On the importance of inconspicuous flowering plants – how a "noxious weed" sustains valuable insects

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Abstract. The importance of floral diversity in providing a source of nectar and pollen for insects in the context of modern agricultural practice is a subject of continuous debate in search of a favourable compromise. The precise role of flowering plants and their value as vital determinants of ecologically sustainable agricultural landscapes remains underestimated. Not only are the consequences of removing inconspicuous herbaceous plants often overlooked, to the detriment of beneficial insects, but current lack of knowledge can result in commercially significant negative effects. This study focuses on the importance of the plant species Common Field Speedwell *Veronica persica* Poir. and Ivy-Leaved Speedwell *Veronica hederifolia* Linn. subspp. *hederifolia* and *lucorum* (Klett & Richt.) to insects. The survey has been conducted in a privately owned garden in Bulgaria. It shows that *Veronica* plants provide a reliable source of nectar and pollen to a large number of beneficial insects and produced a comprehensive species list, accompanied by numerous photographs captured over a short period of time. The site where data were collected is relatively undisturbed by human activity, which helps in obtaining more accurate, spontaneous and unbiased information. In addition to the commercial scouting of the possible use of the plant genus *Veronica*, encouraging studies on these plants is highlighted as a possible means of reversing declines in insect populations.

Samenvatting. Het belang van bloemendiversiteit als bron van nectar en stuifmeel voor insecten in de context van de moderne landbouwpraktijk is een onderwerp van voortdurende discussie op zoek naar betere oplossingen. De precieze rol van bloeiende planten en hun waarde als vitale determinanten van ecologisch duurzame landbouwlandschappen wordt nog steeds onderschat. Niet alleen worden de gevolgen van het verwijderen van onopvallende kruidachtige planten vaak over het hoofd gezien, ten koste van nuttige insecten, maar de huidige kennislacunes kunnen resulteren in commercieel significante, negatieve effecten. Deze studie richt zich op het belang van de plantensoorten Grote ereprijs *Veronica persica* Poir. en Klimopereprijs *Veronica hederifolia* Linn. subspp. *hederifolia* en *lucorum* (Klett & Richt.) voor insecten. Het onderzoek werd uitgevoerd in een particuliere tuin in Bulgarije. Het laat zien dat *Veronica*-planten een betrouwbare bron van nectar en stuifmeel zijn voor een groot aantal nuttige insecten. Het produceerde een uitgebreide soortenlijst, vergezeld van talrijke foto's die in korte tijd werden verkregen. De site waar de gegevens zijn verzameld, is relatief ongestoord door menselijke activiteit, wat helpt bij het verkrijgen van nauwkeurigere, spontane en onbevooroordeelde informatie. Dit artikel benadrukt de kritisch belangrijke waarde van het onderzoek van interacties tussen planten en insecten op kleinschalig niveau om het potentieel van *Veronica persica* en *Veronica hederifolia* subspp*. hederifolia* en *lucorum* als bronnen van nectar en stuifmeel om waardevolle insecten in een agrarische omgeving te ondersteunen. Naast de commerciële implicaties van het mogelijke gebruik van het plantengeslacht *Veronica*, wordt het aanmoedigen van deze planten benadrukt als een mogelijk middel om de achteruitgang in insectenpopulaties om te buigen.

Résumé. L'importance de la diversité florale pour fournir une source de nectar et de pollen aux insectes dans le contexte de la pratique agricole moderne est un sujet de débat permanent à la recherche de meilleures solutions. Le rôle précis des plantes à fleurs et leur valeur en tant que déterminants vitaux des paysages agricoles écologiquement durables restent sous-estimés. Non seulement les conséquences de l'élimination des plantes herbacées peu visibles sont souvent négligées, au détriment des insectes utiles, mais les lacunes actuelles dans les connaissances peuvent entraîner des effets négatifs commercialement significatifs. Cette étude se concentre sur l'importance des espèces végétales *Veronica persica* Poir., *Veronica hederifolia* Linn. subspp. *hederifolia* et *lucorum* (Klett & Richt.) aux insectes. L'enquête est menée dans un jardin privé en Bulgarie. Elle il montre que les plantes *Veronica* fournissent une source fiable de nectar et de pollen à un grand nombre d'insectes utiles. Elle a produit une liste complète des espèces, accompagnée de nombreuses photographies obtenues sur une courte période. Le site sur lequel les données ont été collectées est relativement peu perturbé par l'activité humaine, ce qui permet d'obtenir des informations plus précises, spontanées et impartiales. Cet article met l'accent sur l'importance cruciale d'explorer les interactions entre plantes et insectes à petite échelle afin d'estimer le potentiel de *Veronica persica*, *Veronica hederifolia* subspp. *hederifolia* et *lucorum* comme sources de nectar et de pollen pour soutenir des insectes précieux dans un environnement agricole. Outre les implications commerciales de l'utilisation possible du genre végétal *Veronica*, l'encouragement de ces plantes est mis en évidence comme un moyen possible d'inverser le déclin des populations d'insectes.

Key words: Plant-insect interactions — Ecology — *Veronica hederifolia* — *Veronica persica*.

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Introduction

Hatt *et al*. (2018) outline the importance of diversity when flowering plants are used as an integral part of an agricultural system, drawing special attention to the attractiveness of adjacent wildflower strips. The practice of introducing plants attractive to insects was shown to be beneficial more than 22 years ago when a study clearly demonstrated how flowering plants adjacent to agricultural margins can increase the number of natural enemies of crop pests (Long *et al*. 1998). *Veronica* is a widespread genus of Veronicaceae (Stace 2019), with more than 200 species, many of which contain biologically active compounds with pharmacotherapeutic and food preservation properties (Salehi *et al*. 2019). Both *Veronica persica* and the two subspecies of *Veronica hederifolia* are annual self-fertile herbaceous plants found in cultivated areas, in gardens and on waste ground (Bond *et al*. 2007). Their persistence throughout the year raises the pertinent question whether it would be possible to explore their nutritional potential to help insects and assess their capacity for extended synchronisation of flowering with crop yield and life cycles of beneficial insects. Quantifying the extent of benefit which floral assortments in agricultural landscapes provide to ecosystems is a challenging task due to the fact that perceived usefulness can differ greatly between different plants (Albrecht *et al*. 2020). The authors also discuss findings on the positive effect of patchy distribution of floral diversity on the overall quality of ecosystem services.

Research gaps and challenges relative to the ecological significance of *Veronica* plants

There is currently no research information which explicitly demonstrates an association of *Veronica persica* and *Veronica hederifolia* with particular insect species. Analysis on the potential of the plants as an integral component of both small-scale ecosystems and large intensively cultivated agricultural landscapes is also unavailable. *Veronica persica* and *Veronica hederifolia* with its two subspecies are among the very first plants to flower in early spring, and the ability of seeds to remain viable in soil for many years are features seen as threats to crops and gardens, resulting in constant “weeding”. This well-established constraint greatly complicates research on their potential role as an available food resource for insects, at a time when there is a critical decline in their abundance, and when the elaboration of more immediately efficient strategies to improve natural pest control practices is considered to be of pressing importance. It is sensible to search for methods that do not necessarily conform to widely-accepted frameworks for improving ecosystem services. Our knowledge of inconspicuous plant and insect species, how they interact with each other within agri-environmental systems and how anthropogenic impact affects their complex interconnections is still considerably limited (Leather 2017). The author emphasises that in order to discover poorly studied functional relationships, it is vital to effectively shift from stereotypes to unbiased understanding about the great significance of invertebrates and their interaction with plants as a whole. One particular problem in understanding the contribution made by any plant to an ecosystem is that certain species of the genus (especially *Veronica persica*) occur widely among different crops (Štefanić *et al*. 2020), and are regarded as unwanted vegetation on arable fields. An isolated statement that *Veronica* plants attract insects is provided by Bond *et al*. 2007.

Suggested research terrain

The only feasible way of collecting data on possible benefits generated by the presence of *Veronica persica*, *Veronica hederifolia* and its subspecies is to study an area where they are all abundant, preferably within an agri-environmental landscape. The sampling area chosen for this study has a sufficient number of scattered clusters of *Veronica* in a well-established garden habitat. Such a choice offers more transparent, accurate and comprehensive observation of *Veronica* plants which have been allowed to propagate without restriction for more than 20 years in an area of some 710 m^2. All three species of *Veronica*, but especially *Veronica persica*, form isolated areas of high density and sufficient potential to attract insects. The patches are a permanent component of the garden flora.

The selected area has not received any artificial chemical treatment, either with nutrients or herbicides. The only disturbance the land receives is the routine mechanical removal of dry plant material during the autumn, and highly selective maintenance of wildflower patches twice per year to form pathways and to facilitate access. *Veronica persica* occupies places that are better exposed to sunlight (Fitter & Ashmore 1973). In contrast, *Veronica hederifolia* subsp. *hederifolia* occupies both well-exposed and partially shaded areas, and *Veronica hederifolia* subsp. *lucorum* prefers partial shade under a large assemblage of Hazel (*Corylus*) trees where light conditions are comparable to a woodland habitat. *Veronica hederifolia* is described as a forest therophyte (Fokuhl *et al*. 2019).

Garden habitats are usually disregarded as sources of meaningful data collection. Young *et al*. (2019) propose a convenient methodology to estimate plant species richness reported by garden owners. However, more precision on the complexity of the functional relationships that refer to ecosystem services (in the form of citizen science reports) has not received sufficient scientific backing and credence to allow confident inferences. Professional guidance and advice could lead to the formulation of scientifically rigorous conservation measures and implementation of improved agri-environmental practices. Then, it would be rational to perceive garden spaces as useful ecological centrepieces and invaluable sources of knowledge about alternative plans to assist beneficial insects to thrive. For instance, Foster *et al*. 2019 suggest further research is required to clarify how small urban settlements are able to modify insect populations in agricultural landscapes.

Materials and methods

Equipment used for documenting the interaction of insect species with *Veronica persica* and *Veronica hederifolia* subspp. *hederifolia* and *lucorum* by day consists of a Nikon D70s digital SLR camera, with autofocus zoom lens Nikkor 28-80mm f/3.3~5.6 used in combination with Kenko automatic macro extension tube set with 3 extenders of different length (12, 20 and 36 mm) and a wireless photographic macro flash Nikon SB-R200. All resulting photographic material is processed using the RAW conversion software RawTherapee, images are assembled and final output produced with the application XnView MP and further edited using the workflow GIMP.

Research methodology relies upon documenting insects which are found to feed on any of the *Veronica* species during spatially and temporally randomised inspections of patches in situ. The observations were made between 03/04/2020 and 05/05/2020 in the town of Byala Slatina, Bulgaria; the surveyed area coordinates

43° 28′ N, 23° 56′ E. Restriction of the study to *Veronica* plants provides a simplified species richness overview and relies on preliminary empirical evidence focusing on a strictly isolated plant-insect interaction, with the possibility to extrapolate inferences to wider applicable concepts.

An essential prerequisite to study this plant-insect relationship is that the organisms are observed under field conditions. Hitherto, a significant amount of research evidence on plant-insect interactions has been obtained from controlled experiments, which do not reflect dynamic and unforeseen changes in environmental variables that can trigger unexpected responses in any of the observed organisms. Such effects are best seen under natural conditions. Due to the fact all three *Veronica* species are self-fertile, the potential benefit they provide is expected to be limited to their function as a source of nectar, pollen and seeds, together with provision of food and shelter to insects. Biology of the three plant species suggests the interaction between *Veronica* and insects in this particular study is considered unilaterally, i.e. excluding potential benefits insects may deliver to *Veronica* plants.

Important complementary note

Observations commenced following a period of severe climate anomalies in the selected location, where such conditions had not been observed before. Snow cover occurred on 23/03/2020 after a warm spring spell, and a similar anomaly occurred again on 01/04/2020. The abnormal weather conditions caused damage to trees and disrupted life cycles of many insects and also led to increased aphid infestations. An example which relies upon personal observation is the evidence for disrupted synchronisation between emergence of adult ladybirds (Coccinellidae) and predation on aphids. Ladybird species were unable to counteract increased pest abundance effectively due to unexpected temperature fluctuations, with the direct consequence of improved reproductive success among aphids in the absence of their natural predators.

Results

The plants studied were visited by 43 insect species of the following orders: Coleoptera (8 species), Diptera (18 species), Hemiptera (4 species), Hymenoptera (7 species), Lepidoptera (6 species). Photographs of documented insects from Plate 1 to 7 are numbered 1–56. Plate 8 shows photographs of the surveyed area, numbered 57–64.

Discussion

1. Overview of Coleoptera

Larvae of the genus *Anthrenus* (Desmestidae) (P1: 1 ,2) are known to damage wool, fur and other materials of animal origin when they are found in households, but in their natural habitat they infest bird nests and other animal matter (Peacock *et al*. 1993). It is concluded that beetles found in the specific location utilise the habitat solely as a source of nectar and pollen. Their number increases significantly during spring, when groups of beetles are seen feeding on different flowering plants in the surveyed garden; often small groups of individuals are found trapped in flowering tulips. *Anthrenus* larvae have been found previously feeding on dead insect material in the same garden habitat. This suggests the beetle has a meaningful role here in decomposing decaying animal material, and its survival is aided by the supplementary food resource provided by *Veronica persica* and *Veronica hederifolia* subsp. *hederifolia*. Although widespread in Europe, the occurrence of *Anthrenus pimpinellae* and records in Britain have recently been reviewed, and the species is now thought to be absent from the British entomofauna, contrary to previous suggestions (Holloway *et al*. 2018).

The Rose Chafer, *Cetonia aurata* Linn. (Scarabaeidae) is a widespread species in Europe, and is usually regarded as a garden pest. However, the adults are pollinators and the saproxylic larvae (Stokland & Meyke 2008) feed on decaying wood and compost, which makes this scarabaeid a valuable denizen of gardens, especially in urban areas (Fremlin, 2019). The documented individual was observed to feed without destroying the flowering plant. Its appearance on *Veronica hederifolia* (P1: 3) was the very first observed spring emergence of an adult *Cetonia aurata* in 2020, suggesting the plant supplies a primary food resource for overwintered adults attempting to locate flowering vegetation to obtain an energy supply as soon as possible after hibernation. *Malachius aeneus* Linn. and *Malachius bipustulatus* Linn. (Malachiidae) (P1: 4, 5) are probably pollinators of some importance (El-Torkey *et al*. 2012). However, in the absence of sufficient knowledge on feeding habits and more details on their biology (Yıldırım & Bulak 2012) and the specific nature of their interaction, if at all, with *Veronica persica* cannot be determined. However, they do consume nectar and pollen from sundry other flowering plants. The current study could not confirm predatory behaviour by this species, but Foster *et al*. 2019 mention *Malachius bipustulatus* feeding on other insects. Detailed information on its predatory preferences and behaviour would be useful, especially if further research could confirm its ability to control pest insects. More information on this would be valuable, because data from the current observation shows *Malachius bipustulatus* to be one of the most frequent visitors to *Veronica persica*.

Plate 1. Coleoptera (1–8) 1. *Anthrenus pimpinellae*. 2. *Anthrenus pimpinellae*. 3. *Cetonia aurata*. 4. *Malachius aeneus*. 5. *Malachius bipustulatus*. 6. *Meligethes* sp. 7. *Oedemera* sp. 8. *Spermophagus sericeus*, VP=*Veronica persica*, VHH=*Veronica hederifolia* subsp. *hederifolia*, VHL=*Veronica hederifolia* subsp. *lucorum*.

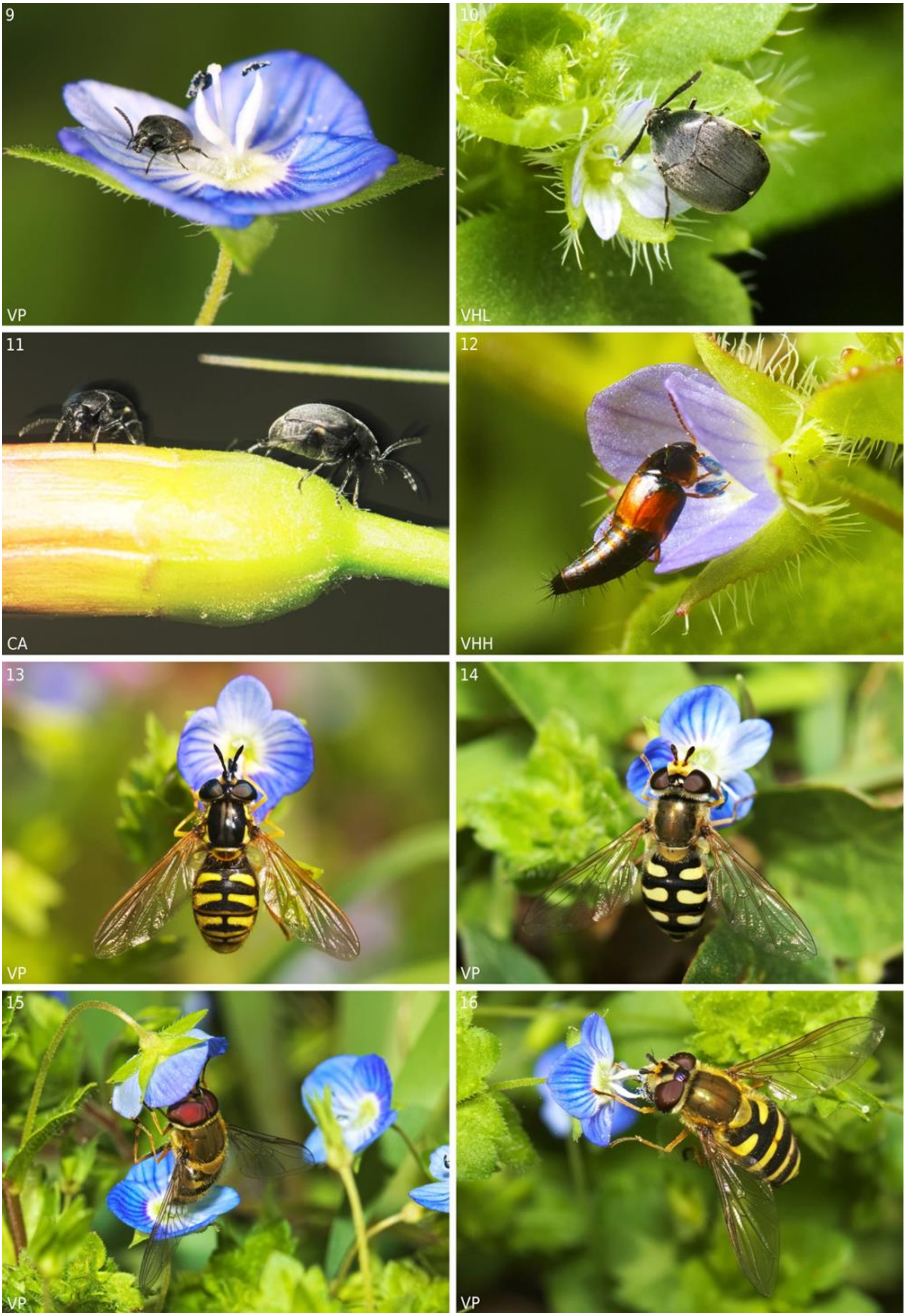

Plate 2. Coleoptera (9–12), Diptera (13–16) 9. *Spermophagus sericeus.* 10. *Spermophagus sericeus*. 11. *Spermophagus sericeus*. 12. *Tachyporus hypnorum*. 13. *Chrysotoxum cautum*. 14. *Eupeodes corollae*. 15. *Syrphus* sp. 16. *Syrphus* sp. CA=*Convolvulus arvensis.*

The pollen beetles *Meligethes* (Nitidulidae), mainly *Meligethes aeneus*, cause considerable damage to oilseed rape crops. Use of the entomogenous fungus *Metarhizium anisopliae* brings about high mortality in pollen beetles attacking the plant (Butt *et al*. 1998). Limiting the damaging impact of the beetles is becoming increasingly difficult: application of chemicals for their control is detrimental to other insects and is becoming less efficient as the beetles develop resistance to the applied substances (Heckel 2012) with the added cost of increases in pest abundance (Krauss *et al*. 2011). The Ichneumonid *Tersilochus heterocerus* Thomson is reported to be the main natural parasitoid of *Meligethes aeneus* and special attention is paid to the negative effects of insecticide use on *T. heterocerus*, as well as the importance of exploring the spatio-temporal management crop cover in respect to pest control (Schneider *et al*. 2015). Adult *Meligethes* sp. were found in very low numbers during the last day of the study. They showed a preference to feed on an isolated patch of *Veronica persica* (P1: 6) away from the dense flowering areas where most other insect recording took place. Its presence was thought to be a direct result of warm weather that triggered its appearance rather than any specific feeding preference for *Veronica persica.*

The genus *Oedemera* Olivier (Oedemeridae), false blister-beetles, includes many generalist species which feed on nectar and pollen from various flowers. There is currently no scientific evidence to confirm the exact mechanism of interaction between these species and particular flowers. However, Blažytė-Čereškienė *et al*. (2019) provide species-specific details on certain volatile organic compounds produced by plants that attract *Oedemera* beetles, suggesting that a similar analysis on *Veronica* plants could well substantiate the underlying mechanism how these plants attract insects. The fact that *Oedemera* is found on *Veronica persica* (P1: 7), indicates that this plant can supply ready food resources to these insects. Knowing more on the contribution of generalist species which are not reported to be harmful to crops or other plants is of great significance. Their interactions with plants, especially not very well-researched ones, could perhaps offer solutions for enhancing ecosystem services in a wider context. The study demonstrated a single incident involving *Oedemera* that cannot be treated as qualitatively significant, but it does prompt further examination of the mechanism of preference regarding *Veronica persica*.

Spermophagus sericeus (Geoffroy) (Chrysomelidae) is known to be associated with *Convolvulus arvensis* L., Field Bindweed (P2: 11) and has the potential to be used as a biocontrol agent against this plant (Tóth *et al*. 2001). Current literature on the genus *Spermophagus* does not report any particular association between this genus and *Veronica persica* or *Veronica hederifolia* subsp. *lucorum*. The appearance of *Spermophagus* on *Veronica* plants (P1: 8; P2: 9, 10) requires further studies to discover whether the beetle damages reproductive organs of the *Veronica* plants.

Tachyporus hypnorum (Fabr.) (Staphylinidae, rove beetles) which feeds on plant material (P2: 12) was reported on *Veronica hederifolia* subsp. *hederifolia* during the survey. Staphylinidae are very rarely phytophagous (Thayer 2016), and subjecting them to a plant diet under experimental conditions results in severe morphological and life cycle disruption (Lipkow 1966). The occurrence of *Tachyporus hypnorum* on *Veronica hederifolia* subsp. *hederifolia* suggests anomalous behaviour likely to have been triggered by an environmental factor. The only plausible explanation for this unusual habit is related to weather conditions.

Tachyporus hypnorum is known to be a polyphagous predator. Kyneb & Toft (2006) suggest that exposure of the species to monotypic diet is an unnatural condition. Balog *et al*. (2013) specify *Tachyporus hypnorum* feeds on arthropods and fungus. It is not known whether it can switch to an alternative diet under natural conditions. Not all beneficial polyphagous insects of agricultural significance as natural biocontrol agents are able to adapt to environmental anomalies. It is therefore suggested the abnormal feeding habit *Tachyporus hypnorum* revealed during the study is a direct consequence of disrupted diapause of an overwintering adult due to climate anomalies that resulted in starvation, rather than a manifestation of behavioural plasticity, and that this species should be treated with extra caution in regard to its agricultural value and responses to the consequences of extremes of temperature. It would be apposite to highlight this behaviour as a warning of how climate change can disrupt or modify insect phenology.

2. Overview of Diptera

Family Syrphidae

The genus *Chrysotoxum* Meigen (P2: 13) includes 19 described European species (Masetti *et al*. 2006), but a single specimen of *Chrysotoxum cautum* Harris was encountered on two occasions in the current *Veronica* plant study, in flight just above the *Veronica persica* patches, and was a new find for the study area. Feeding habits of the larva are still unclear (Reemer & Goudsmiths 2004). *Eupoeodes corollae* Fabr. was seen frequently feeding on *Veronica persica* (P2: 14). This species has been reported as a successful biocontrol agent on aphids (Putra & Yasuda 2006).

Species of *Syrphus* Fabr. frequently visit *Veronica persica* (P2: 15, 16) which also applies to *Scaeva* Fabr. (P3: 17, 18), represented by *Scaeva selenitica* in this study. *Syrphus* and *Scaeva* were often observed in April, feeding on pollen and nectar from *Veronica persica.* Larvae of both genera are aphidophagous (Speight 2014). Another regular visitor on *Veronica persica* patches was *Episyrphus balteatus* De Geer (P3: 19). It is an important pollinator and is said to play a vital role in pollinating strawberries (Hodgkiss *et al*. 2018). However, the authors understand the ability of *Episyrphus balteatus* to pollinate strawberry flowers was studied under controlled conditions. *Veronica persica* appears to be a food resource for all aphidophagous hoverflies documented during the study, its role when present adjacent to strawberry crops in the field, could supply evidence of its potential to improve pollination service.

Plate 3. Diptera (17–24) 17. *Scaeva selenitica* (male). 18. *Scaeva selenitica* (female). 19. *Episyrphus balteatus.* 20. *Neoascia* sp. 21. *Paragus* sp. 22. *Lucilia* sp. 23. *Scathophaga stercoraria.* 24. *Empis* sp.

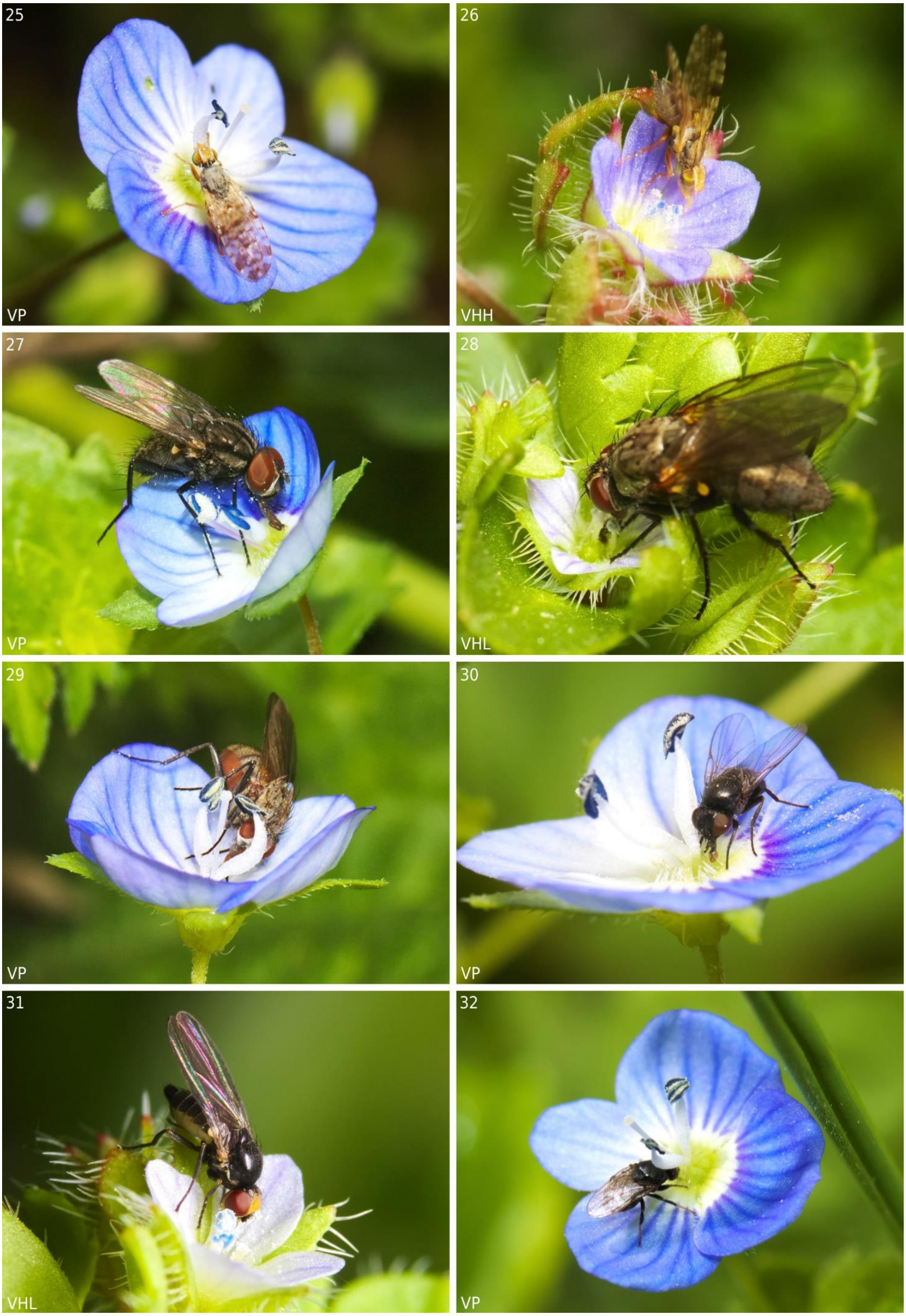

Plate 4. Diptera (25–32) 25. *Dioxyna bidentis.* 26. *Dioxyna bidentis.* 27. Family Muscidae 28. Family Muscidae 29. Family Muscidae 30. *Ophiomyia* sp. 31. *Phytomyza* sp. 32. *Polyodaspis ruficornis*.

Episyrphus balteatus is a hugely beneficial insect because it consumes large quantities of aphids during its larval stage (Singh *et al*. 2020); for instance, larvae assist in the control of the Green Apple Aphid, *Aphis pomi* De Geer (Kumari 2020). Singh *et al*. (2020) also report increased adult longevity and fecundity when adults are supplied with fresh mustard pollen grains: these findings suggest that there are good reasons to offer *Veronica persica* as an additional sustenance boost to Syrphids.

The nutritional value of *Veronica persica* pollen grains has not been quantitatively assessed to date, and the present study can only confirm a strong preference of *Episyrphus balteatus* for *Veronica persica*. The adaptability of its larvae to consume non-prey food has been researched by Vosteen *et al*. (2018). The authors conclude that since the larvae cannot locate aphid colonies outside the immediate vicinity, they probably browse vegetation randomly. Perhaps *Veronica* spp. could provide a food source and help survival of larvae of this and other species before they are able to locate another aphid colony, but hard evidence is not at present available.

A particularly interesting genus observed to feed on *Veronica persica* is *Paragus* Latreille (P3: 21). It is the smallest aphid-feeding Syrphid (Coe 1953) found to visit *Veronica persica*, and the first to be observed frequently in early spring within the surveyed area. The genus is also considered valuable due to the importance of adult forms as pollinators (Hassan *et al*. 2008; Turk *et al*. 2014).

Haenke *et al*. 2009 emphasise the importance of flower strips as sources of beneficial insects. A large proportion of the visitors to *Veronica persica* are beneficial Diptera, and it would therefore be sensible to perceive this plant as an easily manageable floral food supply for hoverflies. Like *Tachyporus hypnorum*, hoverflies deliver vital ecosystem services and are sensitive to unexpected climate-driven changes (Doyle *et al*. 2020). The only non-aphidophagous exception in the current study belongs to the genus *Neoascia* Williston (P3: 20) the larvae of which feed on decaying plant material (Rotheray 1993). It could be that *Veronica persica* provides a reliable food resource to the adults, which produce larvae that contribute to soil nutrient cycles. Availability of detritus-feeding larvae could be of importance in counteracting starvation of beneficial pest controllers.

Family Calliphoridae

This family is represented by the genus *Lucilia* Robineau-Desvoidy, which is frequently observed on *Veronica persica* (P3: 22). It is important in entomological forensics as a decomposer of flesh (Roe & Higley 2015) and beneficial to the ecosystem as a pollinator (Zych 2006). *Scathophaga stercoraria* (L.) (Family Scathophagidae) is also a decomposer, and is valuable to farming management practices (Geiger *et al*. 2010). This species clearly has a strong preference for *Veronica persica* (P3: 23) and is always among the early spring visitors in the area surveyed. It also utilises the plant as a shelter. Another intriguing find is a species of *Empis* sp. (Family Empididae) recorded once visiting *Veronica persica* (P3: 24), but the role played by Empididae in the ecosystem is unclear.

Family Tephritidae

Dioxyna bidentis Robineau-Desvoidy feeds on nectar from *Veronica persica* and *Veronica hederifolia* subsp. *hederifolia* (P4: 25, 26). It is a rare visitor within the surveyed area. White (1988) indicates that it is a nectar-feeding species. The current study confirms that the fly obtains nectar from *Veronica persica* and other herbaceous plants such as *Galium aparine* Linn. and *Oxalis corniculata* Linn. According to Kapoor (2002) other species of *Dyoxina* are pests on beneficial plants. *Dioxyna sororcula* Wiedemann is a pest on Niger (*Guizotia Cass.*) (Family Asteraceae) which is cultivated in India (Jakhmola 1983), but the biology and potential ecological role of *Dioxyna* species in relation to *Veronica* have not been sufficiently researched.

Family Muscidae

Muscidae are another important group in forensic entomology (Grzywacz *et al*. 2017). They have been shown to utilise *Veronica* plants as shelters when not actively feeding on the flowers. Although they often just rest on *Veronica* plants or surrounding vegetation, they are among the very first spring visitors (P4: 27, 28, 29).

Family Agromyzidae

The larvae of Agromyzidae are leaf-miners (Kahanpää 2014) and represented by two species which belong to the genera *Ophiomyia* Braschnikov (P4: 30) and *Phytomyza* Fallén (P4: 31). Many *Ophiomyia* are agricultural pests (Yadav *et al*. 2019) and *Phytomyza* also have an impact on food production (Laznik *et al*. 2012). Species of *Ophiomyia* and *Phytomyza* visit *Veronica* plants from time to time, but do not show any consistent floristic preference and are not considered to be of significance in the present study.

Family Chloropidae

Polyodaspis ruficornis (Macquart) has been seen rarely to feed on *Veronica persica* (P4: 32). It causes damage to walnuts (*Juglans*) (Falk *et al*. 2016).

3. Overview of Hemiptera

Geocoris erythrocephalus (Lepeletier & Serville) (Geocoridae) is regarded as a valuable predator of agricultural pests. Its biology and overall significance are summarised by Rajan *et al*. (2018). The proboscis, or stylet, is used to pierce prey and inject digestive enzymes, followed by sucking out the contents. It is instantly recognised by its unusually large eyes and diagnostic colour (Kóbor *et al*. 2018). This hugely beneficial bug has inhabited the survey area for many years and there are records of it feeding on nectar on *Erigeron annuus* (P5: 34) in 2013. The population is stable and dense. *Geocoris erythrocephalus* also takes nectar from *Veronica persica*, emphasising the importance of this plant (P5: 33), and from *Mentha spicata* Linn. until late autumn which enables the species to maintain biocontrol throughout the year.

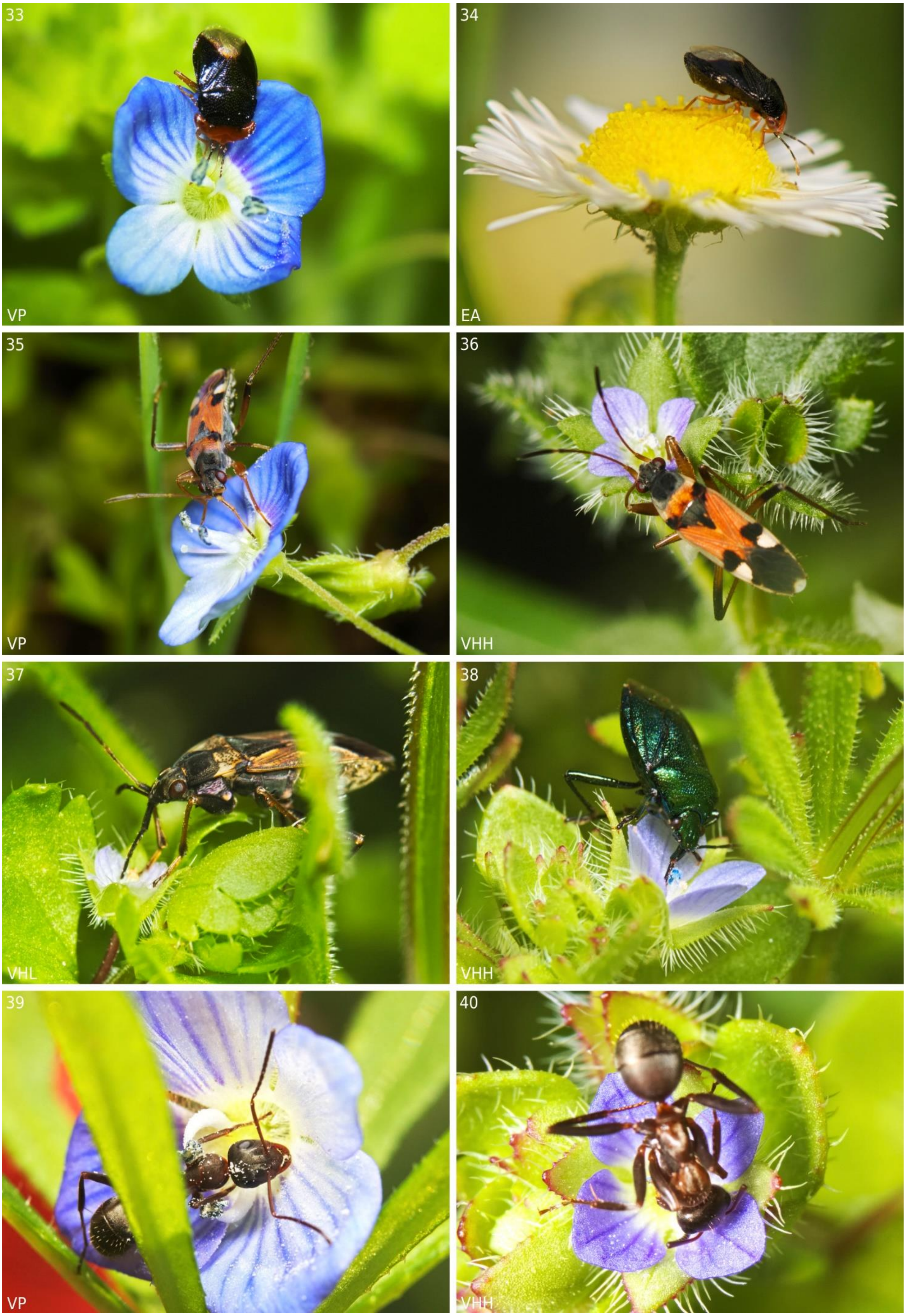

Plate 5. Hemiptera (33–38), Hymenoptera (39–40) 33. *Geocoris erythrocephalus*. 34. *Geocoris erythrocephalus.* 35. *Beosus quadripunctatus.* 36. *Beosus quadripunctatus.* 37. *Rhyparochromus vulgaris*. 38. *Zircona caerulea.* 39. *Formica* sp. 40. *Formica* sp., EA=*Erigeron annuus.*

Plate 6. Hymenoptera (41–47), Lepidoptera (48) 41. *Plagiolepis* sp. 42. *Plagiolepis* sp. 43. *Temnothorax* sp. 44. *Eucera nigrilabri*s. 45. *Osmia* sp. 46. *Polistes nimpha*. 47. Pteromalidae. 48. *Glaucopsyche alexis*.

Zicrona caerulea (Linn.) (Pentatomidae) is another bug that predates agricultural pests, and has been observed to take nectar from *Veronica hederifolia* subsp. *hederifolia* (P5:38). *Beosus quadripunctatus* (Müller) and *Rhyparochromus vulgaris* (Schilling) (Family Rhyparochromidae) (P5: 35, 36, 37) are stated to inhabit gardens (Akimzhanov *et al*. 2019). Their presence is largely determined by the quality of mowing and farming practices (Limonta *et al*. 2004). Rabitsch (2018) confirms their significance as meaningful habitat quality indicators. They, together with *Zicrona caerulea*, make infrequent visits to all three species of *Veronica.*

4. Overview of Hymenoptera

Several genera of ants, bees and wasps have been seen to visit *Veronica* plants. Ants are represented by the genera *Formica* Linn., *Plagiolepis* Mayr and *Temnothorax* Mayr (Formicidae) (P5: 39, 40; P6: 41–43). Although there is an insufficiency of data to make safe conclusions, *Veronica hederifolia* appears to be a myrmecochorous plant (Fokuhl *et al*. 2019). The Solitary Bee *Eucera nigrilabris* (Lepeletier) (Apidae) (P6: 44) visited *Veronica persica* as well as *Lamium purpureum* Linn. and *Taraxacum officinale* agg. Mason Bees, *Osmia* Panzer (Megachilidae) were also found during the study, and are quite frequent on *Veronica persica*. (P6:45). Horth & Campbell (2017) confirm the importance of Mason Bees in commercial crop pollination. The most frequent visitor during early April has been the Paper Wasp *Polistes nimpha* (Christ) (Vespidae) (P6: 46). The presence of this species is described as indicative of the extent of anthropogenic impact in a given area (Szczepko *et al*. 2020), and its frequency in the study area confirms the suitability of this habitat in providing an initial overview of valuable insects associated with *Veronica* plants. Pteromalidae (Dalman) was also observed but its association with VP is not clear based on this single record (P6: 47).

5. Overview of Lepidoptera

Several species of butterfly and day-flying moth have been observed to make use of all three *Veronica* species, especially *Veronica persica*. *Glaucopsyche alexis* (Poda) (Lycaenidae) (P6: 48) is associated with wildflower-rich meadows. It has been very rarely recorded in the sampled area (one sighting per year for the last 3 years).

Heliothela wulfeniana (Scopoli) (Crambidae) (P7: 49) and *Pancalia leuwenhoekella* (Linn.) (Cosmopterigidae) (P7: 50–53) are diurnal species with well-established populations in the sampled area. *Heliothela wulfeniana* visits wide range of wildflowers, but *Veronica persica* is the only Speedwell it selects. In contrast, *Pancalia leuwenhoekella* visits any wildflower species in the surveyed area including all three species of *Veronica*. Another notable find was *Scythris sinensis* (Felder & Rogenhofer) (P7: 54) on *Veronica persica*. This species is often recorded visiting other wildflowers, including *Mentha spicata* L..

Tyta luctuosa (Denis & Schiffermüller) (Four-spotted) (Noctuidae) (P7: 55) populations depend on the presence of suitable habitats where the larval food plant, *Convolvulus arvensis* Linn. grows. It breeds freely within the sampled garden area, and foliage of the food plant often shows evidence of damage by the larvae. Patches of *Veronica persica* were regularly visited in spring by *Tyta luctuosa* before alternative nectar-sources became available.

Panemeria tenebrata (Scopoli) (Small Yellow Underwing) (Noctuidae) (P7: 56) is another diurnal moth that regularly seeks nectar on *Veronica persica*. It is also attracted to the dense patches of flowering *Stellaria media* (Linn.) *Veronica* has a longer flowering period than *Stellaria media*, and the moth switched to *Veronica persica* when *Stellaria media* was going over. It has not been observed at *Veronica hederifolia* apart from one seen at rest on the plant.

Conclusions

Despite being regarded as an unwanted weed in agricultural landscapes, *Veronica persica* attracts a significant number of beneficial insects, including the moths *Pancalia leuwenhoekella* and *Heliothela wulfeniana*, with established populations in the surveyed area. The exact number of individual visits has not been monitored during the course of this study, but the regular attendance of several species of micro moth, as well as the Noctuids *Panemeria tenebrata* and *Tyta luctuosa* at *Veronica* plants, suggest the interaction between diurnal insects and these plants is beneficial to the ecosystem, and merits more detailed research. The potential benefit of introducing *Veronica* flower strips in an agricultural landscape deserves serious consideration, along with attempts to redress the balance between beneficial invertebrates and crop pests.

Private gardens need to be kept reasonably tidy and organised, but the quality, depth and manner of doing this can affect insect populations in different ways. The removal of a specific foodplant can disrupt or terminate the presence of many species; the liberal use of fertilisers may enhance growth of desirable plants but is detrimental to those which thrive on poorer soils. The adverse effects of insecticides and pesticides is self-evident. Showy plants such as *Rhododendron* and *Buddleia* are often planted for their attraction to butterflies and other insects as well as for their beauty, but the present study suggests that less conspicuous plants have an important role too, and that 'weeding' might be adjusted accordingly.

A sufficiency of hard evidence having been obtained from small-scale surveys such as this one, would allow similar approaches to conservation problems to be encouraged in forestry, in agriculture and in maintenance of pasture.

Human intrusion into sensitive habitats, with its attendant pollutants and mechanical destruction, is one of the underlying reasons for global declines and extinctions of insects and many other organisms, but effective ways of countering this seriously adverse effect require consistent effort. The best we can do is to try to mitigate the problem locally, starting with the kind of investigation undertaken in the current project, assuming nothing.

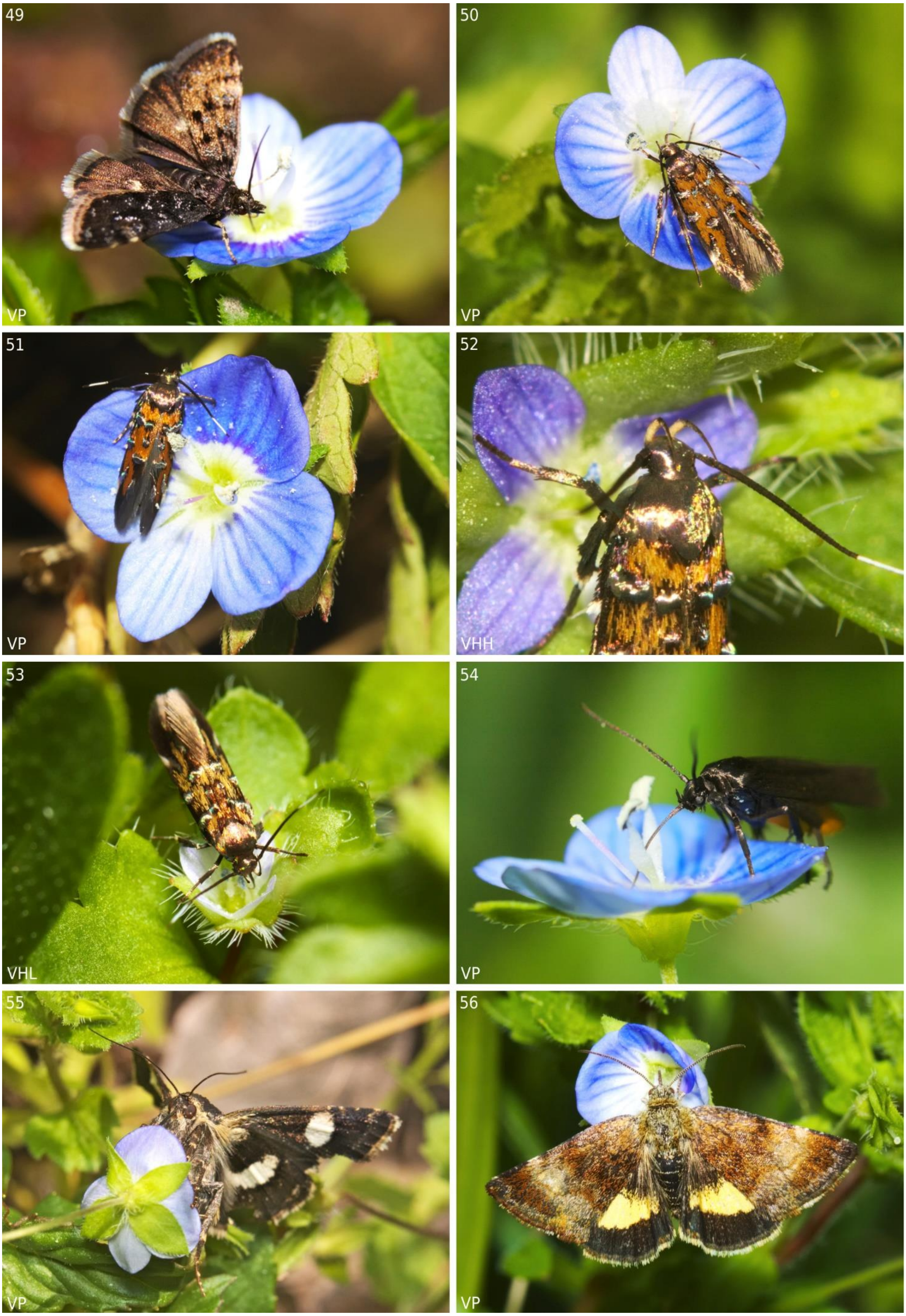

Plate 7. Lepidoptera (49–56). 49. *Heliothela wulfeniana*. 50. *Pancalia leuwenhoekella*. 51. *Pancalia leuwenhoekella*. 52. *Pancalia leuwenhoekella*. 53. *Pancalia leuwenhoekella*. 54. *Scythris sinensis*. 55. *Tyta luctuosa*. 56. *Panemeria tenebrata*.

Plate 8. Sampling area 57. Main sampling site. 58. *Veronica persica*. 59. *Veronica persica*. 60. *Veronica persica*. 61. *Veronica persica* and *Ballota nigra*. 62. *Veronica persica* and *Veronica hederifolia* subsp. *hederifolia*. 63. *Veronica persica*. 64. *Veronica hederifolia* subsp. *lucorum*.

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