheme (Poms-ký) that would provide the scientific evidence base for assessing changes in Cyprus pollinators' populations (abundance and distribution) and communities (diversity and composition) and also the interactions between them and native and non-native plants.

Same as before, we hypothesised that non-native plants would have negative impacts on species richness and abundant of pollinating insects, especially on some native, specialised pollinators.

2 MATERIALS AND METHODS

All surveys were conducted in the area of Akrotiri Peninsula, in Cyprus (map below shows the sampling areas). Six different habitat types (five dominated by native species (habitat classification have been done by EUNIS and the EU Habitats Directive Annex I habitat types) and one invaded by *Acacia saligna*) were selected:

1. Thermo-mediterranean riparian galleries (*Nerio-Tamariceteae*) (code 92D0) and Coastal lagoons 1150*/ (Thermo-mediterranean riparian galleries and Coastal lagoons),
2. *Juniperus phoenicea* arborescent matorral (code 5212) /(arborescent matorral with *Juniperus phoenicea*),

3. Mediterranean pine forests with endemic mesogean pines (code 9540) and *Sarcopoterium spinosum* phryganas (code 5420) /(Mediterranean pine forests and *Sarcopoterium spinosum* phryganas),
4. Reed beds (habitat type CY02) and Mediterranean tall humid grasslands of the *Molinio-Holoschoenion* (code 6420) /(Mediterranean tall humid grasslands),
5. *Sarcopoterium spinosum* phryganas (code 5420) and
6. *Acacia saligna-Eucalyptus spp.* plantations.

Figure 1: Geographic location of the six habitat types studied in Akrotiri peninsula, in Cyprus. Numbers one-six shows the sampling areas: (1) Thermo-mediterranean riparian galleriesand Coastal lagoons, (2) *Juniperus phoenicea* arborescent matorral, (3) Mediterranean pine forests with endemic mesogean pines and *Sarcopoterium spinosum* phryganas, (4) Reed bedsand Mediterranean tall humid grasslands of the Molinio-Holoschoenion, (5) *Sarcopoterium spinosum* phryganas and (6) *Acacia saligna-Eucalyptus* spp. plantations.

2.1 Study Area – the different habitats

Thermomediterranean riparian galleries (*Nerio-Tamariceteae*) (code 92D0) and Coastal lagoons 1150*/ (Thermomediterranean riparian galleries and Coastal lagoons)

This area is at an altitude 1 m and it has 220 m distance from the sea. The habitat consists of Thermomediterranean riparian galleries and Coastal lagoons. They are the most common type of riparian woody vegetation in Cyprus and spread throughout the island. Coastal lagoons are considered as priority habitat of European interest requiring strict protection through SAC designation. The main plant species present in this habitat are *Sarcopoterium spinosum*, *Thymus capitatus*, *Cistus* spp., *Convolvulus oleifolius*, *Fumana* spp., *Helianthemum obtusifolium*, *Helianthemum* spp., *Helichrysum conglobatum*, *Lithodora hispidula* subsp. *Versicolor*, *Micromenia* spp., *Noaea mucronata*, *Onosma fruticosa*, *Phagnalon rupestre*, *Teucrium* spp., *Tamarix tetragyna*, *Asparagus stipularis* and *Ruppia maritima* (Delipetrou and Christodoulou, 2010; AP Marine Environmental Consultancy Ltd & Atlantis Consulting Cyprus Ltd 2012; SBA ADMINISTRATION, 2012).

Figure 2: Photographs above shows the sampling area of Thermo-Mediterranean riparian galleries and Coastal lagoons habitat type.

THE JUNIPER FORMATIONS (*JUNIPERUS PHOENICEA* ARBORESCENT MATORRAL) (CODE 5212) / (ARBORESCENT MATORRAL WITH *JUNIPERUS PHOENICEA*)

This area is at an altitude 8 m and it has 980 m distance from the sea. The junipers extend all along the coastal zone of Cyprus. The dominant species is *Juniperus phoenicea.* Other characteristic species present are *Ceratonia siliqua*, *Cistus* spp., *Myrtus communis, Olea europaea, Pistacia lentiscus, Prasium majus, Rhamnus oleoides* subsp. *graecus, Thymus capitatus, Thymelaea hirsuta* (Delipetrou and Christodoulou, 2010; SBA Administration, 2012).

Figure 3: Photographs above shows the sampling area of arborescent matorral with *Juniperus phoenicea.*

THE MEDITERRANEAN PINE FORESTS WITH ENDEMIC MESOGEAN PINES (CODE 9540) AND *SARCOPOTERIUM SPINOSUM* PHRYGANAS (CISTO-MICROMERIETEA) (CODE 5420) / (THE MEDITERRANEAN PINE FORESTS AND *SARCOPOTERIUM SPINOSUM* PHRYGANAS)

This patch is covered by a mixture of Mediterranean pine forest and phrygana with *Sarcopoterium spinosum* (altitude: 2 m, distance from the sea: 3260 m). Mediterranean pine forests with endemic species of Mediterranean pine, represented in Cyprus by the Calabrian pine (*Pinus brutia*), and they are the most extensive forest habitat of Cyprus. This habitat consists of pine forest with endemic Mesogean pines and *Cisto-Micromeretea* phrygana. The main plant species present in this habitat are *Pinus brutia, Pistacia lentiscus, Juniperus phoenicea, Pistacia terebinthus, Lithodora hispidula* subsp. *versicolor, Convolvulus oleifolius, Fumana* spp.*, Onosma fruticosa, Phagnalon rupestre, Teucrium* spp.*, Cistus* spp.*, Myrtus communis, Rhamnus oleoides* subsp. *graecus, Thymus capitatus, Sarcopoterium spinosum, Helianthemum obtusifolium, Helianthemum* spp.*, Helichrysum conglobatum, Lithodora hispidula* subsp. *versicolor* and *Noaea mucronata* (Delipetrou and Christodoulou, 2010; SBA Administration, 2012).

Figure 4: Photographs above shows the sampling area of Mediterranean pine forests and *Sarcopoterium spinosum* phryganas habitat type.

THE REED BEDS (HABITAT TYPE CY02) AND MEDITERRANEAN TALL HUMID GRASSLANDS OF THE *MOLINIO-HOLOSCHOENION* (CODE 6420) / (MEDITERRANEAN TALL HUMID GRASSLANDS)

This patch is covered by a mixture of Reed beds and sedges (habitat type CY02) and Mediterranean tall-herb and rush meadows (altitude: -1 m, distance from the sea: 1700 m). It is a unique representative wet grassland at the Fasouri Marsh. Reed beds and sedges (habitat code CY02) are consisted of tall herb communities of brackish and fresh water swamps of the class Phragmito-Magnocaricetea. Mediterranean tall humid grasslands of the *Molinio-Holoschoenion* include communities of fresh or brackish water, in meso- to eutrophic, basic soils reaching full bloom in summer. The main species are *Phragmites australis*, *Imperata cylindrica*, *Calystegia sepium*, *Cladium mariscus*, *Saccharum ravennae*, *Juncus* spp., *Scirpus maritimus*, *Panicum repens, Teucrium scordium* subsp. *scorpioides, Centaurea calcitrapa* subsp. *angusticeps, Cyperus* spp*., Juncus* spp*., Lotus corniculatus, Lythrum junceum, Ononis spinosa, Pulicaria dysenderica* subsp. *Uliginosa, Ranunculus peltatus, Saccharum ravennae, Schoenus nigricans, Scirpoides holoschoenus* (Delipetrou and Christodoulou, 2010; AP Marine Environmental Consultancy Ltd 2012; SBA Administration, 2012).

This area is also very important as it hosts some rare and threatened species that are included in the The Red Data Book of the Flora of Cyprus, such as *Mentha aquatica, Euphorbia pubescens* and *Baldelia ranunculoides*, this area is the only known site in Cyprus where these plants exist (BirdLife Cyprus, 2017). Those species are found in an area very close to the reed beds and the tall humid grasslands, in Akrotiri marsh.

Figure 5: Photographs above show the sampling area of Mediterranean tall humid grasslands.

THE *SARCOPOTERIUM SPINOSUM* PHRYGANA (CODE 5420) / THE *SARCOPOTERIUM SPINOSUM* PHRYGANA

This patch is at an altitude 4 m and it has 3320 m distance from the sea. *Cisto-Micromeretea* phrygana are the most common type of vegetation in the coastal Thermi-Mediterranean zone and the central plain of Cyprus, but also occur at higher altitudes throughout the island. The main plant species occurring are *Sarcopoterium spinosum*, *Thymus capitatus*, *Cistus* spp., *Convolvulus oleifolius*, *Fumana* spp*., Helianthemum obtusifolium*, *Helianthemum* spp*., Helichrysum conglobatum*, *Lithodora hispidula* subsp*. versicolor*, *Micromenia* spp., *Noaea mucronata*, *Onosma fruticosa*, *Phagnalon rupestre*, *Teucrium* spp. (Delipetrou and Christodoulou, 2010; SBA Administration, 2012).

Figure 6: Photographs above shows the sampling area of *Sarcopoterium spinosum* phryganas habitat type.

The *Acacia saligna-Eucalyptus* spp. forest stand / *Acacia saligna-Eucalyptus* spp. plantations

The forest of Akrotiri peninsula is north to the salt lake (Peyton *et al*., 2017). The area is flat and part of it is below or at the sea level (altitude: -1 m, distance from the sea: 3506 m). Planting was carried out on raised banks, on the north side of the salt lake on heavy clay, saline soils, and the main species planted, were *Acacia saligna*, *Eucalyptus camaldulensis, E. gomphocephala* and *Casuarina cuningchamiana* (Christodoulou 2003; Pescott *et al.,* 2018). *Acacia saligna* and *Casuarina cuningchamiana* are both currently invasive on the peninsula (Hadjikyriakou and Hadjisterkotis 2002; Pescott *et al.,* 2018), whereas the eucalypt species are not, although casual occurrences can be found in the forest/ plantations and elsewhere on the island (Pescott *et al.,* 2018).

Figure 7: Photographs above shows the sampling area of *Acacia saligna-Eucalyptus* spp. plantations habitat type.

2.2 Sampling methods

Different sampling methods were employed in order to get a good picture of the insect community. Beat sheet sampling, pan trapping and pitfall trapping are some of the most common used methods to collect insects. The choice of method is determined by the insect taxa that scientists are interested in and the purpose of the study (Krüger and Fiore, 2018).

2.2.1 Beat tray sampling (beating umbrellas, beating trays, ground sheets)

Beat sheet sampling is used to estimate the relative abundance, species richness and diversity of insects (e.g. caterpillars, true bugs, many beetles) that feed and/or rest on trees, shrubs and other plants (White, 1975; Mississippi Entomological Museum, http://extreme-macro.co.uk).

Beat sheet sampling was carried out over eight months, commencing on November 2018 and ending in June 2019. The samples were collected once a month, from all the different habitats. Specimens were obtained from three different individual plants from each habitat. Plants were selected randomly in each habitat.

For the plants that were smaller and low to the ground, the sheet was placed on the ground next to the plant. Otherwise, for plants that were higher, the beat sheet was held in one hand while hitting the plant several times with a stick held in the other hand. The insects that were on the plant fell onto the sheet during beating and were collected quickly, with an aspirator, before they escaped (Mississippi Entomological Museum) and placed in a falcon tube with an amount of 70% alcohol.

In the winter period, some of the samplings were not carried out because of weather conditions (too much rain and wind).

2.2.2 Pan trap

Pan traps are a passive sampling approach which is used to collect phytophagous and pollinating insects in a qualitative manner, or may be used when quantitative samples are required, as in many ecological studies (Leong and Thorp, 1999). Obtaining a representative sample is important in probability sampling, as generalizability is one of the most important goal. According to generalizability, the results of a study will tell us something about a group larger than the collected sample. Core principle of probability sampling is that all elements of target population have an equal chance of being selected for inclusion in the study (Blackstone, 2012). In conclusion, pan trap samples can yield estimates of the relative abundance of particular insect taxa and have the potential to yield estimates of species richness and diversity also (Leong and Thorp, 1999).

The pan traps consisted of small plastic bowls of different colours, typical colours (yellow, dark blue, and white) employed previously for surveying insect populations for ecological studies were used. Pans were situated on the ground, in a way to form an isosceles triangle-shaped (Leong and Thorp 1999; Nielsen *et al.,* 2011; Joshi *et al.,* 2015).

In each study site / type of habitat 3 clusters of pan traps were placed. Each cluster contained three pan traps, one of each colour (9 pan traps per habitat in total). The pan traps left active for 24 h (Cope *et al*., 2019), during 3 rounds of sampling, from April till June 2019. Insects approach the bowls, land on the water, and drown. Collected insects were temporarily stored in 70% alcohol before they were pinned for identification.

Some encountered problems were the heavy wind that dislodged the traps and that people or animals interfered with them.

2.2.3 Pitfall traps

Pitfall traps have been used over the years to collect a wide variety of animals (arthropods, reptiles, amphibians and mammals) (Clark and Blom; 1992) and they can also yield estimates of the relative abundance of particular insect taxa and have the potential to yield estimates of species richness and diversity.

Pitfall traps were arranged in groups of five, in a line (three repetitions per habitat). The traps ran for eight months (from November 2018 till June 2019). The traps were reset every three-four weeks and left for around a week. To reset the trap, we had to pull out the top plastic/ wooden glass only; and put the specimen into a falcon tube. Collected insects were temporarily stored in 70% alcohol before they were pinned for identification.

Sometimes the traps filled up with rainwater, windblown sand, leaves or invertebrates. Moreover, sometimes pitfalls were flooded out, were dry out, were interfered with by people, their content was drunk by animals or were trampled by them. They also stopped working when a twig fallen in those allows all trapped invertebrates to escape (Telfer 2010). This happened twice in the area of *Acacia saligna - Eucalyptus* spp*.* stands. Another common problem was that the action of wind and rain eroded effectively the soil from around the rim of the trap so that the trap stands proud from the surface and only invertebrates were able to climb into the trap (Telfer 2010). For all these reasons sometimes we had to reset the traps.

2.2.4 SORTING CATCHES (SAME FOR ALL TYPES OF TRAPPING)

Identification included the separation of arthropods into broad taxonomic groups (e.g. Hemiptera, Hymenoptera, Coleoptera, Lepidoptera etc.) and subsequently genus or species for each individual where possible. When species identification was not possible, a special code given to the samples, to make them single out of other samples. Other pieces of information that provided were the dates of the trapping period and the habitat type. The identification relied on body-shape, the shape of antennas, legs and mouth, and on patterned of wings, by the use of low magnification stereoscope.

2.3 CITIZEN SCIENCE- POLLINATOR MONITORING SCHEME KÝPROS

2.3.1 MEETING WITH STAKEHOLDERS

The workshop took place at Akrotiri Environmental Education Centre and thereto attended by the Poms-ký team, some insect experts, the teachers of the Centre and some volunteers. Aim of the Workshop was to modify the British Pollinator Monitoring Scheme (PoMS) in a way that would fit the needs of Cyprus. For this reason, we designed a recording form (http://www.ris-ky.eu/poms-ky) (form is provided in Appendix 2).

We also undertook the first steps to design an insect and plant guide, to help volunteers learn to identify some species of plants and insects that they may encounter during Flower-Insect Timed Count (FIT Count). The Flower guide includes both native and non-native plants that grow in Cyprus. Finally we began to design an environmental education programme (mini Poms-ký) which will take place in the Environment Centres of Cyprus and will include a lecture that will explain the importance of insects and help young people in understanding the differences between different groups' levels, an insects' collection and the mini FIT count.

2.3.2 POMS-KÝ METHODOLOGY (INSECT TIMED COUNT)

The Poms-ký monitoring scheme involves a ten-minute Flower-Insect Timed Count (FIT Count) to count all the insects that are already present or land on a patch (50cm x 50cm quadrat) of target flowers (of either a native or a non-native plant) in that ten-minute period. Counts can be made at any location where there are flowers, and whenever the weather is suitable (dry, warm and sunny). FIT Count offers an accessible and enjoyable approach to generating data on abundance and visitation rates at least at group level.

Figure 8: Example of a patch (50cm x 50cm quadrat), of a target flower.

MINI POMS-KÝ METHODOLOGY (INSECT TIMED COUNT)

The mini Poms-ký monitoring scheme is very similar to Poms-ký but designed for children. The mini Poms-ký survey involves only a five-minute Flower-Insect Timed Count (FIT Count) and every FIT count involves a group of five young people (nine to twelve years old). The mini Poms-ký monitoring scheme involves counting again all the insects that are already present or land on a patch (50cm x50cm quadrat) of target flowers (of either a native or a non-native plant) but this time in that five-minute period. Counts can be made at any location where there are flowers, and whenever the weather is suitable (dry and warm weather).

2.3.3 WORKSHOPS

Two workshops took place at the Akrotiri Environmental Education Centre (28 of February and 29 of May 2019). The aim of the workshops was to inform citizens about Poms-ký.

The age of the citizens was between thirty to sixty years old. Counts were done around the Akrotiri Peninsula area, and the areas that were used were either native habitats or non-native habitats. Moreover, the target flowers that these FIT Counts were focused on, were both native and non-native plants of Cyprus.

2.3.4 DATA COLLECTION AND FORM TESTING

Flower-Insect Timed Counts (FIT Counts) were carried out for eight months (from November 2018 till June 2019) in different habitat types (native and non-native), in many different areas as Akrotiri, Episkopi, Parekklisia, Troodos, Kyrenia, Famagusta etc. During the entire period of the eight months, a total 194 FIT Counts were done, in five different habitat types (salt marsh, acacia scrub, semi-natural (grassland with wild flowers, dry scrub and woodland), commercially managed/agricultural and urban habitats), on different plant species (native and non-native plants). Some of the FIT Counts were collected by citizen-scientists. Those FIT Counts offered an approach to collect data on abundance and visitation rates at the insect' group level. They also offered educational and recreational benefits for citizens/participants and the opportunity of testing the forms and the methodology in order to help us improve them, as this scheme is taking place in Cyprus for the first time.

2.4 STATISTICAL ANALYSIS

2.4.1 CLASSICAL ENTOMOLOGICAL SURVEY METHODS

Data from the beat sheet sampling were analysed using Generalized Linear Model (GLM) with a Poisson distribution, in R-3.6.1, with habitat type, plant type and seasonality as fixed variables, GLMs were used to test the difference in abundance and species richness of pollinating insects, predatory insects and other insects’ categories within different habitat types (no random effect was used). The Poisson process is a commonly used starting point for modelling stochastic variation of ecological count data (like number of individuals of a species counted or number of species) around a theoretical expectation (Lindén and Mäntyniemi, 2011). In this study, Poisson process was used to describe the abundance and biodiversity indices of different insect categories, in six different habitat types. The habitats were defined as stable through the study period. Model validation was conducted by visually checking residual plots for violations of model assumptions. Table 1 presents describe the fixed and the random effects of this model.

Data from the pan traps were analysed using Generalized Linear Mixed Model (GLMM), in R-3.6.1, with a Poisson distribution with habitat type and trap colour as fixed effects, and trap number as a random effect, to test the abundance and species richness of pollinating insects, predatory insects and other insects’ categories to varying habitat types. Model validation was conducted by visually checking residual plots for violations of model assumptions. Table 1 presents describe the fixed and the random effects of this model.

Data from the pitfall traps were analysed using Generalized Linear Mixed Model (GLMM), in R-3.6.1, with a Poisson distribution with habitat type and seasonality as fixed effects, and location as a random effect, to test also the abundance and species richness of pollinating insects, predatory insects and other insects' categories to varying habitat types Model validation was conducted by visually checking residual plots for violations of model assumptions. Table 1 presents describe the fixed and the random effects of this model.

Diversity measures, including Shannon-Weiner index $\boldsymbol{H = -\sum_{i=1}^{R} pilnpi}$, and Simpson's index $\boldsymbol{D = 1/\sum_{i=1}^{R} pi^2}$, where, ***p*** is the proportion (***n/N***) of individuals belonging to one genus (n) found in the collection, ***N*** is the total number of individuals, ***ln*** is the natural log and ***R*** is the total number of genera in the sample, were calculated for each collection period. Shannon-Weiner index combines evenness and richness into a single measure and assumes that all genera are represented in a sample while Simpson's index gives more weight to common genera and assumes that the few rare ones with only a few representatives will not affect the diversity values (O'Brien & Arathi, 2019).

Table 1: Selected models for abundance of pollinating insects

	Beat sheet sampling		**Pan trapping**		**Pitfall trapping**	
Response	Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
All insects abundance	Habitat type Plant type Seasonality		Habitat type Trap colour	Trap number	Habitat type Seasonality	Location
Pollinator Abundance	Habitat type Plant type Seasonality		Habitat type Trap colour	Trap number	Habitat type Seasonality	Location

2.4.2 POLLINATOR MONITORING SCHEME OF CYPRUS - FIT COUNTS

To assess variations in abundance of pollinating insects, three models were used:

The first model tests the hypothesis that the abundance of insects is affected by plant type, habitat type and seasonality. GLMM with a Poisson distribution was fitted to the number of insects counted using plant type (native or non-native plants), habitat type (salt marsh, acacia scrub, semi natural, commercial managed/ agriculture and urban habitats) and sampling season as fixed variables and location, which was the (address) name of the sampling area, as random effect to avoid pseudo-replication (Full model).

The second model tests the hypothesis that the abundance of insects is affected by plant type and habitat type. GLMM with a Poisson distribution using plant type (native or non-native plants) and habitat type (salt marsh, acacia scrub, semi natural, commercial managed/ agriculture and urban habitats) as fixed variables and location as random effect (Reduced model1).

The third model tests the hypothesis that the abundance of insects is affected by seasonality. GLMM with a Poisson distribution using sampling season as fixed variables and location as random effect (Reduced model2).

These models tested the abundance of Honey bees, Solitary bees and Bees (this category includes honey bees, solitary bees and bumble bees), Flies (this category includes hoverflies and other flies), Pollinators (which includes honey bees, solitary bees, bumble bees, wasps, hoverflies, other flies, butterflies, moths and beetles) and All insects (which includes the pollinators and other beneficial insects and invertebrates), in different habitats (Table 2 shows within separate sections for honey bees, solitary bees, bees, flies pollinators and all insects. Columns shows the fixed and the random effects). Model validation was conducted by visually checking residual plots for violations of model assumptions.

Table 2: Selected models for abundance of pollinating insects					
Honey bees		**Solitary bees**		**Bees**	
Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Habitat type Plant type Seasonality	Location	Habitat type Plant type	Location	Habitat type Plant type Seasonality	Location
Flies		**Pollinators**		**All insects**	
Fixed effects	Random effects	Fixed effects	Random effects	Fixed effects	Random effects
Habitat type Plant type Seasonality	Location	Habitat type Plant type Seasonality	Location	Habitat type Plant type Seasonality	Location

3 RESULTS

3.1 CLASSICAL ENTOMOLOGICAL SURVEY METHODS

3.1.1 BEAT SHEET SAMPLING

3.1.1.1 POLLINATORS

During the entire sampling period (November 2018 - June 2019), a total of 283 individuals of pollinating insects were recorded by beat sampling, from the six different habitats (eight surveys in each habitat type). Of those, 59 were beetles (Coleoptera), 41 flies (Diptera), 182 bees (Hymenoptera), 1 butterfly (Lepidoptera). Figure 9 shows pollinators collected from the six different habitats, during the study period including from native and non-native plants.

Abundance of pollinators was higher in the Mediterranean pine forests and *Sarcopoterium spinosum* phrygana, and in the Thermo-mediterranean riparian galleries and Coastal lagoons compared to the other habitats. The highest abundance was recorded in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. Significantly lower abundance was found in the arborescent matorral with *Juniperus phoenicea*, and in the *Sarcopoterium spinosum* phrygana compared to the other habitat types. The lowest abundance was recorded in the arborescent matorral with *Juniperus phoenicea*. There were no significant differences observed in pollinating insect abundance between the different types of habitats.

The number of individuals sampled in different seasons was significantly higher in summer and significantly lower in spring and autumn compared to the other seasons. The lowest abundance was recorded in spring.

When the number of pollinators between native and non-native plants was compared, the abundance of pollinating insects was higher in native plants compared to non-native plants. However, this difference was not statistically significant.

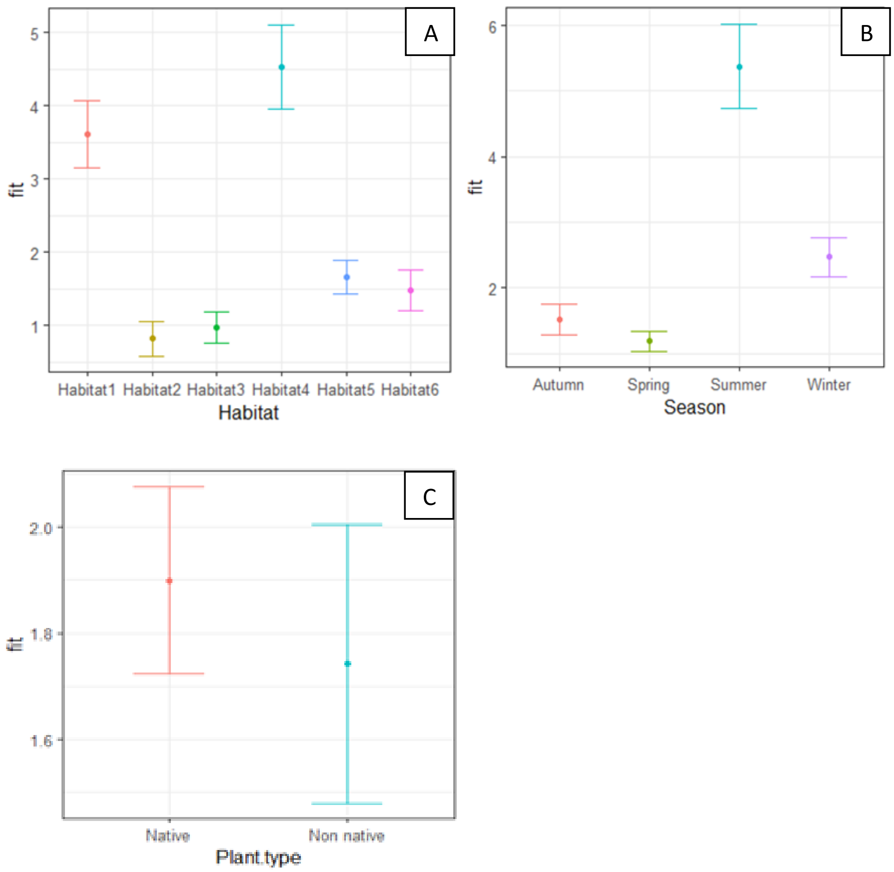


Figure 9: Effect of habitat type (A), seasonality (B) and flower type (native or non- native plants) (C) on abundance of pollinating insects, from beat sheet sampling. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

sampling, from the six different habitats (eight surveys in each habitat type). Of those 44 were beetles (Coleoptera), 4 earwigs (Dermaptera), 3 bugs (Hemiptera), 1 parasitic Hymenoptera, 1 mantis (Mantodea) and 3 lacewings (Neuroptera). Figure 10 shows predators collected from the six different sampling habitats, during the study period including from native and non-native plants.

Abundance of insect predators was greater in the *Sarcopoterium spinosum* phrygana compared to the other five habitat types when they were collected by the beat sheet method. The lower abundance was recorded in *Acacia saligna-Eucalyptus* spp. plantations. However, there were no statistically significant differences between the habitats.

The number of individuals sampled in different seasons was higher in the autumn and lower in the summer. However there were no statistically significant differences between the sampling seasons.

When the number of predators between native and non-native plants was compared, the number of individuals sampled from non-native plants was significantly higher than the number sampled from native plants.

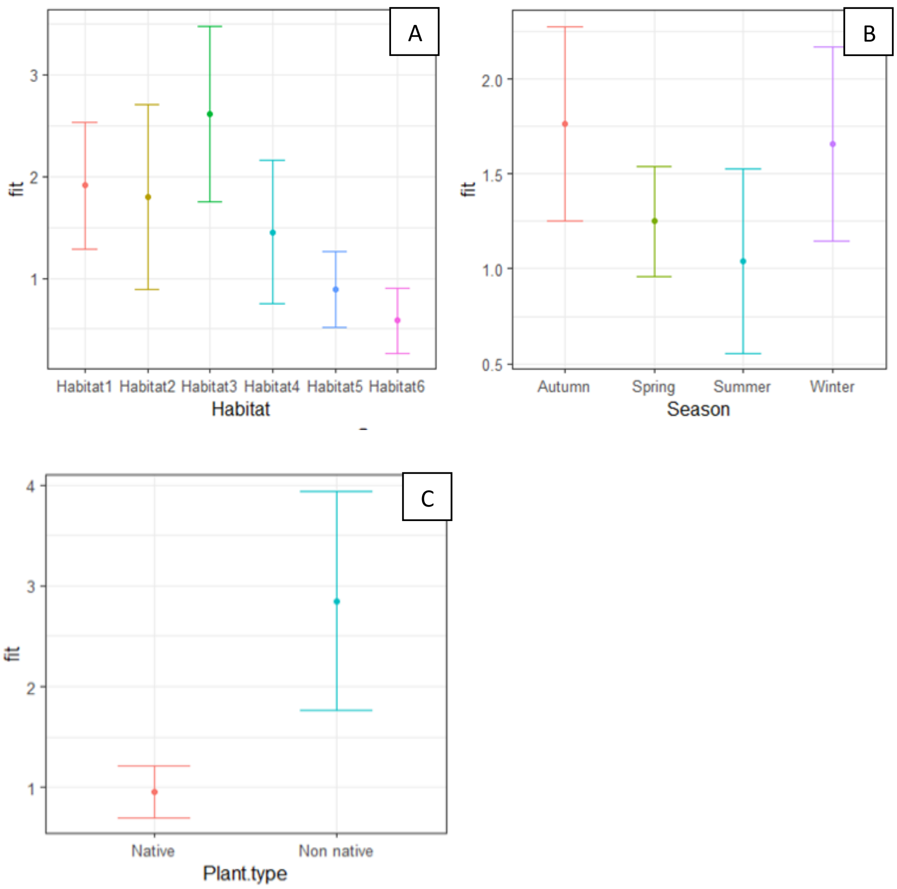


Figure 10: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of predator insects, from beat sheet sampling. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

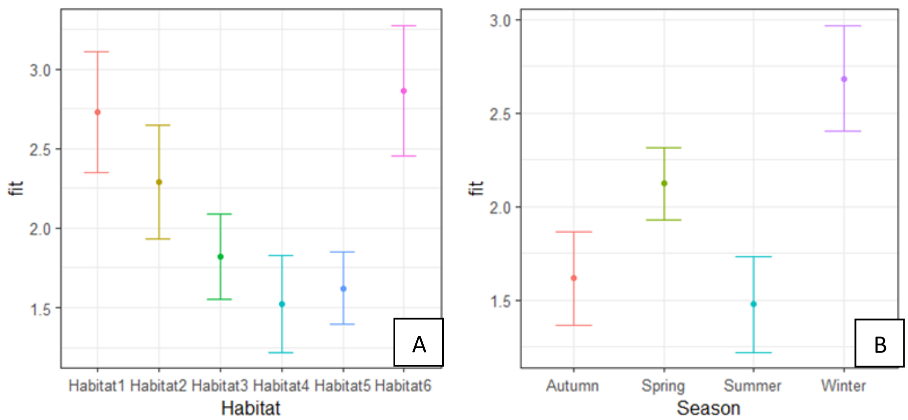
***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

During the entire sampling period, a total of 315 individuals of other insects' categories were recorded by beat sampling, from the six different habitats (eight surveys in each habitat type). Of those 26 were beetles (Coleoptera), 7 flies (Diptera), 4 bees (Hymenoptera), 150 bugs (Hemiptera), 1 termite (Isoptera), 98 booklice (Psocoptera), 2 fleas (Siphonaptera), 6 thrips (Thysanoptera) and 21 caddisflies (Trichoptera). Figure 11 shows other insect categories collected from the six different sampling habitats, during the study period including from native and non-native plants.

Abundance of other insect categories was higher in the *Acacia saligna-Eucalyptus* spp. plantations compared to the other habitats. Lower numbers of insects was sampled in the Mediterranean pine forests and *Sarcopoterium spinosum* phrygana. However there were no statistically significant differences between the habitat types.

The number of individuals sampled in different seasons was significantly higher in the winter compared to other seasons. The abundance of other insect categories was lower in summer compared to the other seasons. However there were no statistically significant differences between autumn and summer.

The number of individuals sampled from non-native plants was higher than number that the number of individuals sampled from native plants. However, this difference was not statistically significant.



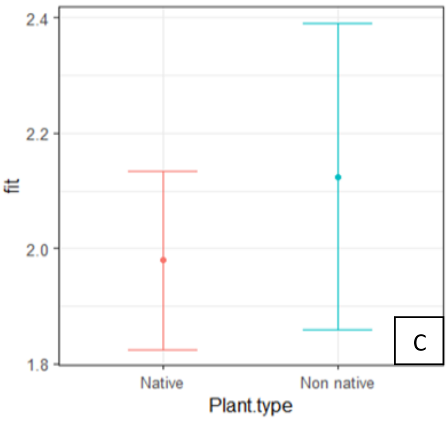


Figure 11: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of other insects' categories, from beat sheet sampling. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

Abundance and diversity indices were calculated separately for total insects and pollinators from beat sampling in the different habitats.

The abundance of total insects (Figure 12) from beat sampling in the different habitats was higher in the Mediterranean tall humid grasslands and lower in the arborescent matorral with *Juniperus phoenicea*. On the other hand the abundance of pollinating insects in the Mediterranean pine forests and *Sarcopoterium spinosum* phrygana and were lower in the arborescent matorral with *Juniperus phoenicea* (Figure 9 (A)).

Diversity indices for the total of insects and pollinating insects, in each habitat, were shown in Table 3 (A and B). Peak of total insects' diversity values were recorded in the *Sarcopoterium spinosum* phryganas while lower values of diversity were in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. Peak of pollinators' diversity values were recorded in the arborescent matorral with *Juniperus phoenicea* while lower values of diversity were in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas.

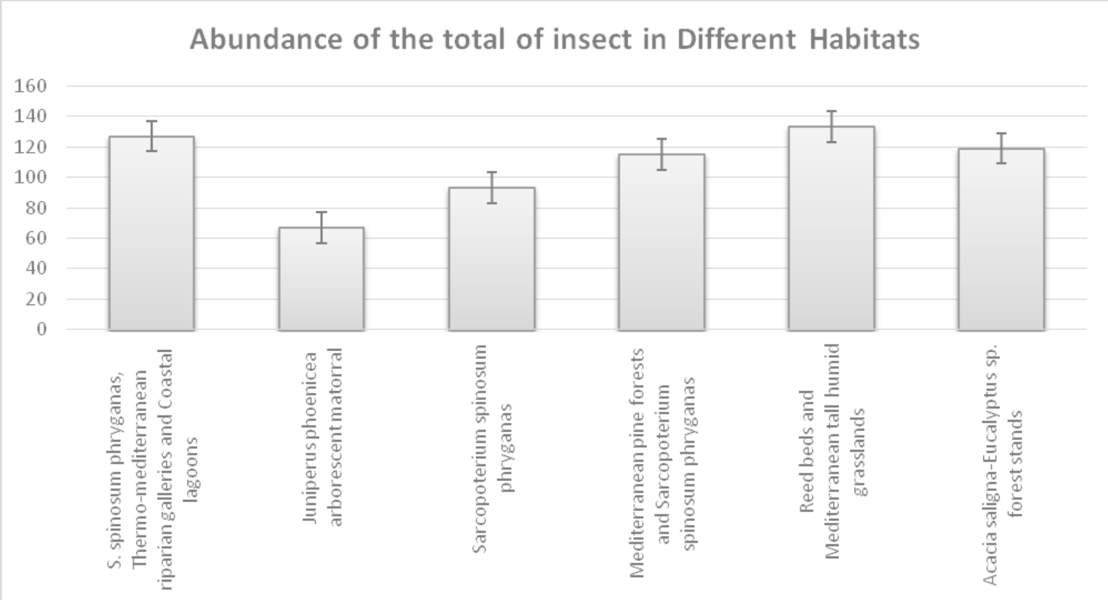


Figure 12: Abundance of the total of insects from beat sheet sampling, in different habitat types.

Table 3: Diversity indices of the total of insects (A) and pollinating insects (B) from beat sheet sampling, in different habitat types

	Thermo-mediterranean riparian galleries and Coastal lagoons	**Arborescent matorral with *Juniperus phoenicea***	**Mediterranean pine forests and *Sarcopoterium spinosum* phryganas**	**Mediterranean tall humid grasslands**	***Sarcopoterium spinosum* phryganas**	***Acacia saligna-Eucalyptus* spp. plantations**
A. Diversity indices of the total of insects						
Shannon	2.73012	2.72055	3.35108	1.73662	3.08158	2.6056
Simpson's dominance	8.61132	7.56998	19.1774	2.37305	12.7168	8.18082
B. Diversity indices of Insect Pollinators						
Shannon	2.6982	10.889	5.6471	1.2551	3.65111562	3.1232
Simpson's dominance	1.3489	2441	2.1808	0.5481	1.78512299	1.6978

3.1.2 PAN TRAPPING

3.1.2.1 POLLINATORS

During the entire sampling period (April - June 2019), a total of 2467 individuals of pollinating insects were recorded from the six different habitats (three surveys in each habitat type), of which 345 were beetles (Coleoptera), 1554 flies (Diptera), 566 bees (Hymenoptera) and 2 butterflies (Lepidoptera). Figure 13 shows pollinators collected from the six different sampling habitats, during the study period.

Abundance of pollinators was significantly higher in the Thermo-mediterranean riparian galleries and Coastal lagoons, in the *Sarcopoterium spinosum* phryganas and in the Mediterranean tall humid grasslands compared to the other types of habitat. The higher abundance was recorded in the Mediterranean tall humid grasslands and the lower abundance was recorded in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. There were no significant differences observed in pollinating insect abundance between the different types of habitat.

The number of individuals sampled in different traps' colour was significantly higher in yellow traps, while there was no significant difference between the number of pollinators in blue and white traps.

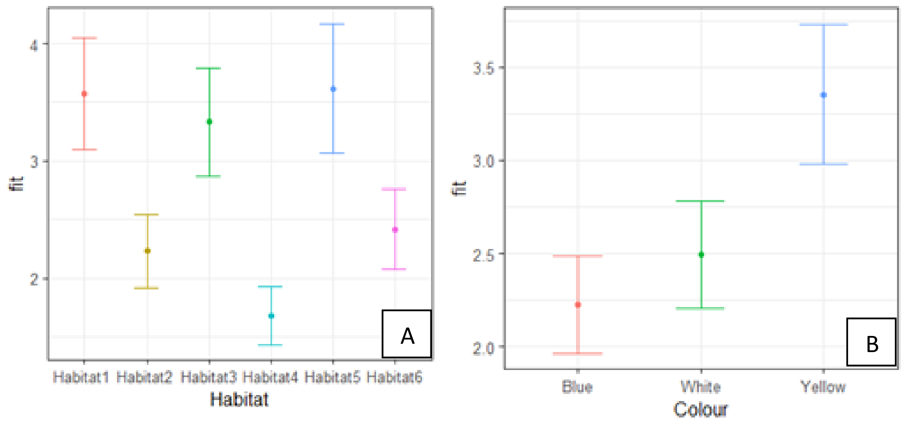


Figure 13: Effect of habitat type (A) and trap' colour (B) on abundance of pollinating insects, from pan trapping. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

3.1.2.2 PREDATORS

During the whole sampling period, a total of 60 insect predators were recorded by Pan trapping method, from the six different habitats (three surveys in each habitat type). Of those 39 were beetles (Coleoptera), 14 flies (Diptera), 4 odonata (Odontognathae) and 3 orthoptera.

The models that have been fitted to the abundance of predator insects was the same that have been fitted to the abundance of pollinating insects and other insect' categories, but given the low sample size (n = 60) and residual patterns found in the residual versus fitted values plot, the results were deemed unreliable and therefore they are not presented here.

3.1.2.3 OTHER INSECTS

During the entire sampling period, a total of 1089 individuals of other insect' categories were recorded by pan trapping, from the six different habitats (three surveys in each habitat type). Of those 39 were beetles (Coleoptera), 170 mayflies (Ephemeroptera), 322 flies (Diptera), 351 bugs (Hemiptera), 8 bees (Hymenoptera), 3 lacewings (Neuroptera), 8 booklice (Psocoptera), 1 fleas (Siphonaptera), 171 thrips (Thysanoptera) and 16 caddis flies (Trichoptera). Figure 14 shows other insects' categories collected from the six different sampling habitats, during the study period including.

Abundance of other insect' categories were significantly greater in the arborescent matorral with *Juniperus phoenicea* and in the *Acacia saligna-Eucalyptus* spp. plantations compared to the other types of the habitats. Higher abundance was recorded in the arborescent matorral with *Juniperus phoenicea*. The abundance was significantly lower in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas and in the Mediterranean tall humid grasslands. Fewer other insect' categories were sampled in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. However there were no statistical significantly differences between the different types of habitats.

The number of individuals sampled in yellow traps was significantly higher than the blue or the white traps. The degree of correlation between the different traps' colour was significant.

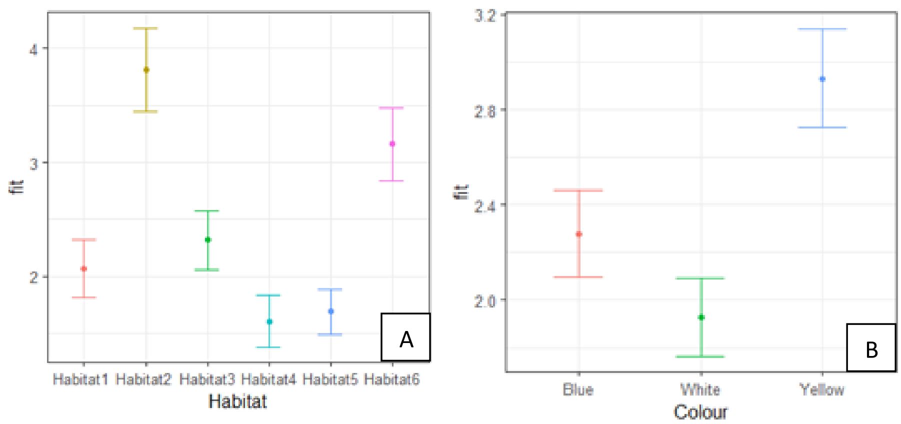
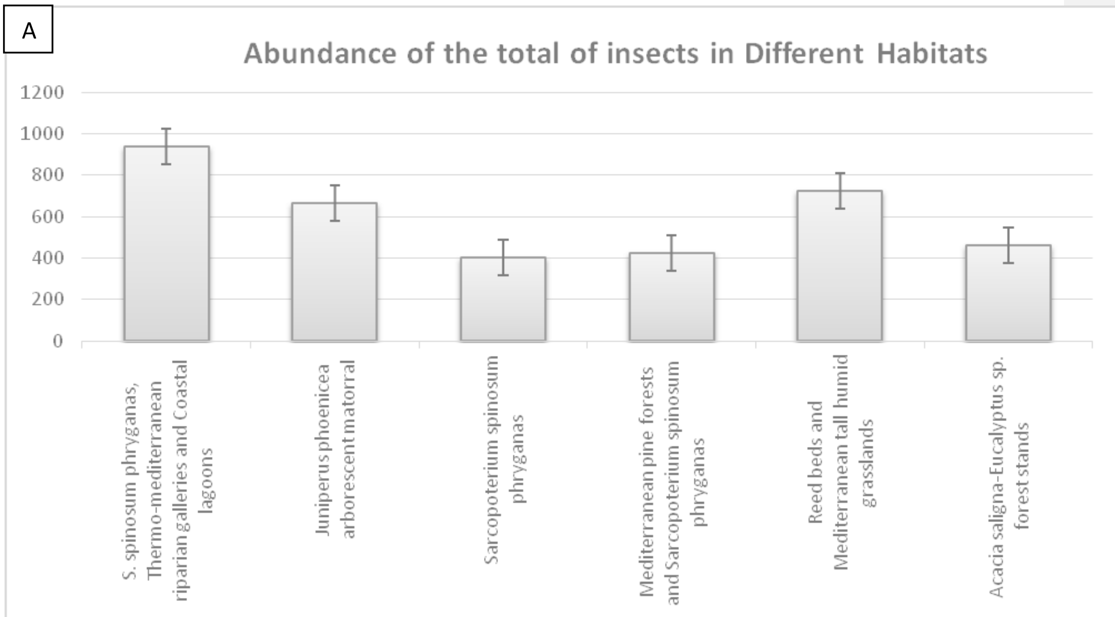


Figure 14: Effect of habitat type (A) and trap' colour (B) on abundance of other insects' categories, from pan trapping. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

Abundance and diversity indices were calculated separately for total insects, pollinators and solitary bees from pan trapping in the different habitats.

The abundance of total insects (Figure 15 (A)) from pan trapping in the different habitats was higher in the Thermo-mediterranean riparian galleries and Coastal lagoons and lower in the *Sarcopoterium spinosum* phryganas than other habitats. The abundance of pollinating insects (Figure 13 (A)) was higher Thermo-mediterranean riparian galleries and Coastal lagoons, in the *Sarcopoterium spinosum* phryganas and in the Mediterranean tall humid grasslands and lower in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. On the other hand the abundance of solitary bees (Figure 15 (B)) was higher in the Mediterranean tall humid grasslands and lower in the *Acacia saligna-Eucalyptus* spp. plantations.



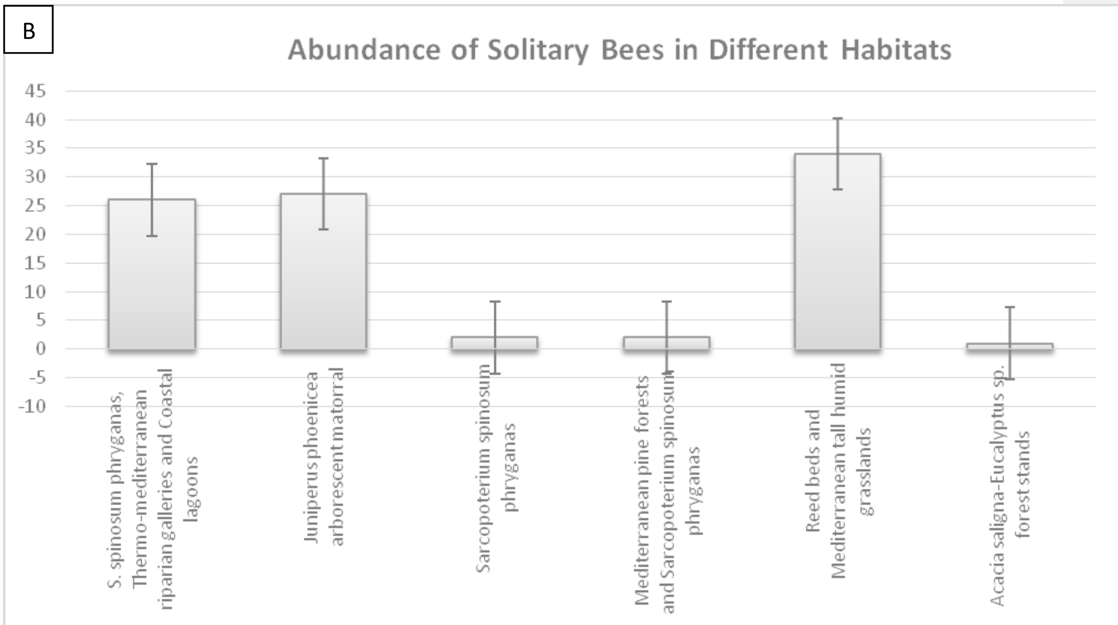


Figure 15: Abundance of the total of insects (A) and solitary bees (B) from pan trapping, in different habitat types.

Diversity indices for the total of insects, pollinating insects and solitary bees, in each habitat, were showed in Table 4 (A, B and C). Peak of the total of insects' diversity values were recorded in the Mediterranean tall humid grasslands, while lower values of diversity were in the Thermo-mediterranean riparian galleries and Coastal lagoons. On the other hand, the higher value of the Shannon's diversity index for pollinating insects recorded in the arborescent matorral with *Juniperus phoenicea*, while the higher value of the Simpson's diversity index for pollinating insects recorded in *Acacia saligna-Eucalyptus* spp. plantations. Lower values of diversity indices were in the Thermo-mediterranean riparian galleries and Coastal lagoons. Finally, peak of solitary bees' diversity values were recorded in the Thermo-mediterranean riparian galleries and Coastal lagoons, while lower values of diversity were in the *Acacia saligna-Eucalyptus* spp. plantations.

Table 4: Diversity indices of the total of insects (A), pollinating insects (B) and solitary bees (C) from pan trapping, in different habitat types.						
	Thermo-mediterranean riparian galleries and Coastal lagoons	**Arborescent matorral with *Juniperus phoenicea***	**Mediterranean pine forests and *Sarcopoterium spinosum* phryganas**	**Mediterranean tall humid grasslands**	***Sarcopoterium spinosum* phryganas**	***Acacia saligna-Eucalyptus* spp. plantations**
A. Diversity indices of the total of insects						
Shannon	5.757839904	12.35739	8.597163	9.015418	15.09122	10.60431
Simpson's dominance	2.794447055	3.252861	2.799975	3.031056	3.439531	3.027332
B. Diversity indices of Insect Pollinators						
Shannon	3.841220508	11.8292	5.08998	5.93312	9.54753	12.1316
Simpson's dominance	2.219426034	3.02868	2.28423	2.55794	2.89081	3.00301
C. Diversity indices of Solitary Bees						
Shannon	1.561252499	1.36465	0.69315	0.69315	1.55018	0
Simpson's dominance	4.225	3.12876	2	2	3.80263	1

3.1.3 PITFALL TRAPPING

3.1.3.1 POLLINATORS

During the entire (November 2018 - June 2019) sampling period, a total of 6171 individuals of pollinating insects were recorded by pitfall trapping, from the six different habitats (eight surveys in each habitat type). Of those 118 were beetles (Coleoptera), 919 flies (Diptera), 5130 bees (Hymenoptera) and 4 butterflies and moths (Lepidoptera). Figure 16 shows pollinating insects collected from the six different sampling habitats, during the study period.

Abundance of pollinators was significantly greater in the *Sarcopoterium spinosum* phryganas compared to the other of the habitats. The abundance of pollinators was significantly lower in the Thermo-mediterranean riparian galleries and Coastal lagoons and in the arborescent matorral with *Juniperus phoenicea* compared to the other types of habitats. There were no significant differences observed in pollinating insect abundance between those two types of habitat.

The number of individuals sampled in different seasons was significantly higher in summer and significantly lower in winter compared to the other seasons. There were significantly differences between all the seasons.

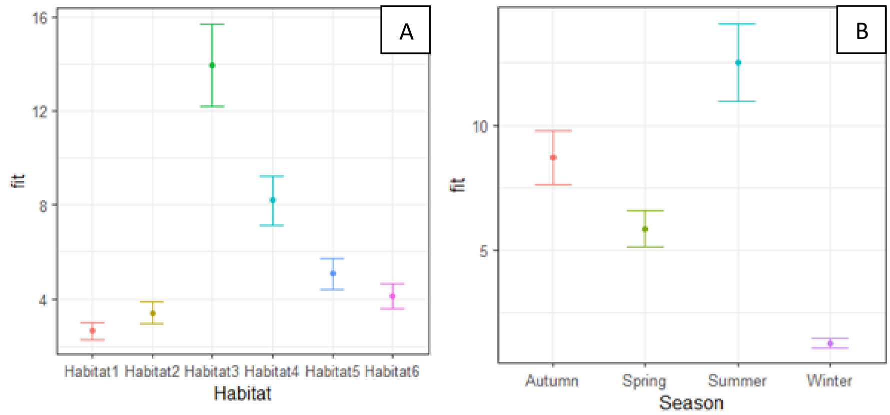


Figure 16: Effect of habitat type (A) and seasonality (B) on abundance of pollinating insects, from pitfall trapping. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

3.1.3.2 PREDATORS

During the entire sampling period, a total of 946 individuals of predator insects were recorded by pitfall trapping, from the six different habitats (eight surveys in each habitat type). Of those 922 were beetles (Coleoptera), 4 earwig (Dermaptera), 5 flies (Diptera), 1 bug (Hemiptera), 1 mantis (Mantodea), 3 lacewings (Neuroptera) and 10 grasshoppers or crickets (Orthoptera). Figure 17 shows predator insects collected from the six different sampling habitats, during the study period.

Abundance of predators was significantly higher in the arborescent matorral with *Juniperus phoenicea* and significantly fewer in the Thermo-mediterranean riparian galleries and Coastal lagoons compared to other habitats. However, there were no significant differences observed in pollinating insect abundance between other types of habitats.

The number of individuals sampled in different seasons was higher in the autumn and significantly lower in the summer compared to other seasons. There were no significant differences between autumn and winter, but also spring and winder.

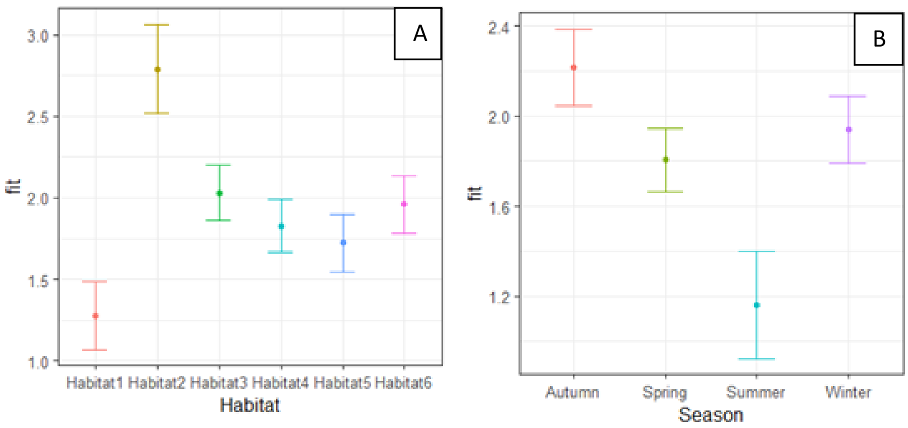


Figure 17: Effect of habitat type (A) and seasonality (B) on abundance of predator insects, from pitfall trapping. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

3.1.3.3 Other insects

During the entire sampling period, a total of 3499 individuals of other insect categories were recorded by pitfall trapping, from the six different habitats (eight surveys in each habitat type). Of those 342 were beetles (Coleoptera), 9 Dictyoptera, 2836 flies (Diptera), 150 bugs (Hemiptera), 72 parasitic Hymenoptera, 2 termites (Isoptera), 17 booklice (Psocoptera), 1 fleas (Siphonaptera), 13 thrips (Thysanoptera), 38 Thysanura and 19 caddis flies (Trichoptera). Figure 18 shows other insect' categories collected from the six different sampling habitats, during the study period.

Abundance of other insect' categories were significantly higher in the Reed beds and Mediterranean tall humid grasslands compared to the other habitats. The number of other insect' categories found in Thermo-mediterranean riparian galleries and Coastal lagoons, in the arborescent matorral with *Juniperus phoenicea* and in the *Sarcopoterium spinosum* phryganas, was significantly lower than the number of other insect' categories found in *Acacia saligna-Eucalyptus* spp. plantations, in the Mediterranean tall humid grasslands and in the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas. Fewer other insect' categories were sampled in the Thermo-mediterranean riparian galleries and Coastal lagoons. However, the number of other insects' categories recorded was not significantly different among different habitat types, with the exception of the number of other insects' categories recorded in the Mediterranean tall humid grasslands.

The number of individuals sampled in different seasons was significantly higher in the autumn and lower in the winter, compared to the other seasons. However, there were no significant differences between spring and summer, summer and winter.

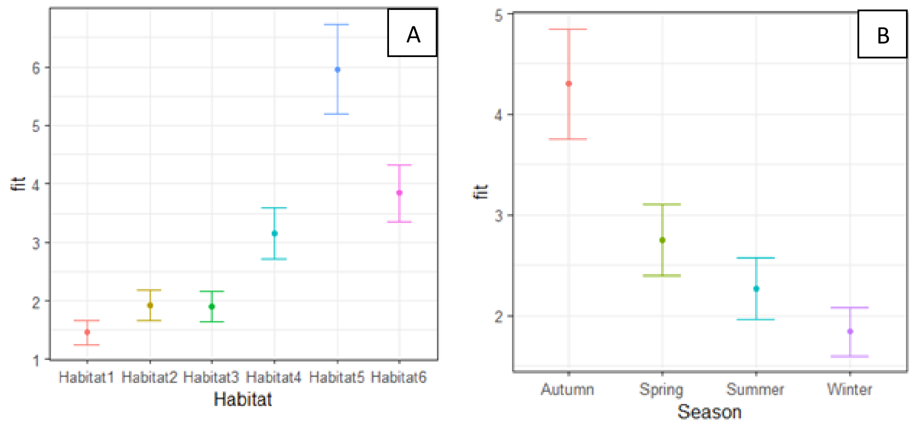


Figure 18: Effect of habitat type (A) and seasonality (B) on abundance of other insects' categories, from pitfall trapping. Results are plotted on the scale of the linear predictor. Errors bars = standard error.

***Habitat1**: Thermo-mediterranean riparian galleries and Coastal lagoons, **Habitat2**: arborescent matorral with *Juniperus phoenicea*, **Habitat3**: *Sarcopoterium spinosum* phryganas, **Habitat4**: Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, **Habitat5**: Mediterranean tall humid grasslands, **Habitat6**: *Acacia saligna-Eucalyptus* spp. plantations.

Abundance and diversity indices were calculated separately for the total of insects and pollinators from pitfall trapping in the different habitats.

The abundance of the total of insects (Figure 19) and pollinating insects (Figure 16 (A)) from pitfall trapping in the different habitats was higher in the *Sarcopoterium spinosum* phryganas and lower in the Thermo-mediterranean riparian galleries and Coastal lagoons, compared to other habitats.

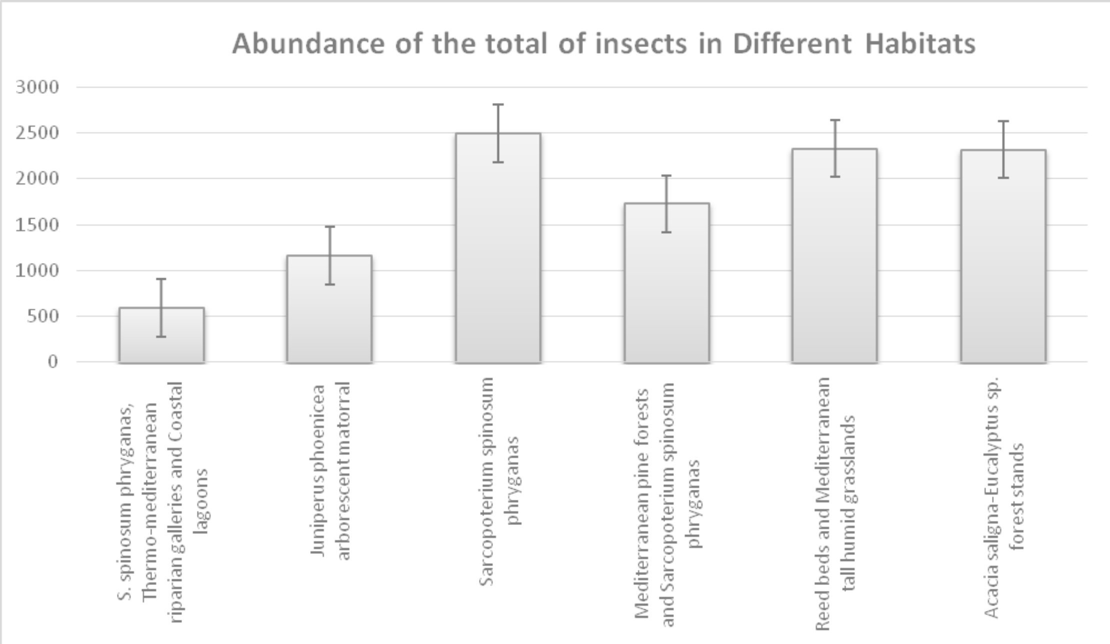


Figure 19: Abundance of the total of insects from pitfall trapping, in different habitat types.

Diversity indices for total insects and pollinating insects, in each habitat, were showed in Table 5 (A and B). Peak of total insects' diversity values were recorded in the Thermo-mediterranean riparian galleries and Coastal lagoons, while lower values of diversity were in the *Sarcopoterium spinosum* phryganas. On the other hand, the higher value of the Shannon's diversity index for pollinating insects recorded in Thermo-mediterranean riparian galleries and Coastal lagoons, while the higher value of the Simpson's diversity index for pollinating insects recorded in Mediterranean pine forests with endemic mesogean pines and *Sarcopoterium spinosum* phryganas. Lower values of diversity were in the *Sarcopoterium spinosum* phryganas.

Table 5: Diversity indices of the total of insects (A) and pollinating insects (B) from pitfall trapping, in different habitat types.						
	Thermo-mediterranean riparian galleries and Coastal lagoons	**Arborescent matorral with *Juniperus phoenicea***	***Sarcopoterium spinosum* phryganas**	**Mediterranean pine forests and *Sarcopoterium spinosum* phryganas**	**Mediterranean tall humid grasslands**	***Acacia saligna-Eucalyptus* spp. plantations**
A. Diversity indices of the total of insects						
Shannon	5.53841	4.86044	1.63549045	4.09984677	2.85225	4.60377
Simpson's dominance	2.7571	2.42092	1.2942723	2.047996166	1.65251	2.22359
B. Diversity indices of Insect Pollinators						
Shannon	1.37195	0.586895	0.208124459	1.146649595	0.552954	0.99674
Simpson's dominance	2.20494	1.235471	1.057300954	2.368214613	1.211868	1.455074

3.2 Pollinator Monitoring Scheme of Cyprus - FIT COUNTS

The best model, in each case, was selected according to Akaike information criterion (AIC) (Table 6 and Table 7 show the degrees of freedom (df), the AIC for each model and the difference between the AIC of the different models, for all cases: Honeybees, Solitary bees, Bees, Flies, Pollinators and All insects). In all cases Full model was the best model, with an exception of solitary bees, where the best model was the Reduced model1.

Table 6: AIC number of the different models of pollinating insects						
	Full model		**Reduced model1**		**Reduced model2**	
	df	AIC	df	AIC	df	AIC
All insects	10	1643.577	7	1686.467	5	1827,468
Solitary bees	10	364.1067	7	364.8845	5	389,0410
Honeybees	10	465.7096	7	478.0645	5	505,1445
Bees	10	666.813	7	685.5055	5	708,9476
Flies	10	750.4262	7	762.4612	5	785,7637
Pollinators	10	1263.876	7	1295.942	5	1370,078

Table 7: Difference between the AIC of the different models			
	Full model and the Reduced model1	**Full model and the Reduced model2**	**Reduced model1 and the Reduced model2**
All insects	-42.89	-183.89	-141
Solitary bees	-0.78	-24.93	-24.16
Honeybees	-12.35	-39.43	-27.08
Bees	-18.69	-42.13	-23.44
Flies	-12.03	-35.34	-23.30
Pollinators	-32.06	-106.2	-74.14

3.2.1 POLLINATING INSECTS

During the entire (November 2018 - June 2019) period, a total of 972 individuals of pollinating insects were recorded by Fit counts, from salt marsh (27 surveys), *Acacia* scrub (3 surveys), semi-natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Of those 272 bees (107 solitary bees, 141 honeybees, 5 bumblebees and 19 wasps), 329 flies (67 hoverflies and 262 other flies), 74 butterflies and moths, 114 were beetles and 183 small insects. Figure 20 shows the abundance of pollinating insects recorded on native and non-native plants, in different habitat types, through the recording period.

Given a differences in AIC of -32.06 (Full model and Reduced model1) -106.2 (Full model and Reduced model2) and -74.14 (Reduced model1 and Reduced model2), the most parsimonious model that best described the variability in the data was the full model that included a random effect for location and the variable habitat type, plant type and seasonality as fixed effects.

Abundance of pollinating insects was significantly higher in *Acacia* scrub and in semi-natural habitats compared to the other habitats. Higher abundance was recorded in *Acacia* scrub. The number of pollinating insects recorded was significantly lower in commercial managed/ agriculture habitats compared to the other habitats. However, the number of pollinators recorded was not significantly different among the different habitat types, with the exception of the number of pollinators recorded in commercial managed / agriculture habitats.

Significantly higher abundance was found in summer and significantly lower in winter, compared to the other seasons. There were no significant differences between autumn and spring.

When the number of pollinators recorded between native and non-native plants was compared, the number of individual pollinating insects was higher when the FIT counts were done on native plants than on non-native plants. However, there were no significant differences between them.

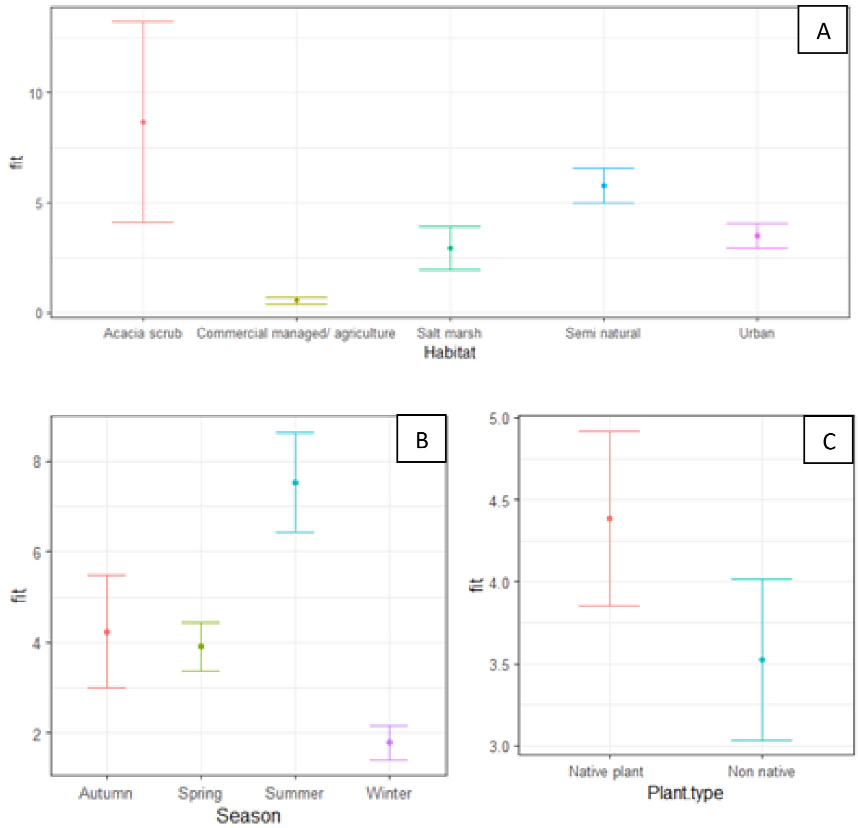


Figure 20: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of pollinating insects, recorded by using the FIT counts. Results are plotted on the scale of the linear predictor. Errors bars= standard error.

3.2.2 HONEY BEES

During the entire period, a total of 141 individuals of honey bees were recorded by FIT counts, from salt marsh (27 surveys), Acacia scrub (3 surveys), semi natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Figure 21 shows the abundance of honey bees recorded on native and non-native plants, in different habitat types, through the recording period.

Given a differences in AIC of -12.35 (Full model and Reduced model1) -39.43 (Full model and Reduced model2) and -27.08 (Reduced model1 and Reduced model2), the most parsimonious model that best described the variability in the data was the full model that included a random effect for location and the variable habitat type, plant type and seasonality as fixed effects.

Abundance of honey bees was greater in salt marsh and lower in urban habitats compared to the other types of habitats. However, there was no significant difference in the number of honey bees recorded between the different habitat types.

Significantly higher abundance was found in autumn compared to the other seasons. The abundance of honey bees was lower in the spring compared to the winter, the summer and the autumn. However, there were no significant differences between spring, summer and winter.

When the number of honeybees recorded between native and non-native plants was compared, the number of individual insects was significantly higher when the FIT counts were done on non-native plants than on native plants.

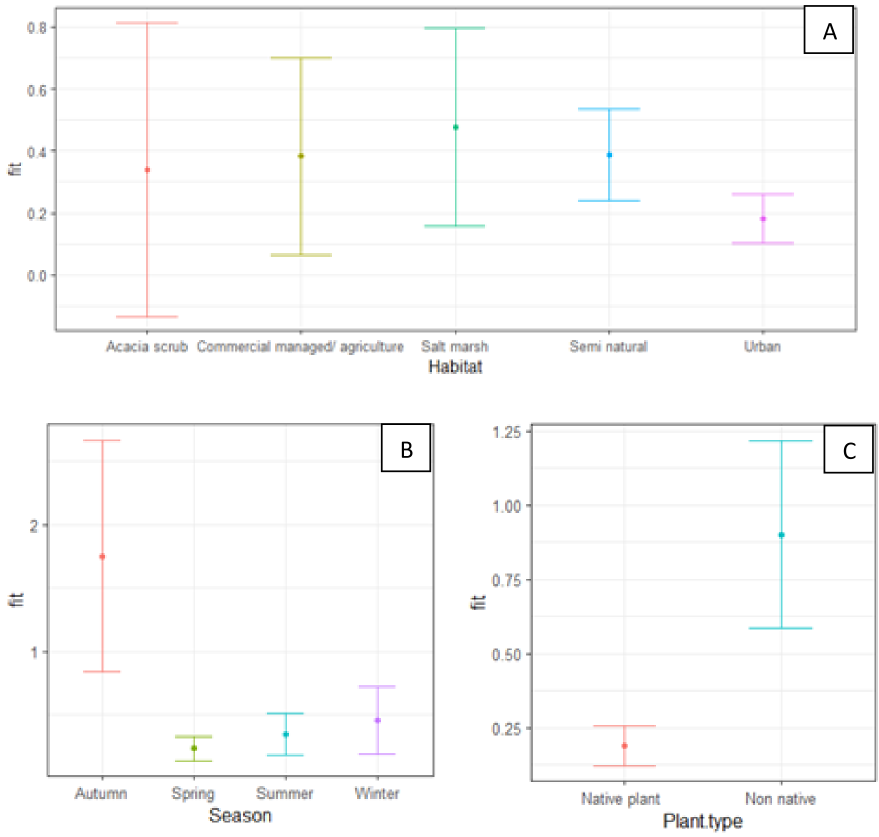


Figure 21: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of honey bees, recorded by using the FIT counts. Results are plotted on the scale of the linear predictor. Errors bars= standard error.

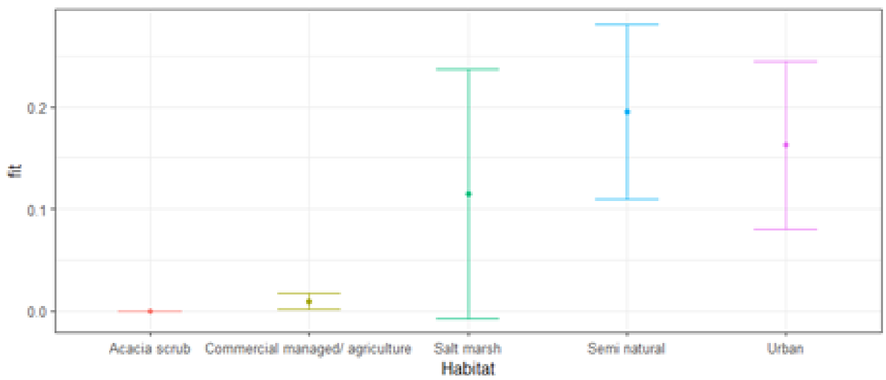
3.2.3 Solitary bees

During the entire period, a total of 107 individuals of solitary bees were recorded by Fit counts, from salt marsh (27 surveys), Acacia scrub (3 surveys), semi natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Figure 22 shows the abundance of solitary bees recorded on native and non-native plants, in different habitat types, through the recording period.

Given a differences in AIC of -0.78 (Full model and Reduced model1) -24.93 (Full model and Reduced model2) and -24.16 (Reduced model1 and Reduced model2), the Reduced model 1 was favoured. The difference in AIC between Full model and Reduced model 1 tested was less than 2, therefore the most parsimonious model was selected. That model included a random effect for location and the following fixed effects: habitat type and plant type.

Abundance of solitary bees was higher in semi natural, and lower in Acacia scrub and commercial managed/ agriculture habitats compared to other habitats. However there were no significantly differences between the different types of habitats.

There weren't statistically significant differences between native and non-native plants.



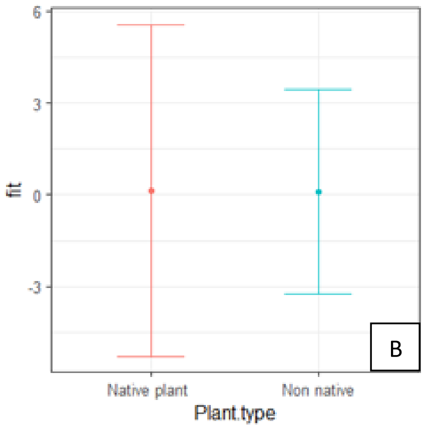


Figure 22: Effect of habitat type (A) and flower type (native or non-native plants) (B) on abundance of solitary bees, recorded by using the FIT counts. Errors bars= standard error.

3.2.4 Bees

During the entire period, a total of 253 individuals of bees (solitary bees, honey bees and bumble bees) were recorded by Fit counts, from salt marsh (27 surveys), Acacia scrub (3 surveys), semi natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Figure 23 shows the abundance of bees recorded on native and non-native plants, in different habitat types, through the recording period.

Given a differences in AIC of -18.69 (Full model and Reduced model1) -42.13 (Full model and Reduced model2) and -23.44 (Reduced model1 and Reduced model2), the most parsimonious model that best described the variability in the data was the full model that included a random effect for location and the variable habitat type, plant type and seasonality as fixed effects.

Abundance of total bees was higher in semi natural habitats and lower in commercial managed/ agriculture compared. There were no significantly differences between the different types of habitats.

Higher abundance was found in the autumn and lower abundance was found in the spring compared to the other seasons. There were no significantly differences between different seasons.

When the number of total bees between native and non-native plants was compared, the number of individual bees was significantly higher when the Fit counts were done on non-native plants than on native plants.

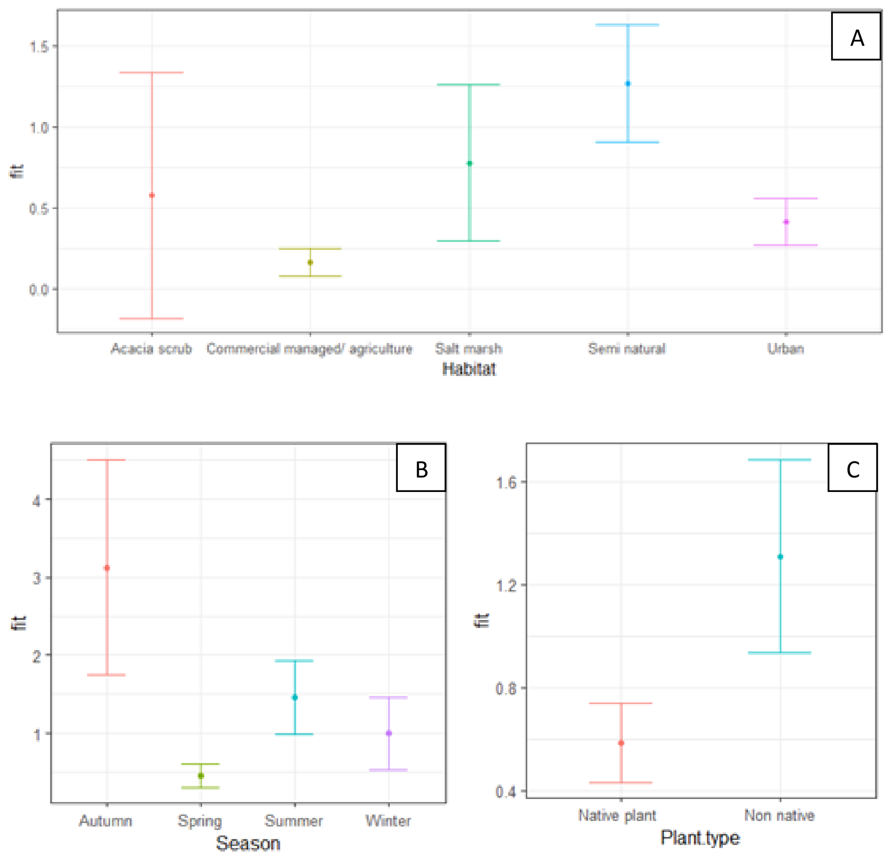


Figure 23: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of bees, recorded by using the FIT counts. Results are plotted on the scale of the linear predictor. Errors bars= standard error.

3.2.5 FLIES

During the entire period, a total of 329 individuals of flies (hoverflies and other flies) were recorded by FIT counts, from salt marsh (27 surveys), Acacia scrub (3 surveys), semi natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Figure 24 shows the abundance of flies recorded on native and non-native plants, in different habitat types, through the recording period.

The differences in AIC for the three models tested was -12.03 (Full model and Reduced model1) -35.34 Full model and Reduced model2) and -23.30 (Reduced model1 and Reduced model2), therefore I selected the model with the lowest AIC, which was the Full model. This model included a random effect for location and the following fixed effects: habitat type, plant type and seasonality.

Abundance of flies was higher in Acacia scrub compared to the other types of habitats. The abundance of flies was significantly lower in commercial managed/ agriculture habitats compared to the other habitats. There were no significantly differences between different types of habitats, with the exception of the number of flies recorded in the commercial managed/ agriculture habitats.

Abundance of flies was significantly higher in the summer and significantly lower in the autumn compared to the other seasons. The degree of correlation was significant between all seasons.

When the number of flies recorded between native and non-native plants was compared, the number of individual insects was significantly higher when the Fit counts were done on native plants than on non-native plants.

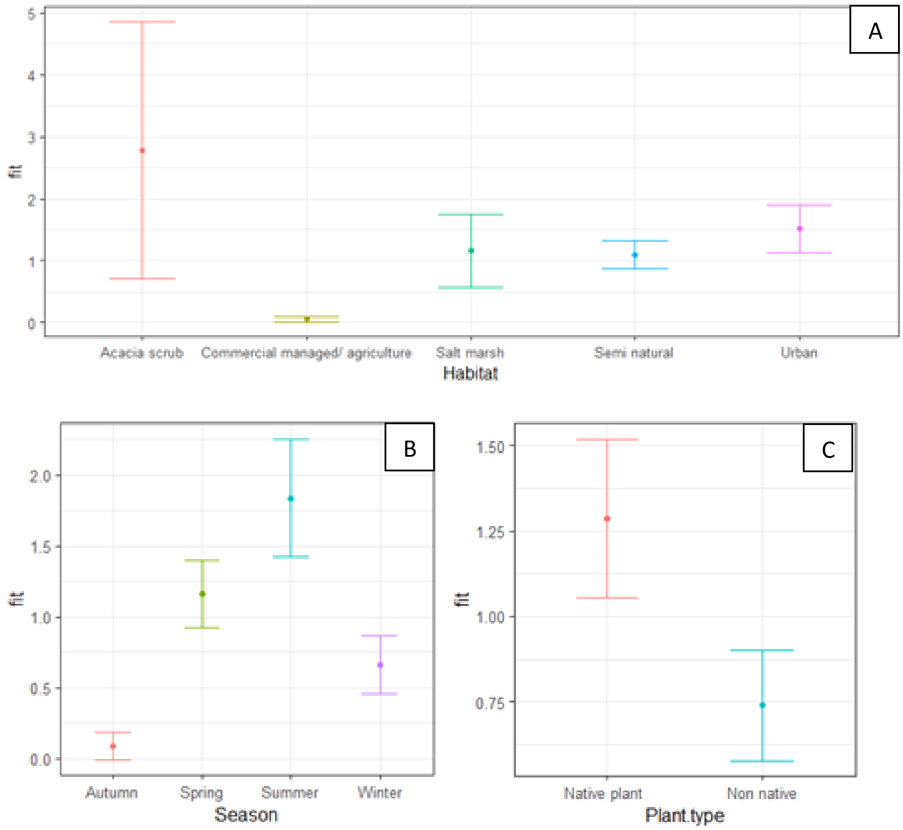


Figure 24: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of flies, recorded by using the FIT counts. Results are plotted on the scale of the linear predictor. Errors bars= standard error.

3.2.6 ALL INSECTS AND INVERTEBRATES

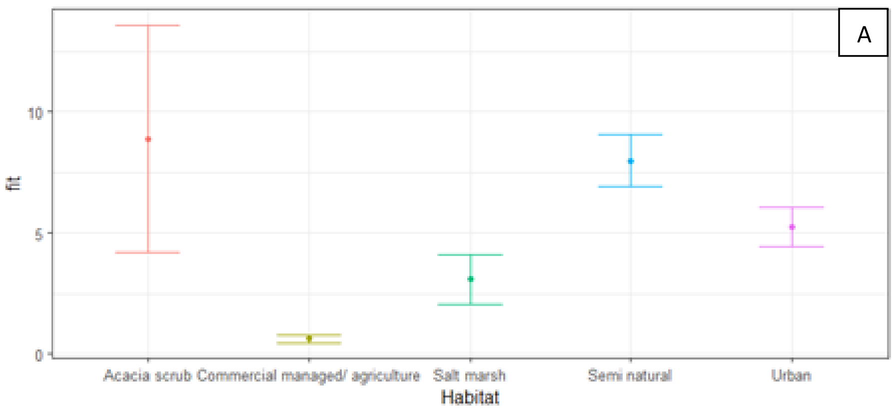
During the entire period, a total of 1380 individuals of insects and invertebrates were recorded by FIT counts, from salt marsh (27 surveys), Acacia scrub (3 surveys), semi natural (98 surveys), commercial managed/ agriculture (9 surveys) and urban habitats (57 surveys). Figure 25 shows the abundance of insects and invertebrates recorded on native and non-native plants, in different habitat types, through the recording period.

Given a differences in AIC of -42.89 (Full model and Reduced model1) -183.89 (Full model and Reduced model2) and -141 (Reduced model1 and Reduced model2), the most parsimonious model that best described the variability in the data was the full model that included a random effect for location and the variable habitat type, plant type and seasonality as fixed effects.

Abundance of total insects and invertebrates was higher in Acacia scrub compared to other types of habitats. The abundance was significantly lower in commercial managed/ agriculture compared to the other habitat types. There were no significantly differences between the different types of habitats, with the exception of the number of individuals recorded in the commercial managed/ agriculture habitats.

Significantly higher abundance was found in the summer and significantly lowers in the winter compared to the other seasons. There were no statistically significant differences between autumn and spring.

When the number of the total of insects and invertebrates recorded between native and non-native plants were compared, the number of individuals was higher when the Fit counts was done on native plants than on non-native plants. However there weren't statistically significant differences between them.



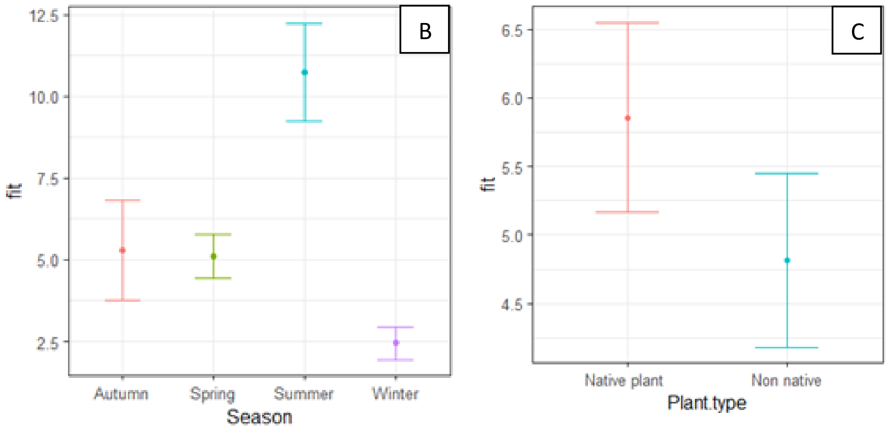


Figure 25: Effect of habitat type (A), seasonality (B) and flower type (native or non-native plants) (C) on abundance of insects and invertebrates, recorded by using the FIT counts. Results are plotted on the scale of the linear predictor. Errors bars= standard error.

4 Discussion

In this particular study, three classical entomological methods were applied for insect monitoring and recording: beat sheet sampling, pan trapping and pitfall trapping. Diversity indices and abundance were calculated for each species and used together to integrate information on the potential for the different habitat types to support ecosystem services and functions. This is the first study in Cyprus that calculates and compares diversity indices and insect abundance in those types of habitats. Moreover in this study helps towards the design and testing of a citizen-science initiative for monitoring pollinators and other beneficial insects, the Pollinator Monitoring Scheme Kýpros (Poms-ký).

Habitat type has a key role in the fluctuation of insect populations and in species diversity, as it is a prerequisite for accessing food or oviposition sites (Khaliq *et al.*, 2014; Wäschke *et al.,* 2014). In this study similar to the study by Kiatoko *et al.*, 2017 the results of the pitfall trapping showed that abundance and diversity of the insect species varied across the different habitats, with insect abundance was higher in some native habitats. In particular, results show significantly higher pollinating insects' abundance in *Sarcopoterium spinosum* phryganas, significantly higher abundance for insect' predators in arborescent matorral with *Juniperus phoenicea* supported and significantly higher diversity of other insect categories (herbivores and parasitoids) in Mediterranean tall humid grasslands, between them and compared to the *Acacia saligna-Eucalyptus* spp. plantations, the Thermo-mediterranean riparian galleries and Coastal lagoons and the Mediterranean pine forests and *Sarcopoterium spinosum* phryganas.

Significantly lower predators' abundance was observed in Thermo-mediterranean riparian galleries and Coastal lagoons compared to the other habitats. However this habitat type showed the higher values of the Shannon and Simpson's diversity indices of the total of insects, and higher value of the Shannon's diversity index for pollinating insects collected by pitfall trapping, while the higher value of the Simpson's diversity index for pollinating insects recorded in Mediterranean pine forests and *Sarcopoterium spinosum* phryganas.

Invasive plant species impact composition and structure of plant communities, altering the suitability of invaded habitats. Similar to Van Hengstum et al. (2013) we found that plant invasions reduce local arthropod abundance and taxonomic biodiversity. Thus, during our study the non-native habitat *Acacia saligna-Eucalyptus* spp. plantations shows lower insect abundance and diversity compared to some, but not all of the native habitats. However, insect responses (e.g., behaviour, health, abundance) to plant invasions are sometimes highly variable (i.e., negative, positive or neutral). The results showed that *Acacia saligna-Eucalyptus* spp. plantations shows higher insect abundance and diversity compared to Mediterranean pine forests and *Sarcopoterium spinosum* phryganas, and Mediterranean tall humid grasslands and Thermo-mediterranean riparian galleries and Coastal lagoons, higher insect diversity compared to *Sarcopoterium spinosum* phryganas, making difficult both understanding and prediction of invasive alien plants' impact on insect conservation.

The results of the beat sheet sampling showed that in *Sarcopoterium spinosum* phryganas contained higher the diversity indices values (Shannon and Simpson), for the total of insects' collected, compared to other habitats. Although the values of the Shannon and Simpson's diversity indices of pollinators, were higher in arborescent matorral with *Juniperus phoenicea* compared to the other habitats. Both habitats are native habitats of Cyprus. Different habitat types, have different type of vegetation. That may explain the preference of different insect taxa in different habitat types. However, beat sheet sampling might not the best method to estimate the abundance or values for the Shannon and Simpson indices of pollinating insects.

The results of the pan trapping showed that the values of the Shannon and Simpson's diversity indices of the totals of insects, were higher when insects collected in Mediterranean tall humid grasslands contained than in other habitats. However, higher value of the Shannon's diversity index for pollinating insects recorded in arborescent matorral with *Juniperus phoenicea*, while the higher value of the Simpson's diversity index for pollinating insects recorded in *Acacia saligna-Eucalyptus* spp. plantations. According to Drossart *et al*. (2017) non-native plant species can be integrated in generalist pollinators' diet as a new resource potential, which coupled with massive, accessible and/or attractive floral display, probably explains local abundance and wide diversity on some of them. That explains the high diversity of pollinators in *Acacia saligna-Eucalyptus* spp. plantations.

On the other hand, some taxa display floral specificity, restricting their flower visits to closely related plant taxa (pollen specialists) (Nieto *et al.,* 2014). Thus, some bee species are not able to forage or develop on alternative plants (including invasive species) because of behavioural (e.g. flower handling, host recognition) and/or physiological constraints (e.g. toxin occurrence, nutrient deficiency) (Drossart *et al.* 2017). That may explain the lower values solitary bees divesrity (according to Shannon and Simpson's diversity indices) in *Acacia saligna-Eucalyptus* spp. plantations, the only invaded habitat, and the higher values of solitary bees diversity (according to Shannon and Simpson's diversity indices), in a native habitat of Cyprus, in Thermo-mediterranean riparian galleries and Coastal lagoons, when they were compared to the other habitats.

These results provide not only valuable knowledge about the important habitats for insects in Cyprus, but additionally highlight the need for their conservation. If I had to prioritise conservation actions based on the results of this thesis, I would suggest to protect 1) the Thermo-mediterranean riparian galleries and Coastal lagoons, as it is the habitat type with the higher indices diversity values of solitary bees, 2) the *Sarcopoterium spinosum* phryganas as it is the habitat with significant higher abundance of pollinating insects, 3) the arborescent matorral with *Juniperus phoenicea*, as it is the habitat with significant higher abundance of predators and 4) the Mediterranean tall humid grasslands and *Sarcopoterium spinosum* phryganas, as it is the habitat with significant higher abundance of other beneficial or not insects.

Regarding the impact of non-native plants on native insects, are likely to vary according to the taxon of plant, the function specificity of the insects, and ecosystem context (Stout and Morales, 2009). So, some non-native plants may serve as an important food resource and prove beneficial for some native insects (Sunny *et al*., 2015, Bezemer *et al*., 2014). On the other hand, some non-native plants can be toxic to native herbivores or they can indirectly alter the abundance or performance of native insects, via their effects on the quality, abundance, or diversity of native plants or on the structure of their habitat. Moreover, in some instances, survival of insect herbivores is high but development time is extended and/or adult body mass is reduced (Bezemer *et al*., 2014).

Effects of non-native plants on pollinating species richness and diversity appear to be more consistently negative, while some studies have found no change in species richness following invasion (Hejda *et al.,* 2009) and some other found that non-native plants have high attractiveness to pollinators, leading to deleterious impact on native plants pollination and reproduction (Sunny *et al.,* 2015; Stout & Tiedeken, 2016).

The results of this study showed that the impact of non-native plants had positive impacts on predator' abundance (beat sheet sampling), while in other cases no impact of non-native plants showed on insect abundance (pollinators and other insects by applying the beat sheet sampling, and for pollinators, predators and other insects by applying the pan trapping method).

Insects' population growth parameters (e.g. fecundity, development and mortality), diversity and behaviour (e.g. flight activity) of insects, are affected by the climate (Lord, 2004). However, some studies show that insects can outlive phases of unfavourable environmental conditions in larval stages or overwintering as adults (Abrahamczyk *et al.,* 2011). Therefore, little is known about seasonal changes of different insect guilds at a given locality.

This study showed that the abundance of pollinating insects was significantly higher in the summer (beat sheet sampling), when native plants dominate, and significantly lower in the winter (beat sheet sampling and pitfall trapping), during the rain period, compared to the other seasons. However, none of those methods (beat sheet sampling and pitfall trapping) is appropriate to estimate the abundance of species richness of pollinating insects. On the other hand, predator' abundance was significantly lower in the summer (pitfall trapping), and other insect categories' abundance was significantly higher in autumn (pitfall trapping) and winter (beat sheet sampling).

The biggest problem that I had to deal with in this project was difficulties with species identification, due to lack of suitable identification guides and limited taxonomic knowledge of insects' diversity in Cyprus. Based on this it is really important to create inventories and identification keys that could be used during insect biodiversity studies in Cyprus.

Except of those three classical entomological methods for insect monitoring and recording, the Pollinator monitoring Scheme of Kýpros (Poms-ký) was used to calculate the pollinators' abundance.

Citizens, ecologists, entomologists and teachers could work together island-wide in order to record insects on native and non-native plants and raise awareness about the importance of insect and other arthropod fauna. Poms-ký can be used to record a wide range of insects that may be important pollinators, and their interactions with native and non-native plants. Identification of insects involves the use of broader taxonomic groupings (e.g. bumblebees, solitary bees, honeybees, beetles etc.). That offers more potential for non-expert involvement, especially if standardised counts and/or flower visitation rates can be generated. Furthermore, it offers educational and recreational benefits for participants.

During this project one hundred and ninety four FIT Counts were made on native and non-native plants. The results so far have shown significantly lower abundances for different groups (pollinating insects, flies and all insects (include pollinators, predators and other) and invertebrates), in commercial managed/ agriculture habitats. A reason for these lower abundances could be the use of synthetic pesticides and fertilisers, habitat loss and the introduction of non-native plants.

Regarding the impact of non-native plants on insect abundances the results are contrasting. Significantly higher abundance of honey bees and bees (honey bees, solitary bees and bumble bees) was observed on non-native plants, compared to native plants. According to Drossart *et al.* (2017) non-native plant species can be integrated in generalist pollinators' diet as a new resource potential, which coupled with massive, accessible and/or attractive floral display, probably explains local abundance and wide diversity on some of them. That explains the high abundance of those pollinators in non-native plants. On the other hand significantly fly abundances were higher for native plants compared to non-native plants, while no significantly differences were shown, between native and non-native plants on abundance of all insects and invertebrates (variety of common and generalist species) and solitary bees. Although, this may is the result of a low number of solitary bee' samples.

Climate and season in the temperate zones affect the plant variation and the seasonal timing of flower production (Memmott *et al.,* 2007; Lawson and Rands, 2019). Thus, most non-native plants (e.g. *Acacia saligna* and *Oxalis pes-caprae*) are blooming in the winter and in the spring seasons. On the other hand, many native plants (e.g. *Glebionis coronarium, Sinapis alba, Convolvulus* spp*., Heliotropium* spp., ect.) are still blooming through the summer season. In addition, season variation and environmental conditions have an effect on insect communities. Interaction between plant populations and insect' populations may be important. Thus in some periods of the year, non-native plant species can be more accessible and attractive, for generalist species of insects, compared to native plants (Drossart *et al*., 2017), and the opposite. That may explain the visitation of different taxa of insects, on native and non-native plants, in different periods of the year. Although, it will be good if there were more samples to confirm that.

Overall, from this study we found that the abundance of pollinators and all insects and invertebrates, was significantly higher in the summer, when native plants dominate, and significantly lower in the winter, during the rainy period, compared to the other seasons. Nevertheless, significantly lower abundance of pollinators can be explained, as rainfall may interfere with the timing of pollinator visitations (Lawson and Rands, 2019). On the other hand, abundance of honey bees was significantly higher, in the autumn, while the flies' abundance was significantly lower in the same season compared to the others. Flies' abundance was significantly higher in the summer, as syrphids and other fly types prefer warm and sunny weather to fly, feed or for egg laying (Van

Steenis *et al.,* 2019; Lindblad & Sigvald1996). Solitary bees and bees didn't show any significant differences in numbers during the different seasons, as bees adjust their behaviour to weather conditions (Conte & Navajas, 2008).

Some of the concerns during the development of Poms-ký are also relevant to for other citizen science projects, such as that the data quality will be poor and may lump taxa or misclassify certain taxonomic groups (Kremen *et al*., 2011; Gardiner *et al.,* 2012). Identification errors can be common during citizen science projects. In particular on a Mediterranean island like Cyprus where there is a large number of insects and lack of suitable identification guides as well as lack of knowledge on different taxonomic groups and lack of experience among participants mistakes could be common (Gardiner *et al.,* 2012).

The effect of volunteer error on researcher interpretation is a major issue (Gardiner *et al.,* 2012). This is why, verifying citizen science records is important, as it can improve the quality of the collected citizen-science data as well as establishing error rates and determining the right sample sizes (Bois *et al.,* 2011; Miller *et al.,* 2011; Gardiner *et al*., 2012).

If I could do something different in this particular study, that would be to measure plant diversity in the six different habitat types, that were used for the classical entomological methods. That might have helped me to understand more about the relationship between native pollinating insects, non-native plants and the different habitats, while I could also have compared better the results of classical entomological methods with Poms-ký results.

4.1 Summary of results

Beat Sheet sampling		
	Significantly higher abundance	**Significantly lower abundance**
	Pollinators	
Habitat type		
Season	Summer	
Plant		
	Predators	
Habitat type		
Season		
Plant	Non-native plants	Native plants

	Other insects	
Habitat type		
Season	Winter	
Plant		
Pan trapping		
	Significantly higher abundance	**Significantly lower abundance**
	Pollinators	
Habitat type		
Trap colour	Yellow	
	Predators	
Habitat type		
Trap colour		
	Other insects	
Habitat type		
Trap colour	Yellow	White

Pitfall trapping		
	Significantly higher abundance	**Significantly lower abundance**
	Pollinators	
Habitat type	*Sarcopoterium spinosum* phryganas	
Season	Summer	Winter
	Predators	
Habitat type	Arborescent matorral with *Juniperus phoenicea*	*Thermo-mediterranean riparian galleries and Coastal lagoons*
Season		Summer
	Other insects	
Habitat type	*Mediterranean tall humid grasslands*	
Season	Autumn	

Pollinator Monitoring Scheme of Cyprus - FIT COUNTS		
	Significantly higher abundance	**Significantly lower abundance**
	Pollinators	
Habitat type		Commercial managed/ agriculture habitats
Season	Summer	Winter
Plant		
	Honey bees	
Habitat type		
Season	Autumn	
Plant	Non-native plants	Native plants
	Solitary bees	
Habitat type		
Season		
Plant		
	Bees	
Habitat type		
Season		
Plant	Non-native plants	Native plants
	Flies	
Habitat type		Commercial managed/ agriculture habitats
Season	Summer	Autumn
Plant	Native plants	Non-native plants
	All insects and invertebrates	
Habitat type		Commercial managed/ agriculture habitats
Season	Summer	Winter
Plant		

5 CONCLUSIONS

The most important findings of this particular study were that native habitats have in general more positive impacts on insects' diversity and abundance (pollinators, predators and other categories), compared to non-native habitats. Nevertheless native pollinators vary in their response to plant invasion according to a number of factors, including the identity and traits of the non-native plant and this has also been observed by Stout & Tiedeken, 2016.

In some cases invasive alien plant species seem to have been integrated in generalist insect' diet. Thus, pollinating insects and predators showed higher abundance on non-native plants. On the other hand, non-native plants can indirectly alter the abundance or performance of native insects, via their effects on the quality, abundance, or diversity of native plants or on the structure of their habitat (Bezemer *et al*., 2014), causing a decrease in some specialist insect abundance and biodiversity. However, in this study, the abundance of insect specialists like some solitary bee species was not significantly different between native and non-native plants, but more sampling will be needed in order to confirm this result.

In conclusion insect behaviour and abundance are highly variable and that make plant invasion impacts difficult. Further studies will be needed to understand insect-plant interactions in these habitats, something that will also help to develop mitigation strategies for maintaining the bee diversity as well as the inherent ecosystem services.

Poms-ký is the first scheme in Cyprus for recording pollinating insects on native, non-native and cultivated plants. This scheme can be used to raise awareness about the importance of insect and other arthropod fauna and helping to fill gaps in knowledge of insect biodiversity in Cyprus.

The frequency of the Fit counts is up to the participants. Although multiple counts during the year, would add value to the data when they would be analysed. Ideally it is preferred that counts that are repeated over time at the same location (or few locations), by use different plant species.

REFERENCES

Abrahamczyk, S., Kluge, J., Gareca, Y., Reichle, S., & Kessler, M. (2011). *The Influence of Climatic Seasonality on the Diversity of Different Tropical Pollinator Groups.* PLoS ONE, 6(11), e27115. [doi:10.1371/journal.pone.0027115]

AP Marine Environmental Consultancy Ltd & ATLANTIS Consulting Cyprus Ltd (2012). *Hydrological Study & Further Studies to be incorporated in the Akrotiri Peninsula Management Plan (Work Order: 1044844).* Final report

Austin, K., Makris, C., Small, E. (2011). *Ground beetles of the Akrotiri peninsula, Cyprus (Coleoptera: Carabidae).* Zoology in the Middle East 53: 87-94

Bezemer, T. M., Harvey, J. A., & Cronin, J. T. (2014). *Response of Native Insect Communities to Invasive Plants.* Annual Review of Entomology, 59(1), 119–141. [doi:10.1146/annurev-ento-011613-162104]

BirdLife Cyprus (2017). *Site Management Plan for Akrotiri marsch, Cyprus SBAs .*

Blackstone, A. (2012). *Principles of Sociological Inquiry: Qualitative and Quantitative Methods.* Version 1.0.

Bonebrake, T. C., Guo, F., Dingle, C., Baker, D. M., Kitching, R. L. and Ashton, L. A. (2019). *Integrating Proximal and Horizon Threats to Biodiversity for Conservation.* Trends in Ecology & Evolution 34(9): 781-788

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V. and Shirk, J. (2009). *Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy.* BioScience, 59(11):977-984

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D., Rodrigues, A. S. L. (2006). *Global Biodiversity Conservation Priorities.* Science, 313(5783), 58–61. [doi:10.1126/science.1127609]

Brundu, G., Lozano, V. and Branquart, E. (2018). *Information on measures and related costs in relation to species considered for inclusion on the Union list: Acacia saligna.* Technical note prepared by IUCN for the European Commission.

Cardoso, P., & Leather, S. R. (2019). *Predicting a global insect apocalypse.* Insect Conservation and Diversity, 12(4), 263–267. [doi:10.1111/icad.12367]

Carvell, C., Isaac, N., Jitlal, M., Peyton, J., Powney, G., Roy, D., Vanbergen, A., O'Connor, R., Jones, C., Kunin, B., Breeze, T., Garratt, M., Potts, S., Harvey, M., Ansine, J., Comont, R., Lee, P., Edwards, M., Roberts, S., Morris, R., Musgrove, A., Brereton, T., Hawes, C. and Roy, H. (2016). *Design and Testing of a National Pollinator and Pollination Monitoring Framework. Final summary report to the Department for Environment, Food and Rural Affairs (Defra),* Scottish Government and Welsh Government: Project WC1101

Chivian, E. and Bernstein, A. (2008). *Sustaining Life: How Human Health Depends on Biodiversity.* New York: Oxford University Press. 542 pp. ISBN: 978-0-19-517509-7

Christodoulou, C. S., Griffiths, G. H., & Vogiatzakis, I. N. (2018). *Using threatened plant species to identify conservation gaps and opportunities on the island of Cyprus. Biodiversity and Conservation,* 27(11), 2837–2858. [doi:10.1007/s10531-018-1572-4]

Clark, W. H., Blom, P. E. (1992). *An efficient and inexpensive pitfall trap system.* Ent. News 103(2): 55-59

Conrad, K. F., Woiwod, I. P., Parsons, M., Fox, R. and Warren, M. S. (2004). *Long-term population trends in widespread British moths.* Journal of Insect Conservation 8: 119–136

Conte, Y. L. & Navajas, M. (2008). *Climate change: impact on honey bee populations and diseases.* Rev. sci. tech. off. int. epiz., 27(2), 499-510

Cope, G. C., Campbell, J. W., Grodsky, S. M., & Ellis, J. D. (2019). *Evaluation of nest-site selection of ground-nesting bees and wasps (Hymenoptera) using emergence traps.* The Canadian Entomologist, 1–12. [doi:10.4039/tce.2019.3]

Delipetrou, P. and Christodoulou, C. S. (2010). *Οδηγός αναγνώρισης και χαρτογράφησης των οικοτόπων του Παραρτήματος Ι της Οδηγίας 92/43/ΕΟΚ στην Κύπρο.* Τμήμα Περιβάλλοντος, Υπουργείο Γεωργίας, Φυσικών Πόρων και Περιβάλλοντος, Λευκωσία, Κύπρος.

Department of Environment (2013). *Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. Format for a prioritised action framework (PAF) for NATURA 2000. For the EU Multiannual Financing Period 2014-2020.* Final Version 11 May 2012

Department of Environment. Ministry of Agriculture, Natural Resources and Environment (2010). *Fourth National Report to the United Nations Convention on Biological Diversity*

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, E., Chan, K. M. A., Baste, A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., Van Oudenhoven, A. P. E., Van der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C. A., Hewitt, C. L., Keune, H., Lindley, S., Shirayama, Y. (2018). *Assessing nature's contributions to people.* Science, 359(6373), 270–272. [doi:10.1126/science.aap8826]

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., Phillips, T., Purcell, K. (2012). *The current state of citizen science as a tool for ecological research and public engagement.* Frontiers in Ecology and the Environment, 10(6), 291–297. [doi:10.1890/110236]

Drossart, M., Michez, D., & Vanderplanck, M. (2017*). Invasive plants as potential food resource for native pollinators: A case study with two invasive species and a generalist bumble bee.* Scientific Reports, 7(1). [doi:10.1038/s41598-017-16054-5]

Essl, F., Nehring, S., Klingenstein, F., Milasowszky, N., Nowack, C., & Rabitsch, W. (2011). *Review of risk assessment systems of IAS in Europe and introducing the German–Austrian Black List Information System (GABLIS).* Journal for Nature Conservation, 19(6), 339–350. [doi:10.1016/j.jnc.2011.08.005]

European Environment Agency (2010). *Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe*

European Union (2015). *Science for Environment Policy: Ecosystem Services and Biodiversity*. [doi: 10.2779/57695]

Gardiner, M. M., Allee, L. L., Brown, P. M., Losey, J. E., Roy, H. E., & Smyth, R. R. (2012). *Lessons from lady beetles: accuracy of monitoring data from US and UK citizen-science programs.* Frontiers in Ecology and the Environment, 10(9), 471–476. [doi:10.1890/110185]

Gill, R. J., Baldock, K. C. R., Brown, M. J. F., Cresswell, J. E., Dicks, L. V., Fountain, M. T., Garratt, M. P. D., Gough, L. A., Heard, M. S., Holland, J. M., Ollerton, J., Stone, G. N., Tang, C. Q., Vanbergenkk, A. J., Vogler, A. P., Woodward, G., Arce, A. N., Boatman, N. D., Brand-Hardy, R., Breeze, T. D., Green, M., Hartfield, C. M., O'Connor, R. S., Osborne, J. L., Phillips, J., Suttonkkk, P. B., Potts, S. G. (2016). *Protecting an Ecosystem Service.* Advances in Ecological Research, 135–206. [doi:10.1016/bs.aecr.2015.10.007]

Hadjikyriakou, G. and Hadjisterkotis, E. (2002). *The adventive plants of Cyprus with new records of invasive species. Ministry of Agriculture and Ministry of the Interior; Nicosia, Cyprus. Zeitschrift fur. Jagdwissenschaft 48: 59-71*

Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D., de Kroon, H. (2017). *More than 75 percent decline over 27 years in total flying insect biomass in protected areas.* PLOS ONE, 12(10), e0185809. [doi:10.1371/journal.pone.0185809]

Hegland, S. J., Dunne, J., Nielsen, A., & Memmott, J. (2010). *How to monitor ecological communities cost-efficiently: The example of plant–pollinator networks.* Biological Conservation, 143(9), 2092–2101. [doi:10.1016/j.biocon.2010.05.018]

Hejda, M., Pyšek, P., & Jarošík, V. (2009). *Impact of invasive plants on the species richness, diversity and composition of invaded communities.* Journal of Ecology, 97(3), 393–403. [doi:10.1111/j.1365-2745.2009.01480.x]

Hewitt, G. M. (2011). *Mediterranean Peninsulas: The Evolution of Hotspots.* Biodiversity Hotspots, 123–147. [doi:10.1007/978-3-642-20992-5_7]

Hochkirch, A., Nieto, A., García Criado, M., Cálix, M., Braud, Y., Buzzetti, F.M., Chobanov, D., Odé, B., Presa Asensio, J.J., Willemse, L., Zuna-Kratky, T., Barranco Vega, P., Bushell, M., Clemente, M.E., Correas, J.R., Dusoulier, F., Ferreira, S., Fontana, P., García, M.D., Heller, K-G., Iorgu I.Ș., Ivković, S., Kati, V., Kleukers, R., Krištín, A., Lemonnier-Darcemont, M., Lemos, P., Massa, B., Monnerat, C., Papapavlou, K.P., Prunier, F., Pushkar, T., Roesti, C., Rutschmann, F., Şirin, D., Skejo, J., Szövényi, G., Tzirkalli, E., Vedenina, V., Barat Domenech, J., Barros, F., Cordero Tapia, P.J., Defaut, B., Fartmann, T., Gomboc, S., Gutiérrez-Rodríguez, J., Holuša, J., Illich, I., Karjalainen, S., Kočárek, P., Korsunovskaya, O., Liana, A., López, H., Morin, D., Olmo-Vidal, J.M., Puskás, G., Savitsky, V., Stalling, T. and Tumbrinck, J. (2016). *European Red List of Grasshoppers, Crickets and Bush-crickets.* Luxembourg: Publications Office of the European Union

Hulme P. E., Roy D. B., Cunha T. & Larsson T-B. (2008). *A pan-European inventory of alien species: rationale, implementation and implications for managing biological invasions.* In DAISIE (eds.). The Handbook of European Alien Species. Springer, Dordrecht.

ICOSTACY-«Improving the conservation status of fauna species in Cyprus: From microhabitat restoration to landscape connectivity» (2011). *Αρχική εκτίμηση της έκτασης παρουσίας, της κατάστασης των πληθυσμών και τη διαθεσιμότητα των ενδιαιτημάτων των ειδών του προγράμματος. 1ο παραδοτέο στα πλαίσια της Δράσης Α1. ΠΡΟΓΡΑΜΜΑ LIFE09 NAT/CY/00247. ΜΟΥΣΕΙΟ ΦΥΣΙΚΗΣ ΙΣΤΟΡΙΑΣ ΚΡΗΤΗΣ*

Joshi, N. K., Leslie, T., Rajotte, E. G., Kammerer, M. A., Otieno, M., & Biddinger, D. J. (2015). *Comparative Trapping Efficiency to Characterize Bee Abundance, Diversity, and Community*

Composition in Apple Orchards. Annals of the Entomological Society of America, 108(5), 785–799. [doi:10.1093/aesa/sav057]

Khaliq, A., Javed M., Sohail, M. and Sagheer, M. (2014). *Environmental effects on insects and their population dynamics.* Journal of Entomology and Zoology Studies, 2 (2): 1-7

Kiatoko, N., Raina, S. K., & van Langevelde, F. (2017). *Impact of habitat degradation on species diversity and nest abundance of five African stingless bee species in a tropical rainforest of Kenya. International Journal of Tropical Insect Science, 37(03), 189–197*. [doi:10.1017/s174275841700011x]

Kim, K. C. (1993). *Biodiversity, conservation and inventory: why insects matter.* Biodiversity and Conservation, 2(3), 191–214. [doi:10.1007/bf00056668]

Kremen, C., Ullman, K. S., & Thorp, R. W. (2011). *Evaluating the Quality of Citizen-Scientist Data on Pollinator Communities.* Conservation Biology, 25(3), 607–617. [doi:10.1111/j.1523-1739.2011.01657.x]

Krüger, K., & Fiore, N. (2018). *Sampling Methods for Leafhopper, Planthopper, and Psyllid Vectors.* Methods in Molecular Biology, 37–52. [doi:10.1007/978-1-4939-8837-2_4]

Lawson, D. A., & Rands, S. A. (2019). *The effects of rainfall on plant–pollinator interactions.* Arthropod-Plant Interactions. [doi:10.1007/s11829-019-09686-z]

Lawton, G. (2018). *Life on the brink.* New Scientist, 239(3188), 28–33. [doi:10.1016/s0262-4079(18)31352-6]

Leahy, S. (2019). *Insect 'apocalypse' in U.S. driven by 50x increase in toxic pesticides. Bees, butterflies, and other insects are under attack by the very plants they feed on as U.S. agriculture continues to use chemicals known to kill.* National Geographic.

Leong, J. M. and Thorp, R. W. (1999). *Colour-coded sampling: the pan trap colour preferences of oligolectic and nonoligolectic bees associated with a vernal pool plant.* Ecological Entomology 24, 329-335

Lindblad, M. & Sigvald, R. (1996). *A degree-day model for regional prediction of first occurrence of frit flies in oats in Sweden.* Crop Protection, 15(6), 559–565. [doi:10.1016/0261-2194(96)00024-5]

Lindén, A. and Mäntyniemi, S. (2011). *Using the negative binomial distribution to model overdispersionin ecological count data.* Ecology, 92(7), pp. 1414–1421

Lister, B. C., & Garcia, A. (2018). *Climate-driven declines in arthropod abundance restructure a rainforest food web.* Proceedings of the National Academy of Sciences, 201722477. [doi:10.1073/pnas.1722477115]

Lord, C. C. (2004). *Seasonal population dynamics and behaviour of insects in models of vector-borne pathogens.* Physiological Entomology, 29(3), 214–222. doi:10.1111/j.0307-6962.2004.00411.x

Médail, F., & Quézel, P. (1997). *Hot-Spots Analysis for Conservation of Plant Biodiversity in the Mediterranean Basin.* Annals of the Missouri Botanical Garden, 84(1), 112. [doi:10.2307/2399957]

Memmott, J., Craze, P. G., Waser, N. M., & Price, M. V. (2007). *Global warming and the disruption of plant? pollinator interactions.* Ecology Letters, 10(8), 710–717. [doi:10.1111/j.1461-0248.2007.01061.x]

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

Millennium Ecosystem Assessment (2005a). *Ecosystems and Human Well-being: Health Synthesis: A Report of the Millennium Ecosystem Assessment.* World Health Organization, Switzerland

Millennium Ecosystem Assessment (2005b). *Ecosystems and Human Well-being: Opportunities and Challenges for Business and Industry.* World Resources Institute, Washington, DC

Ministry of Agriculture, Natural Resources and Environment. Department of Environment (2014). *Fifth national report to the United Nations convention on biological diversity: Cyprus*

New, T. R., Pyle, R. M., Thomas, J. A., Thomas, C. D., & Hammond, P. C. (1995). *Butterfly Conservation Management.* Annual Review of Entomology, 40(1), 57–83. [doi:10.1146/annurev.en.40.010195.00042]

Nielsen, A., Steffan-Dewenter, I., Westphal, C., Messinger, O., Potts, S. G., Roberts, S. P. M., Settele, J., Szentgyörgyi, H., Vaissiere, B. E., Vaitis, M., Woyciechowski, M., Bazos, I., Biesmeijer, J. C., Bommarco, R., Kunin, W. E., Tscheulin, T., Lamborn, E., Petanidou, T. (2011). *Assessing bee species richness in two Mediterranean communities: importance of habitat type and sampling techniques.* Ecological Research, 26(5), 969–983. [doi: 10.1007/s11284-011-0852-1]

Nieto, A., Roberts, S. P.M., Kemp, J., Rasmont, P., Kuhlmann, M., García Criado, M., Biesmeijer, J. C., Bogusch, P., Dathe, H. H., De la Rúa, P., De Meulemeester, T., Dehon, M., Dewulf, A., Ortiz-Sánchez, F. J., Lhomme, P., Pauly, A., Potts, S. G., Praz, C., Quaranta, M., Radchenko, V. G., Scheuchl, E., Smit, J., Straka, J., Terzo, M., Tomozii, B., Window, J. and Michez, D. (2014). *European Red List of Bees.* European Commission. Publications Office of the European Union

Oberprieler, S. K., Andersen, A. N., & Braby, M. F. (2019). *Invertebrate by-catch from vertebrate pitfall traps can be useful for documenting patterns of invertebrate diversity.* Journal of Insect Conservation. [doi:10.1007/s10841-019-00143-z]

Oliver, T. H., Isaac, N. J. B., August, T. A., Woodcock, B. A., Roy, D. B., & Bullock, J. M. (2015a). *Declining resilience of ecosystem functions under biodiversity loss.* Nature Communications, 6(1). [doi:10.1038/ncomms10122]

Oliver,T.H., Heard, M. S., Isaac, N. J.B., Roy, D. B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A. , Orme, C. D. L., Petchey, O. L., Proença, V., Raffaelli, D., Suttle, K. B., Mace, G. M., Martín-López, B., Woodcock, B. A. and Bullock, J. M. (2015b). *Biodiversity and resilience of ecosystem functions.* Trends in Ecology & Evolution, 30 (11). pp. 673-684. ISSN 0169-5347 [doi: https://doi.org/10.1016/j.tree.2015.08.009]

Pescott O.L., Harris S.E., Peyton J.M., Onete M., Martinou A.F., Mountford J.O. (2018). *The Forest on the Peninsula: Impacts, Uses and Perceptions of a Colonial Legacy in Cyprus.* In: Queiroz A., Pooley S. (eds) Histories of Bioinvasions in the Mediterranean. Environmental History, vol 8, pp. 195-217. Springer, Cham

Pescott, O., Peyton, J., Mountford, J., Onete, M., Martinou, A. (2017). *Non-native plant species GIS data from Cyprus Sovereign Base Areas, October 2015 and March 2017.* NERC Environmental Information Data Centre. [doi.org/10.5285/7c84e06d-bb1a-4aac-b1d7-33c11310d8a0]

Petanidou, T., Ståhls, G., Vujić, A., Olesen, J. M., Rojo, S., Thrasyvoulou, A., Sgardelis, S., Kallimanis, A. S., Kokkini, A. and Tscheulin, T. (2013). *Investigating plant—pollinator relationships in the Aegean: the approaches of the project POL-AEGIS (The pollinators of the Aegean archipelago: diversity and threats).* Journal of Apicultural Research, 52(2), 106–117. [doi:10.3896/ibra.1.52.2.20]

Peyton, J., Martinou, A. F., Pescott, O. L., Demetriou, M., Adriaens, T., Arianoutsou, M., Bazos, I., Bean, C. W., Booy, O., Botham, M., Britton, J. R., Cervia, J. L., Charilaou, P., Chartosia, N., Dean, H. J., Delipetrou, P., Dimitriou, A. C., Dörflinger, G., Fawcett, J., Fyttis, G., Galanidis, A., Galil, B., Hadjikyriakou, T., Hadjistylli, M., Ieronymidou, C., Jimenez, C., Karachle, P., Kassinis, N., Kerametsidis, G., Kirschel, A. N. G., Kleitou, P., Kleitou, D., Manolaki, P., Michailidis, N., Mountford, J. O., Nikolaou, C., Papatheodoulou, A., Payiatas, G., Ribeiro, F., Rorke, S. L., Samuel, Y., Savvides, P., Schafer, S. M., Tarkan, A. S., Silva-Rocha, I., Top, N., Tricarico, E., Turvey, K., Tziortzis, I., Tzirkalli, E., Verreycken, H., Winfield, I. J., Zenetos, A. & Roy, H. E. (2019). *Horizon scanning for invasive alien species with the potential to threaten biodiversity and human health on a Mediterranean island.* Biological Invasions. [doi:10.1007/s10530-019-01961-7]

Peyton, J., Pescott, O., Mountford, O., Onete, M., Martinou, A. (2017). *COST Action Short Term Scientific Mission – Alien plant species in Overseas Territories in Cyprus.* Centre for Ecology and Hydrology.

Pocock, M. J. O., Evans, D. M., Fontaine, C., Harvey, M., Julliard, R., McLaughlin, Ó., Silvertown, J., Tamaddoni-Nezhad, A., White, P. C.L., Bohan, D. A. (2016). *The Visualisation of Ecological Networks, and Their Use as a Tool for Engagement, Advocacy and Management.* Advances in Ecological Research, 41–85. [doi:10.1016/bs.aecr.2015.10.006]

Reaka-Kudla, M.L., Wilson, D.E., Wilson, E.O. (1997). *Book reviews. Biodiversity II. Understanding and Protecting our Biological Resources.* Journal of Insect Conservation, 247-250.

Roy, H. E., Peyton, J., Aldridge, D. C., Bantock,T., Blackburn, T. M., Britton, R., Clark, P., Cook, E., Dehnen-Schmutz, K., Dines, T., Dobson, M., Edwards, F., Harrower, C., Harvey, M. C., Minchin, D., Noble, D. G., Parrott, D., Pocock, M. J. O., Preston, C. D., Roy, S., Salisbury, A., Schonrogge, K., Sewell, J., Shaw, R. H., Stebbing, P., Stewart, A. J. A., Walker, K.J. (2014). *Horizon scanning for invasive alien species with the potential to threaten biodiversity in Great Britain.* Global Change Biol 20:3859–3871

Roychoudhury, N., Meshram, P. B. and Mishra, R. K. (2019). *Invasive Alien Species. Certificate course on forest entomology and pest control.* Tropical Forest Research Institute. Jabalpur*, pp.72-77*

Samways, M. J. (2005). *Insect Diversity Conservation*

Samways, M. J. (2007). *Insect Conservation: A Synthetic Management Approach.* Annual Review of Entomology, 52(1), 465–487. [doi:10.1146/annurev.ento.52.110405.0913]

Sánchez-Bayo, F., & Wyckhuys, K. A. G. (2019). *Worldwide decline of the entomofauna: A review of its drivers.* Biological Conservation, 232, 8–27. [doi:10.1016/j.biocon.2019.01.020]

Schröter, M., Kraemer, R., Mantel, M., Kabisch, N., Hecker, S., Richter, A., Neumeier, V., Bonn, A. (2017). *Citizen science for assessing ecosystem services: Status, challenges and opportunities.* Ecosystem Services, 28, 80–94. [doi:10.1016/j.ecoser.2017.09.017]

Sfenthourakis, S., Hadjiconstantis, M., Makris, C., & Dimitriou, A. C. (2017). *Revisiting the saproxylic beetle "Propomacrus cypriacus Alexis & Makris, 2002" (Coleoptera: Euchiridae) using molecular, morphological and ecological data.* Journal of Natural History, 51(17-18), 1021–1034. [doi:10.1080/00222933.2017.1319521]

Shialis, T., Illegal Bird Killing Campaigns Manager and BirdLife Cyprus (2016). *UPDATE on illegal bird trapping activity in Cyprus. Covering the spring 2016 findings of BirdLife Cyprus' continuing* *monitoring programme for illegal bird trapping in Cyprus and providing an overview of the latest developments regarding the problem*

Sih, A., Ferrari, M. C. O., & Harris, D. J. (2011). *Evolution and behavioural responses to human-induced rapid environmental change.* Evolutionary Applications, 4(2), 367–387. [doi:10.1111/j.1752-4571.2010.00166.x]

Spector, S. (2002). *Biogeographic Crossroads as Priority Areas for Biodiversity Conservation.* Conservation Biology, 16(6), 1480–1487. doi:10.1046/j.1523-1739.2002.00573.x

Stout, J. C., & Morales, C. L. (2009). Ecological impacts of invasive alien species on bees. *Apidologie*, *40(3), 388–409*. [doi:10.1051/apido/2009023]

Stout, J. C., & Tiedeken, E. J. (2016). *Direct interactions between invasive plants and native pollinators: evidence, impacts and approaches.* Functional Ecology, 31(1), 38–46. [doi:10.1111/1365-2435.12751]

Sunny, A., Diwakar, S., & Sharma, G. P. (2015). *Native insects and invasive plants encounters.* Arthropod-Plant Interactions, 9(4), 323–331. [doi:10.1007/s11829-015-9384-x]

Taylor, C. M., & Hastings, A. (2004). *Finding optimal control strategies for invasive species: a density-structured model for Spartina alterniflora.* Journal of Applied Ecology, 41(6), 1049–1057. [doi:10.1111/j.0021-8901.2004.00979.x]

Taylor, G. S., Braby, M. F., Moir, M. L., Harvey, M. S., Sands, D. P. A., New, T. R., Kitching R. L., McQuillan P. B., Hogendoorn K., Glatz R. V., Andren M., Cook, J. M., Henry, S. C., Valenzuela, I., Weinstein, P. (2018). *Strategic national approach for improving the conservation management of insects and allied invertebrates in Australia.* Austral Entomology, 57(2), 124–149. [doi:10.1111/aen.12343]

Telfer, M. 2010. *Mark Telfer's pitfall trapping protocol .v1*

Tsintides T., Christodoulou C. S., Delipetrou P., Georghiou K. (2007). *The red data book of the flora of Cyprus.* Cyprus Forestry Association, Nicosia

Tzirkalli, E., Kadis, C., Halley, J. M., Vogiatzakis, I., Wilson, J. R., Zografou, K., Antoniou, A., Tsintides, T., Makris, C., Kati, V. (2019). *Conservation ecology of butterflies on Cyprus in the context of Natura 2000.* Biodiversity and Conservation 28(7): 1759-1782. [doi.org/10.1007/s10531-019-01755-2]

Van Hengstum, T., Hooftman, D. A. P., Oostermeijer, J. G. B., & van Tienderen, P. H. (2013). *Impact of plant invasions on local arthropod communities: a meta-analysis.* Journal of Ecology, 102(1), 4–11. [doi:10.1111/1365-2745.12176]

Van Steenis, J., Van Zuijen, M. P., Van Steenis, W., Makris, C., Van Eck, A. & Mengual X. (2017). *Hoverflies (Diptera: Syrphidae) of Cyprus: results from a collecting trip in October 2017.* Bonn Zoological Bulletin 68 (1): 125–146.

Van Swaay, C., Cuttelod, A., Collins, S., Maes , D., López Munguira, M., Šašić , M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M. and Wynhof, I. (2010). *European Red List of Butterflies. European Commission.* Publications Office of the European Union

Van Swaay, C.A.M. & Warren, M.S. (1999) *Red Data book of European butterflies (Rhopalocera).* Nature and Environment, No. 99, Council of Europe Publishing, Strasbourg.

Wäschke, N., Hardge, K., Hancock, C., Hilker, M., Obermaier, E., & Meiners, T. (2014). *Habitats as Complex Odour Environments: How Does Plant Diversity Affect Herbivore and Parasitoid Orientation?* PLoS ONE, 9(1), e85152. [doi:10.1371/journal.pone.0085152]

White, T. C. R. (1975). *A quantitative method of beating for sampling larvae of Selidosema suavis (Lepidoptera: Geometridae) in plantations in New Zealand.* The Canadian Entomologist, 107(04), 403–412. [doi:10.4039/ent107403-4]

Wilson, J.R.U., Gairifo, C., Gibson, M.R., Arianoutsou, M., Bakar, B.B., Baret, S., Celesti-Grapow, L., DiTomaso, J.M., Dufour-Dror, J.M., Kueffer, C., Kull, C.A., Hoffmann, J.H., Impson, F.A.C., Loope, L.L., Marchante, E., Marchante, H., Moore, J.L., Murphy, D.J., Tassin, J., Witt, A., Zenni, R.D. and Richardson, D.M. (2011). *Risk assessment, eradication, and biological control: global efforts to limit Australian acacia invasions.* Diversity and Distributions, 17(5), 1030–1046. [doi:10.1111/j.1472-4642.2011.00815.x]

Xu, H., Wu, J., Liu, Y., Ding, H., Zhang, M., Wu, Y., XI, Q., Wang, L. (2008). *Biodiversity Congruence and Conservation Strategies: A National Test.* BioScience, 58(7), 632–639. [doi:10.1641/b580710]

Zomeni, Z. and Bruggeman, A. (2013) *Soil Resources of Mediterranean and Caucasus Countries. Extension of the European Soil Database. Soil Resources of Cyprus*. Joint Research Centre of the European Commission: 37-59

SITES

Akrotiri Peninsula Environmental Management Plan, Version 2.0 (2012): https://sbaadministration.org/home/docs/eco/20121002_AKI_PEN_MGT_PLAN.pdf

Bees, Wasps & Ants Recording Society (BWARS): http://www.bwars.com/content/pollinator-monitoring-scheme

Department of Forests, 2012. 2012 ANNUAL REPORT OF THE DEPARTMENT OF FORESTS: http://www.moa.gov.cy/moa/fd/fd.nsf/8C35BFC847BC9F5FC2257D1C004088C9/$file/Summary%20of%20Annual%20Report%202012.pdf

Department of Forests, 2019: https://www.pio.gov.cy/ανακοινωθέντα-άρθρο.html?id=6680#flat

European Commission, official website (a): https://ec.europa.eu/environment/nature/natura2000/sites/index_en.htm

European Commission, official website (b): https://ec.europa.eu/environment/nature/invasivealien/index_en.htm

Extreme-Macro.co.uk: http://extreme-macro.co.uk

http://paphos3rdage.org/dragonfly-study-group

http://www.akrotirimarsh.org/en/home

http://www.ciesm.org/marine/programs/jellywatch.htm

http://www.cyprusbutterflies.co.uk/

http://www.moa.gov.cy/moa/environment/environmentnew.nsf/page12_en/page12_en?OpenDocument

http://www.troodos-geo.org/cgibin/hweb?-A=186&-V=troodos

https://cyprus.science.blog/

https://isea.com.gr/activities/programs/alien-species/is-it-alien-to-you-share-it/?lang=en

https://scistarter.org/the-three-mosquiteers

https://www.iucnredlist.org/

https://www.ris-ky.eu/cydas

Mississippi Entomological Museum:

https://mississippientomologicalmuseum.org.msstate.edu/collecting.preparation.methods/Beating.sheet.htm

Ris-ký: http://www.ris-ky.eu/poms-ky

ΚΥΚΠΕΕ: http://kykpee.org/225-ακακία-ένα-ξενικό-είδος/

Field Code Changed

APPENDIX 1

Abundance of insects - Beat sheet sampling												
	Thermo-mediterranean riparian galleries and Coastal lagoons		Arborescent matorral with *Juniperus phoenicea*		Mediterranean pine forests and *Sarcopoterium spinosum* phryganas		Mediterranean tall humid grasslands of the Molinio-Holoschoenion		*Sarcopoterium spinosum* phryganas		*Acacia saligna-Eucalyptus* spp. plantations	
	Native plant	Non-native	Native plant	Non-native	Native plant	Non-native	Native plant	Non-native	Native plant	Non-native	Native plant	Non-native
Pollinators	6	33	14		24		83		37	23	41	22
Predators		8	5		16		5		2	10	6	4
Other insect' categories	14	58	48		53		27		27	34	36	18

Abundance of insects - Pan trapping						
	Thermo-mediterranean riparian galleries and Coastal lagoons	Arborescent matorral with *Juniperus phoenicea*	Mediterranean pine forests and *Sarcopoterium spinosum* phryganas	Mediterranean tall humid grasslands of the Molinio-Holoschoenion	*Sarcopoterium spinosum* phryganas	*Acacia saligna-Eucalyptus* spp. plantations
Pollinators	225	317	754	335	557	279
Predators	4	11	13	13	16	3
Other insect' categories	231	338	171	75	153	121
Abundance of insects - Pitfall trapping						
Pollinators	1016	525	2000	1273	996	361
Predators	189	150	235	192	138	42
Other insect' categories	1109	488	258	262	1194	188

APPENDIX 2

Pollinator Monitoring Scheme Kýpros: www.ris-ky.eu/poms-ky

POMS-Ký

FIT Count field recording form

A Flower-Insect-Timed (FIT) Count can be carried out between 7am and 6pm all year around, as long as the weather is dry and warm (not raining or with very strong winds – see https://www.rmets.org/resource/beaufort-scale for wind measurements):

- If sky is clear (less than half cloud) the minimum temperature for a count is 13°C
- If sky is cloudy (half cloud or more) the minimum temperature for a count is 15°C
  - Do not record if it is more than 30°C as it will be too hot for the insects and you!

1. About you

Your name: ________________________________

☐ I am new to identifying wildlife

☐ I am familiar with identifying some wildlife (e.g. birds or butterflies) but not most pollinating insects

☐ I am familiar with recognising the main **groups** of pollinating insect

☐ I am confident in identifying the commonly-occurring pollinating insects **to species level**

2. Date and location of count

Date of count: ________________________________

Location name: ________________________________

Grid ref if known (or select from online map later): ____________________

Habitat (tick one box that is the best match):

☐ Environment centre grounds
☐ Roadside habitat
☐ Citrus / olive grove
☐ Woodland / plantation
☐ Dry scrub
☐ Coastal scrub
☐ Salt Marsh
☐ Other habitat type (please describe):

☐ Garden
☐ Parks / other recreational area
☐ Farmland
☐ Natural flower area / grassy area
☐ Acacia scrub
☐ Coastal dunes
☐ Freshwater marsh

3. Target flower (please take a photo)

Which target flower have you chosen (check the target flower guide)? ____________________

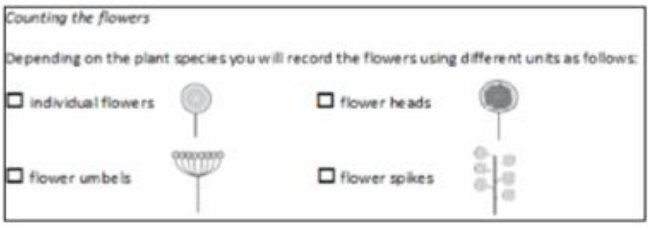
☐ Target flowers cover less than half of 50×50cm patch
☐ Target flowers cover about half of patch
☐ Target flowers cover more than half of patch

Number of flowers in patch:
☐ 1-5 ☐ 6-20 ☐ 21-50 ☐ >50

Is your 50x50cm patch of target flowers:
☐ Growing in a larger patch of the same flower
☐ Growing in a larger patch of many different flowers
☐ More or less isolated

Counting the flowers

Depending on the plant species you will record the flowers using different units as follows:



4. FIT Count

Once you are ready, start counting the insects and other invertebrates you see inside the quadrat for a total of **ten minutes**. Please record whether the insect is seen on a target flower ('On the flower') or whether it is seen in the quadrat, but not ever in contact with a flower of your target species ('Not on the flower') - this also includes when an insect visits a flower in your quadrat that is not the target flower species. Please count **EVERY** insect that you see (if you're not sure what type it is just add it to the "Other insects" category). Please try to count each individual insect just once, and try not to lean over the flowers you are watching, as this can cast shadows and prevent insects approaching. If an insect is recorded visiting a target flower do not record it a second time as 'not on the flower' – each insect should only have an entry in one column.

Time of count start: ______________________________

Insect group (see insect ID guide)	**Number counted (Tally): ~~IIII~~ II = 7, etc.**	
	On the flower	**Not on the flower**
Bumblebees		
Honeybees		
Solitary bees		
Wasps (including ichneumon wasps)		
Hoverflies (including 'non-typical' hoverflies)		
Other flies		
Butterflies and moths		
Beetles		
Small insects (e.g. pollen beetles) less than 3mm long		
Other insects or invertebrates (known). Please write down the type of insects (e.g Bugs) or invertebrates (e.g. Spiders)		
Other insects or invertebrates (unknown)		

5. Weather conditions

Sky above your location:
- ☐ All or mostly blue
- ☐ Half blue and half cloud
- ☐ All or mostly cloud

During the 10-minute count, was your 50×50cm patch:
- ☐ Entirely in sunshine
- ☐ Partly in sun and partly shaded
- ☐ Entirely shaded

Wind strength (for all plants in area, not just target flowers):
- ☐ Leaves still/moving occasionally
- ☐ Leaves moving gently all the time
- ☐ Leaves moving strongly

Don't forget to **take a photo** of your target flower species, and **add your counts** to the online form (www.ris-ky.eu/poms-ky)! And you can add photos of examples of the insects you have seen, but this is optional (please don't take photos during the count as this may disturb the visiting insects).