European hoverflies:

moving from assessment to conservation planning

IUCN

SSC Species Survival Commission

IUCN SSC Hoverfly Specialist Group

CONSERVATION PLANNING SPECIALIST GROUP

European Commission

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IUCN SSC HSG/CPSG (2022). *European Hoverflies: Moving from Assessment to Conservation Planning.* Conservation Planning Specialist Group, Apple Valley, MN, USA.

IUCN: is a membership union uniquely composed of both government and civil society organisations. It provides public, private, and non-governmental organisations with the knowledge and tools that enable human progress, economic development, and nature conservation to take place together.

IUCN – Global Species Programme (GSP): The IUCN Global Species Programme supports the activities of the IUCN Species Survival Commission and individual Specialist Groups, as well as implementing global species conservation initiatives. It is an integral part of the IUCN Secretariat and is managed from IUCN's international headquarters in Gland, Switzerland. The Species Programme includes staff hosted by multiple IUCN offices around the world and several technical units including the IUCN Red List Unit, Species Trade and Use, Freshwater Biodiversity Unit (all located in Cambridge, UK), the Global Biodiversity Assessment Initiative (located in Washington DC, USA), and the Marine Biodiversity Unit (located in Norfolk, Virginia, USA).

IUCN Species Survival Commission (SSC): is the largest of IUCN's six volunteer commissions with a global membership of 1000s of experts. SSC advises IUCN and its members on the wide range of technical and scientific aspects of species conservation and is dedicated to securing a future for biodiversity. SSC has significant input into the international agreements dealing with biodiversity conservation.

IUCN SSC Hoverfly Specialist Group (HSG): was established in 2018. It brings together the experts around the world dealing with hoverflies, which will through their work strive to assess the threat of extinction for these species through Red Listing, generate and disseminate scientific knowledge, engage in conservation actions of these species and build public awareness about hoverfly significance.

IUCN SSC Conservation Planning Specialist Group (CPSG): was established in 1979. Its mission is to increase the effectiveness of conservation efforts worldwide through scientifically sound, collaborative planning processes that bring together people with diverse perspectives and knowledge to catalyse positive change for species. CPSG provides species conservation planning expertise to governments, other SSC Specialist Groups, zoos and aquariums, and other wildlife organisations.

StN (Syrph the Net): was first published in 1997. Its primary objective is to provide an analytical tool for standardising the degree of association between European hoverfly species and their habitats, micro-habitats and other attributes, thereby providing predictive capability. The latest version fully codes 800 of the known European species with the remaining approximately 150 species partially coded. The database is free, distributed electronically and its files are now accessible from all parts of the continent by naturalists, students, conservation practitioners and researchers. It is maintained by Martin Speight and an editorial team comprising Emmanel Castella, Jean-Pierre Sarthou and Cédric Vanappelghem.

CONTENTS

ACRONYMS & ABBREVIATIONS

A2P	Assess to Plan
AOO	Area of Occupancy
BCE	Butterfly Conservation Europe
BfN	Bundesamt für Naturschutz - German Federal Agency for Nature Conservation
BIOSENSE INSTITUTE	Institute based in University of Novi Sad, Serbia
BOLD178	Barcode of Life Database
BR	Bulbs, Roots
CAP	Common Agricultural Policy
CORINE	European Habitats Classification System
DINA	Diversity of Insects in Nature Protected Areas
EAZA	European Association of Zoos and Aquaria
EDF	Electricité de France
EFI	European Forestry Institute
EOO	Extent of Occurence
EPI	European Union Pollinators Initiative
EC	The European Commission
EU PLEDGES	Pledges made by informal groups / organisations in an European Union Member State, to undertake green action
EU POMS	European Union Pollinator Monitoring Scheme
EU27	27 European Countries
EUNIS	European Nature Information System
EVKr	Entomological Association Krefeld
FAP	Farming with Alternative Pollinators
HD	Habitats Directive
HSG	Hoverfly Specialist Group
I-Naturalist	Nature Application (App) for mapping and sharing biodiversity observations
IBA	Important Bird Area
iBOL	International Barcode of Life
IPA	Important Plant Area
LIFE	L'Instrument Financier pour l'Environment – European Union's funding instrument for the environment and climate action
LUOMUS	Finnish Museum of Natural History
MAEC	Mesures Agro-Environnementales et Climatique – Measures supporting farms engaging in practices that combine economic & environmental performance
MHEP	Marketable Habitat Enhancement Plants
N2000	Natura 2000 : Network of protected areas covering Europe's most vulnerable threatened species and habitats
NATURALIS	Netherlands National Research Institution for Biodiversity
NOx	Nitrogen Oxide
ONF	National Forests Office, France
PA	Protected Area
PBA	Prime Butterfly Area
PHA	Prime Hoverfly Area

RSPB	Royal Society for the Protection of Birds
RZSS	Royal Zoological Society of Scotland
SAFEGUARD PROJECT	Safeguarding European wild pollinators
SIT	Syphidae In Trees
SLF	Stem, Leaves, Fungi
SPRING	Strengthening Pollinator Recovery through INdicators and MonitorinG
STING	Science and Technology for pollinating Insects
StN	Syrph the Net
TAXO-Fly	Taxonomic Resources for European Hoverflies Monitoring Scheme
UNSPMF	University of Novi Sad Faculty of Sciences, Serbia
WCPA	World Commission on Protected Areas
ZFMK	Zoological Research Museum Alexander Koenig
CETAF	European organisation of Natural History Museums, Botanic Gardens and Research Centres

EXECUTIVE SUMMARY

WHY HOVERFLIES NEED THEIR OWN PLAN

Around 980[1] hoverfly species (Syrphids) have been reported for Europe (Speight & Castella, 2020). Adults feed mainly on pollen and nectar (Thompson & Rotheray, 1998) and range from large bumblebee mimics to tiny, hairless species, with mimicry of bees and wasps widespread (Howarth *et al.*, 2004; Penny *et al.*, 2012). Their ecology is largely determined by the needs of the larvae, which vary substantially in biology and feeding requirements. Hoverflies visit at least 72% of global food crops (estimated to be worth around US$300 billion per year) and over 70% of animal pollinated wildflowers (Doyle *et al.*, 2020). In Europe they are the most important pollinator group together with native bees and some wildflowers are almost exclusively hoverfly pollinated. Hoverflies generally ensure better pollination than bees at higher altitudes, under Nordic climatic conditions, or in cool microclimate or weather situations. However, their contributions to healthy ecosystems extend beyond simple pollinator services to roles in biocontrol, water purification, and long-distance pollen transfer: adults feature in the diets of insectivorous birds, spiders, ants, solitary wasps, dragonflies, robber flies and even carnivorous plants; many parasitic wasps lay their eggs in hoverfly larvae; and about 40% of species have aphid-feeding larvae that can protect crops by keeping aphid levels at much lower levels than without hoverflies. For this reason, some species are commercially grown[2]. In addition, hoverfly larvae have an important role in the natural decomposition of materials such as dead wood, compost, dung, and rotting aquatic vegetation, and can be used to decompose organic material from agricultural and industrial processes. Their wide distribution and varied larval requirements make hoverflies good bioindicators.

Despite their environmental and economic significance, pollinator conservation efforts to date have been dominated by activities related to bees and butterflies. Fortunately, in 2018, the European Union (EU) launched a comprehensive Pollinators Initiative to extend action to all main pollinator groups. However, given their unusually diverse life-histories and microhabitat requirements, hoverflies will need additional and different measures from those of other groups, to ensure that they are adequately conserved and to realise the full range of benefits provided by them. In short, they need their own plan. Recognising this, the International Union for Conservation of Nature (IUCN) European Red List of Hoverflies initiative extended its work to draft a preliminary multi-species plan of action for European hoverfly species identified as threatened with extinction. This preliminary plan integrates IUCN European Red List data with information from other sources, notably Syrph the Net (StN[3]) and expert opinion to:

- describe the broad needs of hoverfly species recently assessed as threatened;
- consolidate existing recommendations for conservation of European hoverflies from the EU Pollinators Initiative;
- describe remaining gaps and challenges;
- recommend relevant action;
- identify organisations who, resources permitting, might be able and willing to assist implementation.

The aim is to complement other EU work in this area by providing additional information and detail on hoverfly conservation needs and solutions, to decision-makers, funders, and nature conservation implementers.

THE PLANNING APPROACH

The core of this document was drafted during a virtual planning workshop, held on September 18-19th 2020, and attended by 19 participants. The workshop followed the final European Red List Assessment for Hoverflies workshop and was an initiative of the Global Species Programme Team in the IUCN European Regional Office and IUCN Species Survival Commission (SSC) Hoverfly Specialist Group (HSG), supported by the IUCN SSC Conservation Planning Specialist Group (CPSG) in the role of neutral planning facilitator. Following the workshop, both workshop participants and additional experts were consulted on successive drafts (see inside cover for details).

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1 Of these, 890 have been assessed for the European Red List because the others have been either found to be introduced, not yet published or are in some other way not applicable (G. Flinn).
2 For instance at Knoppert biological systems: https://www.koppert.nl/syrphidend/
3 The StN database documents the habitat and micro-habitat associations of European hoverflies.

Planning followed the IUCN SSC CPSG *Species Conservation Planning Principles and Steps* [4] and used CPSG's *Assess to Plan* approach for addressing multi-species datasets. Red List assessments can be freely accessed one species at a time, from the online IUCN Red List website. The Assess to Plan (A2P) process supports the viewing of available data on biology, distribution, habitats, and major threats across many species at once, to help identify groups likely to benefit from the same kinds of conservation activity performed either in the same places or involving the same conservation agencies and actors. For hoverflies, experts identified the most valuable groupings as those relating to larval feeding types and their associated microhabitats (see Box 1). These were the focus of subsequent discussions. Throughout the planning exercise the StN database, which includes fine-scale and comprehensive information on hoverfly ecology, was a major complementary resource.

WORKSHOP SCOPE

The workshop covered 30 Critically Endangered (CR), 170 Endangered (EN) and 60 Vulnerable (VU) hoverfly species either endemic to Europe or whose distribution falls mostly within Europe. However, as planning discussions focused mainly on the microhabitats known to be critical to the larvae of this group, recommended actions should benefit other taxa with overlapping larval feeding traits. Experts noted that there are species categorised in recent assessments as Near Threatened or as Least Concern, which may also require urgent conservation attention to prevent their progression to a higher category of threat in the near future. Recommendations were also made to address this need.

BOX 1. Major feeding trait categories and associated microhabitats for 260 threatened European hoverfly species.

1. SAPROPHAGES
   - Saproxylic (decaying wood, sap runs, tree- holes, etc.) (30 spp.).
   - Semi-terrestrial (decaying organic matter, not dead wood) (2 spp.).
   - Aquatic (not feeding on dead wood) (17 spp.).
2. ZOOPHAGES
   - Feeding on other organisms, mainly aphids (57 spp.).
3. PHYTOPHAGES
   - Feeding on or in bulbs/roots (103 spp.).
   - Feeding on stems, leaves, fungi (51 spp.).

CHALLENGES TO HOVERFLY CONSERVATION IN EUROPE

Challenges to the conservation of hoverflies in Europe are complex but converge on a number of themes: changes in land-use and land management practices (including forestry and agriculture) that favour removal of microhabitat complexity and heterogeneity; shifts in hydrology due to water body management, water abstraction, and the impacts of climate change that have resulted in the loss or alteration of small water bodies essential to larval development; widespread use of pesticides and harmful fertilisers including toxic seed coatings, and a general lack of awareness and understanding of the problems associated with all of these practices, which affect many invertebrate species; gaps in knowledge, tools and expertise which prevent some of these issues from being addressed; and some gaps and conflicting incentives in EU environmental and agricultural policies, that exacerbate the challenge of conserving species such as hoverflies. Further details are included in the report on the European Regional Red List assessments (Vujić *et al.*, 2022)

SUMMARY OF PRIORITIES FOR ACTION

Sufficient habitat and habitat diversity are needed to enable species to breed, feed and mature undisturbed and recommendations were made for each larval feeding trait category. In general, small-scale mosaic landscapes are ideal, with less agricultural and forestry pressure and with large areas or proportions free of pesticides, harmful fertilisers and seed coatings. Habitat fragments such as small patches of woodland within heavily grazed areas, small water bodies and veteran trees and their associated microhabitats are essential to many species and require urgent protection. Pursuing ways to make these issues visible to stakeholders that manage habitats, engaging them at scale and equipping them to implement positive changes, must form an important theme of future activities,

[4] http://cpsg.org/sites/cbsg.org/files/documents/CPSG%20Principles%20and%20Steps.pdf

as well as campaigning for a general shift towards the pursuit of biodiversity values across all land management systems. Finally, enabling the effective conservation and ongoing monitoring of syrphids across Europe will require a significant increase in the availability of and access to, tools, databases, and experts, assisted by the conservation results from the European Red List of Hoverflies and the outputs of the A2P planning exercise. These various needs are distilled into the six goals shown in Figure 1, with further details and associated actions provided in later sections of this document.

THIS DOCUMENT

This document shows five broad areas of work needed to support European hoverfly conservation, as recommended by A2P workshop participants. Each work area has a goal, a series of recommended actions, and a section of preceding text describing the topic, background and supporting evidence that sits behind the recommendations. In addition, for the actions recommended, information is provided on organisations or individuals that might be willing and able to implement or enable the necessary work, resources permitting. As this project extends across Europe, this list is often indicative and generalised and not exhaustive. This should be considered a working document, to be used and re-shaped for other purposes as needed and reviewed and updated as required.

AUDIENCE

The targeted audience is the diverse array of decision-makers, managers, practitioners and scientists required to implement recommended actions. Key audiences include: European and national government agencies and local management authorities, NGOs, policy makers (local, national and regional), developers (and their ecologists), the scientific community and places of learning (universities, institutes, schools), the main land-user groups (agriculture, grasslands, forestry), Natura 2000 site managers, municipal managers of public territory, parks and road-side verges, nature conservation area management bodies, groups with similar conservation interests (e.g. pollinators, veteran trees, small marshes, high mountains, specific host plants), and local communities in areas where action is most needed. Relevant business sectors are also included, such as the agrochemical and food retail industries.

IMPLEMENTATION

This preliminary plan is European in scope. Though much can be implemented at European level, most of the work identified will need to be implemented, supported, and enabled at national, sub-national and local levels and would benefit from dialogue and collaboration among the diverse stakeholder groups working there. National or sub-national planning workshops aimed at customising and operationalising this preliminary plan for the local context, could speed uptake and progress. The first pilot for this approach began in Denmark, in April 2022 and it is hoped that others will follow. Implementation of this preliminary plan will be monitored and encouraged through the Hoverfly Specialist Group.

Figure 1: *summary of recommended goals and priorities.*

1

Sufficient tools, databases & experts for effective hoverfly conservation in Europe

Including:

- increased use of StN and IUCN Red List;
- ID Keys for *Cheilosia*, *Merodon* & *Eumerus*;
- wider integration of Malaise traps into monitoring;
- hoverfly expert capacity building;
- advancement of barcoding.

2

Adequate protection, management & restoration of priority microhabitats & populations

Prioritising:

- diverse habitat mosaics & transition zones;
- herb layer & bulb hotspots in grassland & forest systems;
- veteran or over-mature tree features;
- small water bodies;
- assessing need for intensive population-level support for regionally/nationally threatened species

3

A cultural shift towards biodiversity-friendly attitude and behaviour

Supported through:

- guidance on hoverfly-friendly measures for all relevant sectors, especially Agriculture, Forestry & Grasslands/Grazing systems;
- materials & initiatives to improve public perception of hoverflies.

4

Protected Areas free of toxic substances and better rules for their application outside these areas

Prioritising:

- all Protected Area networks;
- alpine and Mediterranean regions;
- all low nitrogen systems (e.g. bogs, heathlands).

5

Policy support for hoverflies in Europe that aids conservation action

Including:

- re-configured incentives under CAP;
- select hoverflies added as typical species of HD Annex I habitats or equivalent national protections;
- additional considerations for NT & LC species with recent sharp declines;

Table 1. *Examples of microhabitat protection and restoration priorities, and key partners & implementing agencies.*

<table>
<tr><th>Example of recommended measures</th><th>Who could take them</th><th>Enabling bodies</th></tr>
<tr><td>■ ID & protect Prime Hoverfly Areas across Europe (using Vujić et al. 2016);
■ Establish a Veteran Tree Taskforce to map & protect Veteran trees Europe-wide.</td><td>UNSPMF, IUCN SSC HSG, PA networks.</td><td rowspan="4">■ EU, national & local policy makers;
■ Universities & training institutes;
■ Research & data organisations;
■ Education & advocacy organisations;
■ Conservation NGOs;
■ Wildlife and farming charities;
■ Funding agencies.</td></tr>
<tr><td>■ Protect remaining old growth forest (no guarantee hoverfly diversity will return to new forest);
■ Support presence and continuity of veteran tree habitats (rot-holes, sap-runs, windthrows, tree stumps, fallen branches etc); and create artificial habitat where needed (e.g. by drilling holes in stumps);
■ Restrict drainage and maintain or restore small water bodies;
■ Maintain small open areas such as meadows, to increase forest edge habitat;
■ Protect and encourage the herb layer (build ground-level vegetation into management plans and restrict grazing)
■ Identify and protect bulb hotspots when reforesting.</td><td>Forestry & woodland managers & regulators.</td></tr>
<tr><td>■ Establish, protect & manage Prime Hoverfly Areas;
■ Develop hoverfly inventories & ID priority species;
■ Identify and mitigate the main threats to these and monitor closely;
■ Implement “Biodiversity Farming” within-PA forestry & agriculture: ban application of pesticides and harmful fertilisers, ensure practices are net producers of biodiversity;
■ Manage number and distance between beehives.</td><td>Protected Area managers and regulators, farming bodies & partnerships.</td></tr>
<tr><td>■ Use integrated pest management and support healthy populations of aphidophagous hoverflies for biocontrol;
■ Use only pesticides & seed coatings that are fully biodegradable within 1 yr & only on 50% of land each year;
■ Reduce fertiliser application & use semi-natural barriers to reduce aerial dispersal and run-off (e.g. hedgerows, buffer zones);
■ Grow multi-year flower strips & encourage habitat mosaics.</td><td>Farming bodies & partnerships, land managers & regulators.</td></tr>
</table>

■ Preserve even the smallest fragments of undisturbed habitat in grasslands (e.g. woodland patches); ■ Designate & protect bulb plant hotspots; ■ Prevent over-grazing in specific areas by establishing and maintaining sustainable numbers of grazing animals; ■ Delay first grazing/mowing until after peak bloom; ■ Reduce fertiliser input to support less competitive and late flowering plant species.	Grasslands and grazing system managers & regulators.	
■ Develop landscape management plans (rather than for single systems) to ensure habitat complexity, diversity, connectivity, and buffer zones for sensitive areas; ■ Regulate and manage fire frequency and intensity to reduce damage and maximise benefits, tailored to specific habitat types; ■ Maintain or restore natural hydrology and protect the integrity of small water bodies, all systems.	Managers & regulators, all systems.	

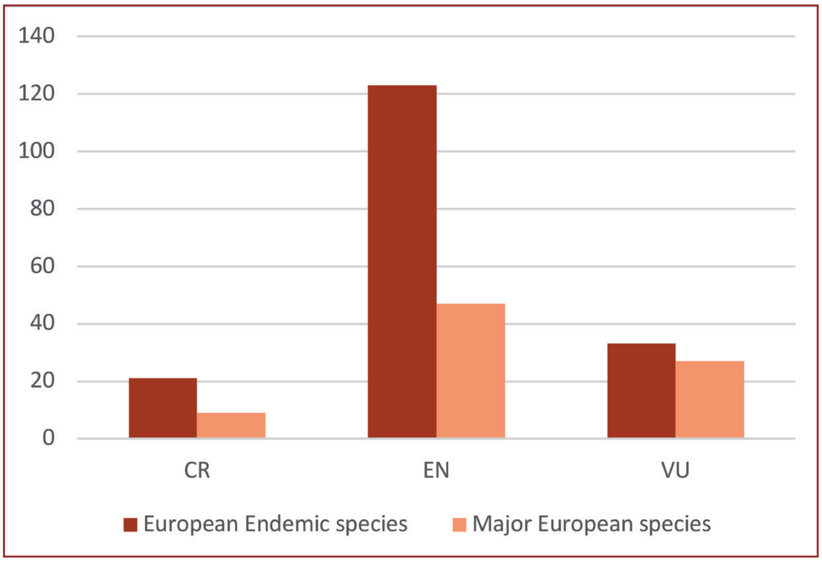
SUMMARY OF THREATENED SPECIES DATA

SCOPE AND CHARACTERISTICS OF THE A2P SPECIES SUBSET

This section explains the data and analyses that helped inform the preliminary planning discussions. For further explanation of the Red List assessment work see Vujić *et al.* (2022). Of the 890 species assessed, 314 species (25%) were placed into one of the IUCN threat categories (CR, EN, or VU). A further 59 species (7%) were assessed as Near Threatened (NT), 469 species (53%) as Least Concern (LC) and 45 species (5%) as Data Deficient (DD). One species, *Helophilus bottnicus*, was assessed as Regionally Extinct (RE) within Europe (though it still occurs elsewhere), and two introduced species were assessed as Not Applicable (NA) (*Copestylum melleum* and *Melangyna pavlovskyi*).

Of the 314 species of hoverflies assessed as threatened, 177 species are endemic to Europe. The global populations of an additional 83 species are mostly distributed within Europe, with just a small proportion of the population of these species occurring outside of Europe (these species are referred to as 'Major European' species throughout the remainder of this section). Eleven of the 314 threatened species occur predominantly outside Europe, but within a narrow distributional range, and the global populations of the remaining 43 threatened species are widely distributed outside Europe. **The Assess-to-Plan workshop focused only on the 260 European endemic and Major European hoverfly species that were assessed as threatened.** Figure 2 shows the numbers of European endemic and Major European species in each of the IUCN Red List threat categories. Thirty species (21 European endemic, 9 Major European species) are assessed as CR, 170 are EN, (123 European endemic, 47 Major European species) and 60 as VU (33 European endemic and 27 Major European species). A full list of the 260 species is provided in Appendix 1.

Figure 2. *The numbers of European endemic and Major European hoverfly species in each IUCN Red List threat category (n = 260 species).*



LARVAL FEEDING TRAITS

Conservation planning discussions focused on groups of species categorised by their larval feeding type and associated microhabitats. Figure 3 shows the distribution of the 260 focal species across the six larval feeding types used for this purpose (finer distinctions were discussed but discarded to reduce discussion complexity), and the number of species assigned to each of the IUCN Red List threat categories within each of those six groups. Of the 260 threatened focal species, 103 species (40%) belonged to the Phytophagous – bulbs and roots group. This group contained 57% of all focal hoverfly species assessed as CR. The Zoophagous larval feeding group contained 57 species (22% of the 260 focal species), sixty-one percent (35 species) of which were assessed as EN. The Phytophagous – stem leaf and fungi group contained 51 (20%) of the 260 focal species. The three Saprophagous larval feeding type groups contained the fewest species (49 species in total). The Saprophagous - xylobiontic group contained 30 species, the Saprophagous – aquatic group contained 17 and two species were in the Saprophagous – (semi) terrestrial group, both of which were assessed as EN.

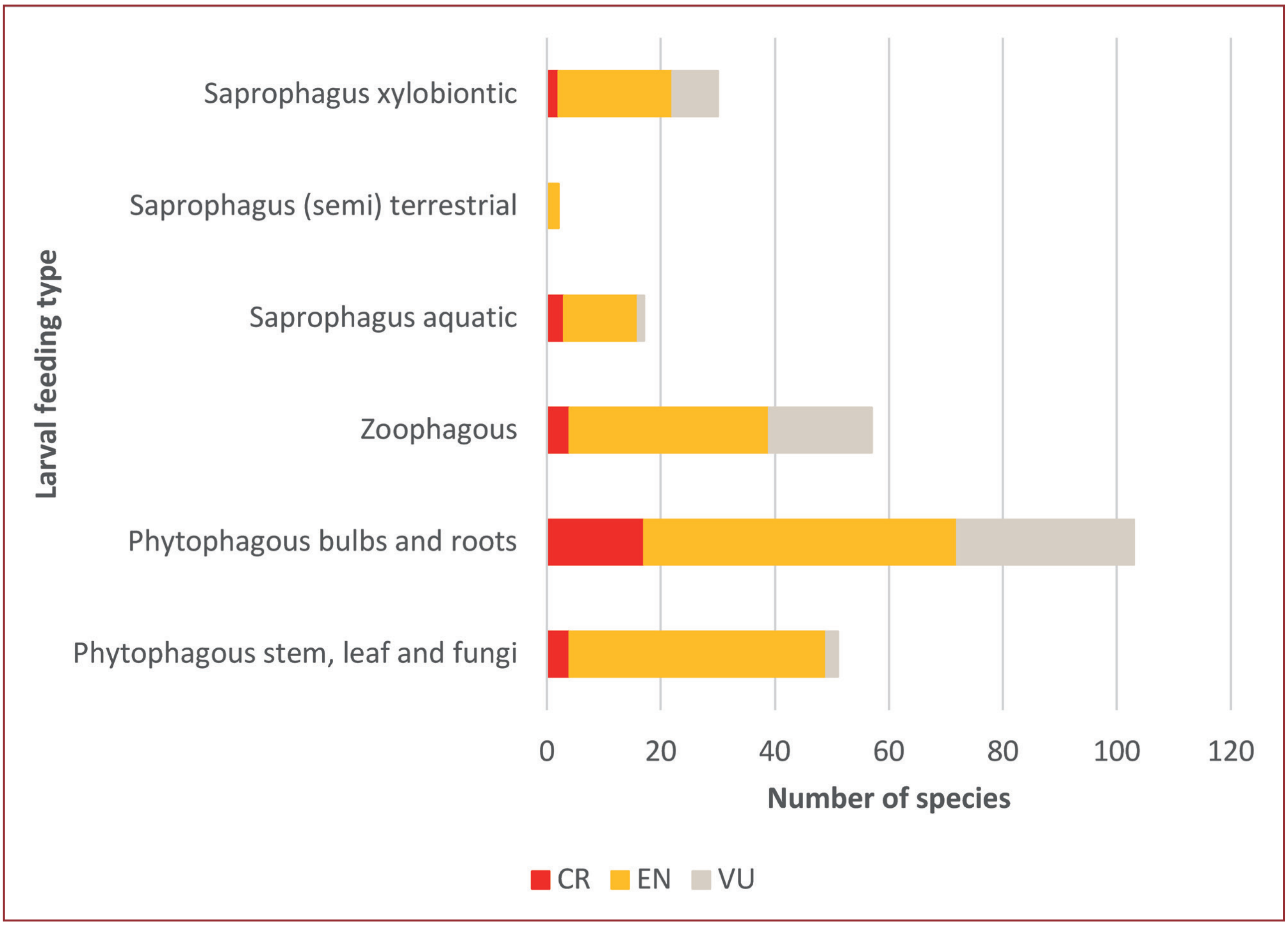


Figure 3. *The number of species in each of the six larval feeding type groups and the IUCN Red List threat categories of species within each group (n = 260 species).*

GEOGRAPHIC DISTRIBUTION & BIOGEOGRAPHIC REGIONS

Ninety-seven (37%) of the 260 focal threatened species are endemic to countries within the European Union (EU) and 157 species (60%) occur within one or more of the EU 27 countries, but also occur in counties outside of the EU. A total of 11 species (4%) do not occur in any EU countries and of these, 9 species are endemic to Europe. It is important therefore, that the knowledge from this in this Red List assessment is shared with European countries outside the EU. The distribution species across the 11 biogeographic zones of Europe is shown in Figure 4. The number of species whose distribution occurs within each of the biogeographic regions is shown in Table 1.

The Mediterranean region has the highest hoverfly species diversity, with 56% (145 species) of the focal threatened species occurring here. Furthermore, 72 (50%) of these species are endemic to that region. The Macaronesian region also has high hoverfly endemicity, with 15 of the 17 species (88%) that occur here, being endemic to it.

Of the 260 focal species, 186 occur only in one of the 11 biogeographic zones, with 138 of these species being endemic to Europe. Forty-two species occur in two zones and 21 species in three zones. Eleven species are more widely distributed across Europe with: six species occurring in four zones and five species distributed across five zones. The global distribution of all 11 species also includes countries outside Europe.

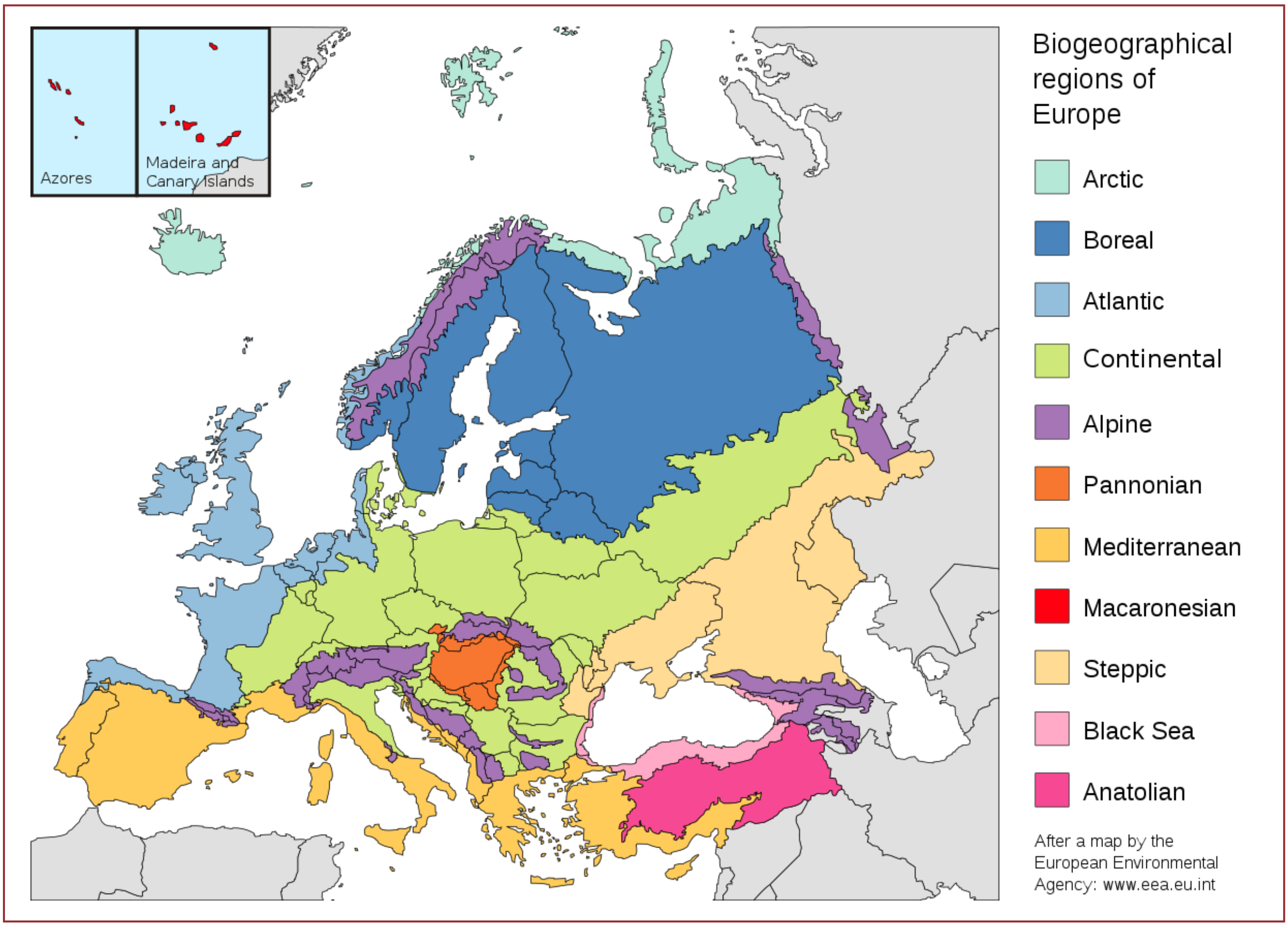


Figure 4. *Map of the biogeographic regions of Europe, after the European Environment Agency's map (Júlio Reis, 2006[5]).*

Table 2. *The 11 biogeographic regions of Europe and the number of focal (threatened) species occurring in each (n=260 species).*

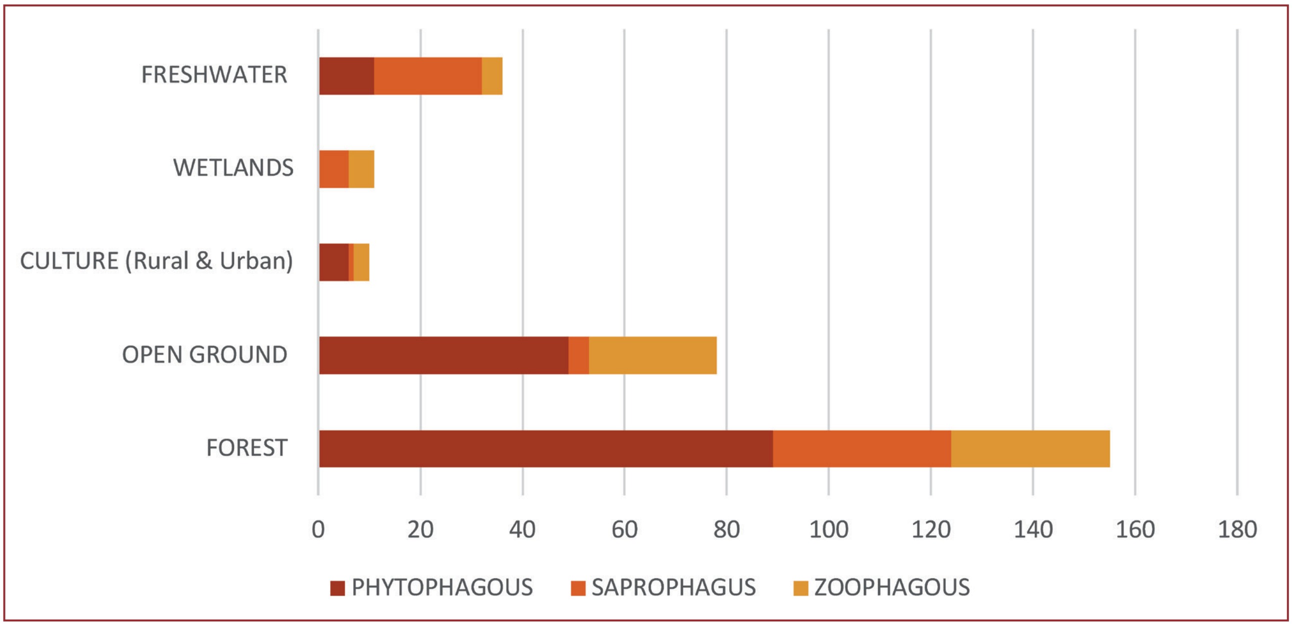
BIOGEOGRAPHIC REGION	NO. OF SPECIES
Mediterranean	145
Continental	85
Alpine	50
Pannonian	26
Atlantic	21
Macaronesian	17
Northern (Boreal)	17
Black Sea	9
Anatolian	5
Steppe	5
Artic	2

[5] https://commons.wikimedia.org/wiki/File:Europe_biogeography_countries_en.svg

MACRO AND MICROHABITAT ANALYSIS & SUMMARY

StN provides detailed information about the macro and microhabitat associations of hoverfly species that occur across Europe and Turkey (Speight and Castella, 2020). Here, information from StN is used to illustrate the major macro and microhabitat types with which the 260 focal species are most associated. In this section, for simplicity, the size larval feeding type groups are collapsed into three (Phytophages, Saprophages and Zoophages)

Figure 5. *Major macrohabitat associations of 260 threatened European hoverfly species indicating three*



As shown above in Figure 5, few threatened species are found in rural and urban environments, or in wetlands. Most are associated with forests and open ground, which are further broken down using StN data, in Figures 6 and 7 below.

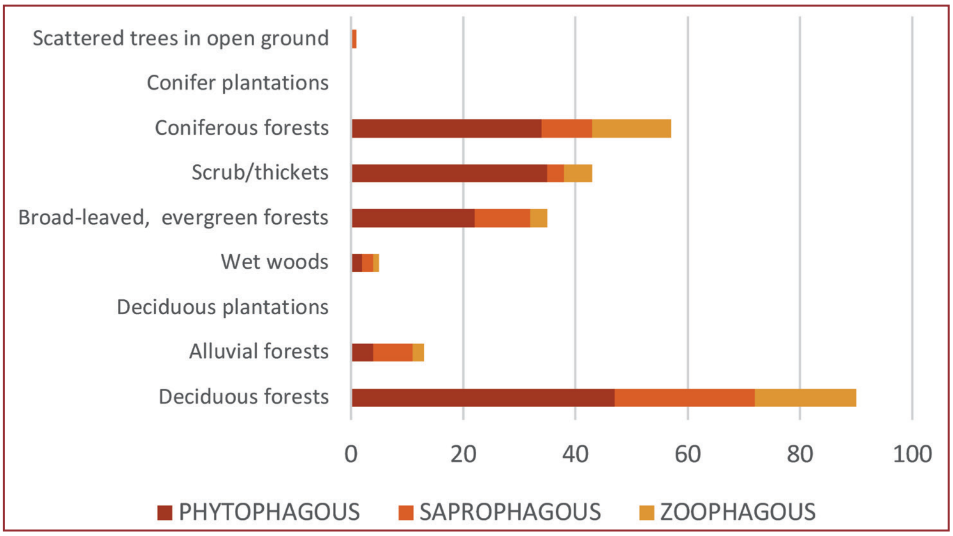


Figure 6. *Number of threatened species associated with each of the major forest macrohabitat types shown, indicating proportions of the three major larval feeding traits.*

As illustrated in Figure 6, though deciduous and coniferous forests are the two most common macrohabitats for threatened European hoverfly species, no threatened species are recorded from deciduous or conifer plantation forests, or from scattered trees in open ground.

Figure 7 illustrates the distribution of Threatened European hoverfly species across a range of open ground macrohabitats. As shown, these habitats are much less important than forest macrohabitats for hoverflies with saprophagous larval feeding traits but are very important for those with phytophagous and zoophagous traits.

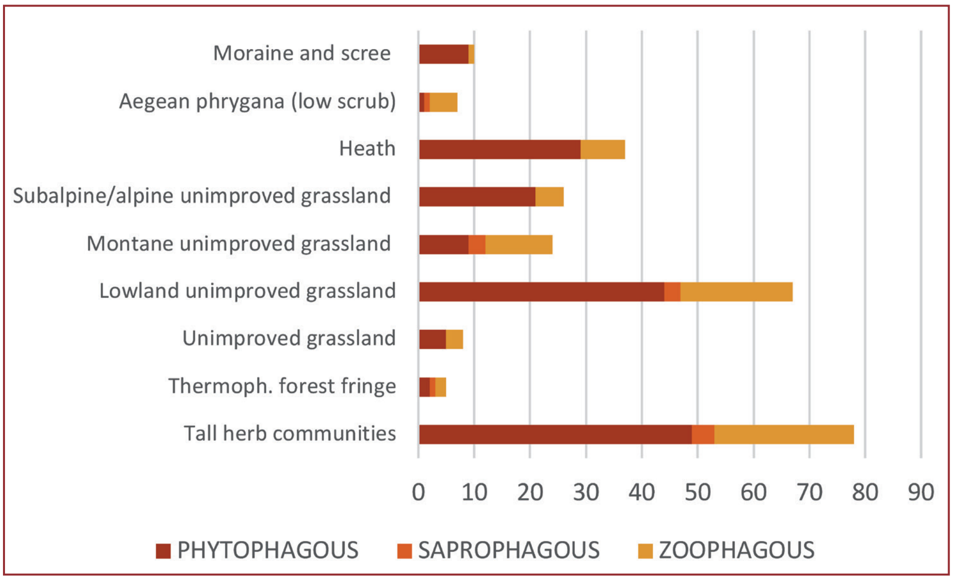
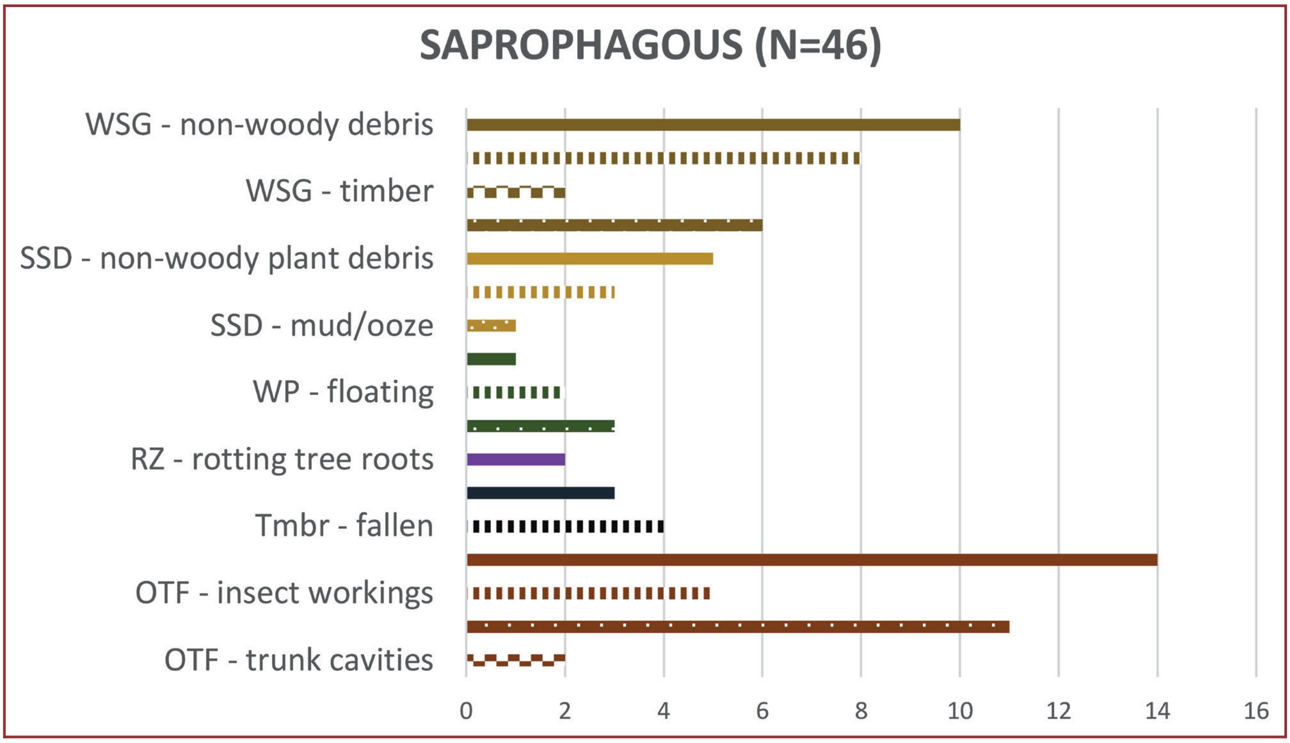


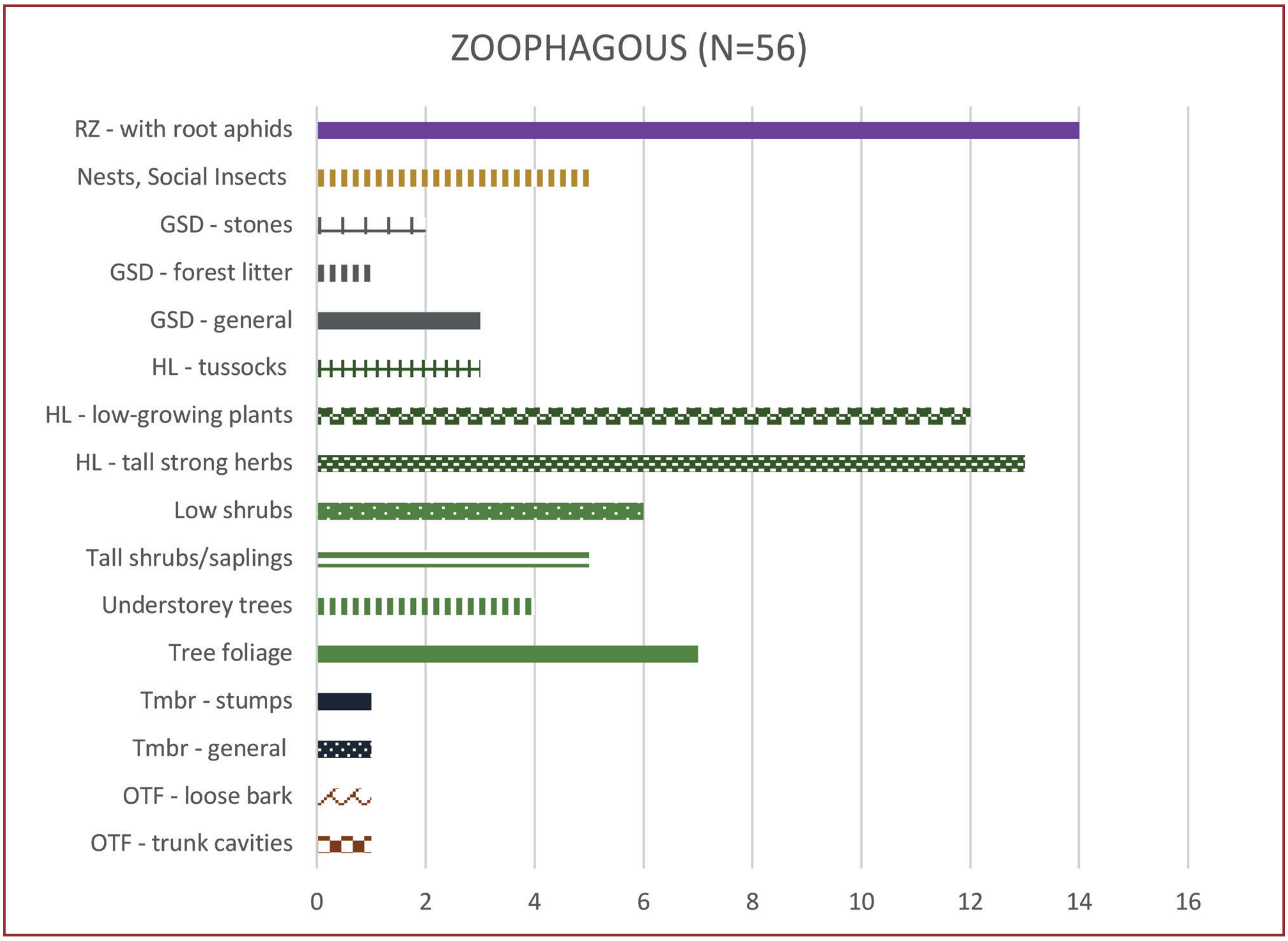
Figure 7. *Number of threatened species associated with each of the major open ground macrohabitat types shown, indicating proportions of the three larval feeding traits.*

StN contains much more detail on distribution (by country and biogeographic region) and on macrohabitats than is shown here. For further information, and for an explanation and definitions of the habitat categorisation system used, see Speight and Castella (2020); Speight *et al.*, (2020).

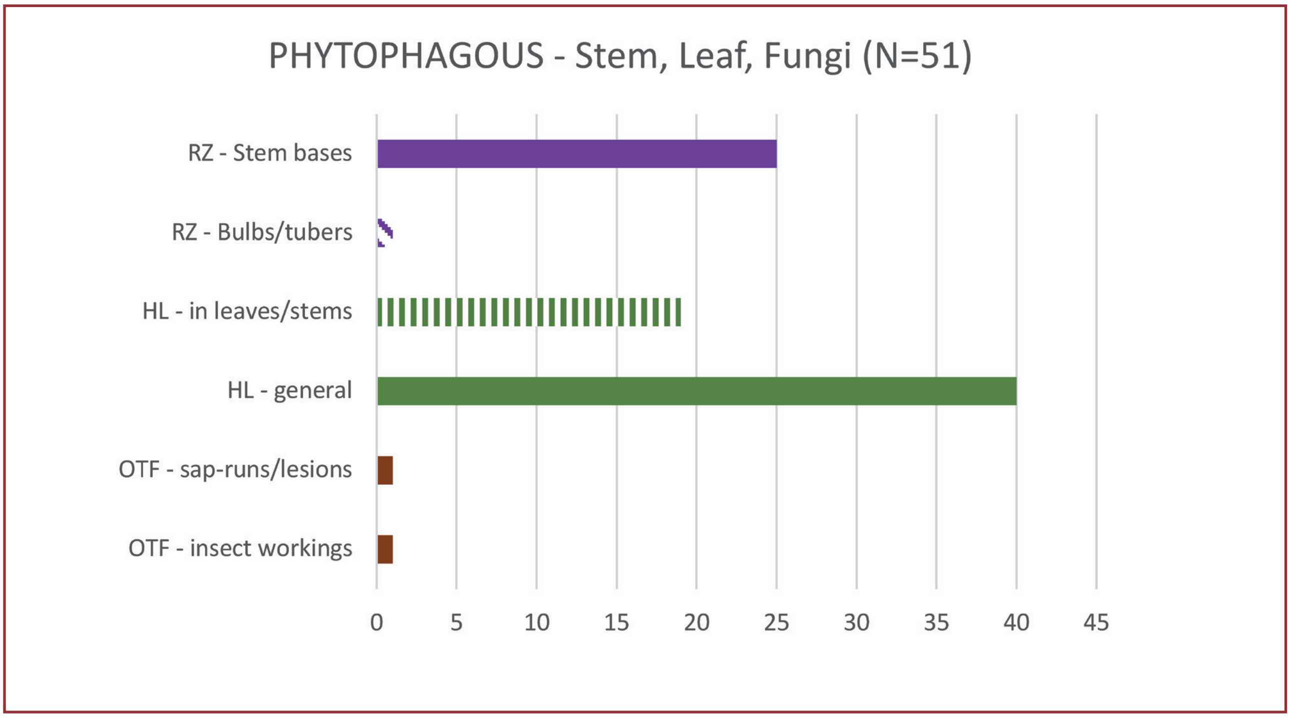
As pointed out in Speight & Castella (2020), these reported macrohabitat associations may not on their own be useful to organisations wishing to understand which threatened hoverfly species should be present or managed for, in specific areas of interest. Many of the macrohabitat associations are conditional, that is a species may occur in a forest macrohabitat, but only in association with certain features (e.g. small water bodies such as springs or seasonal brooks) and not necessarily otherwise. In StN these qualifiers are referred to as supplementary habitats and they provide additional insight into the requirements of different species. Of the 675 macrohabitat associations described in Figures 8 and 9, 355 (53%) of them have a qualifying supplementary habitat. Given this, StN takes habitat association information a step further still, and describes in finer detail the microhabitat associations of each species (where known). Microhabitats can be shared by multiple species and can straddle different macrohabitats. Therefore, for the purpose of the A2P project, and on advice from the core organising team, the required microhabitats of the major larval feeding types of the threatened species were used as the focus for discussions and proved a useful way to approach planning for such a large and diverse set of species.

As an example of the level of detail available in StN, the "larval activity zones" (or microhabitats minus additional qualifying information on condition) for the three major larval feeding traits, are shown in Figures 8 - 11. These represent some of the microhabitats that will need to be more widely recognised, valued, and protected, in order to support the conservation of this group of pollinators.

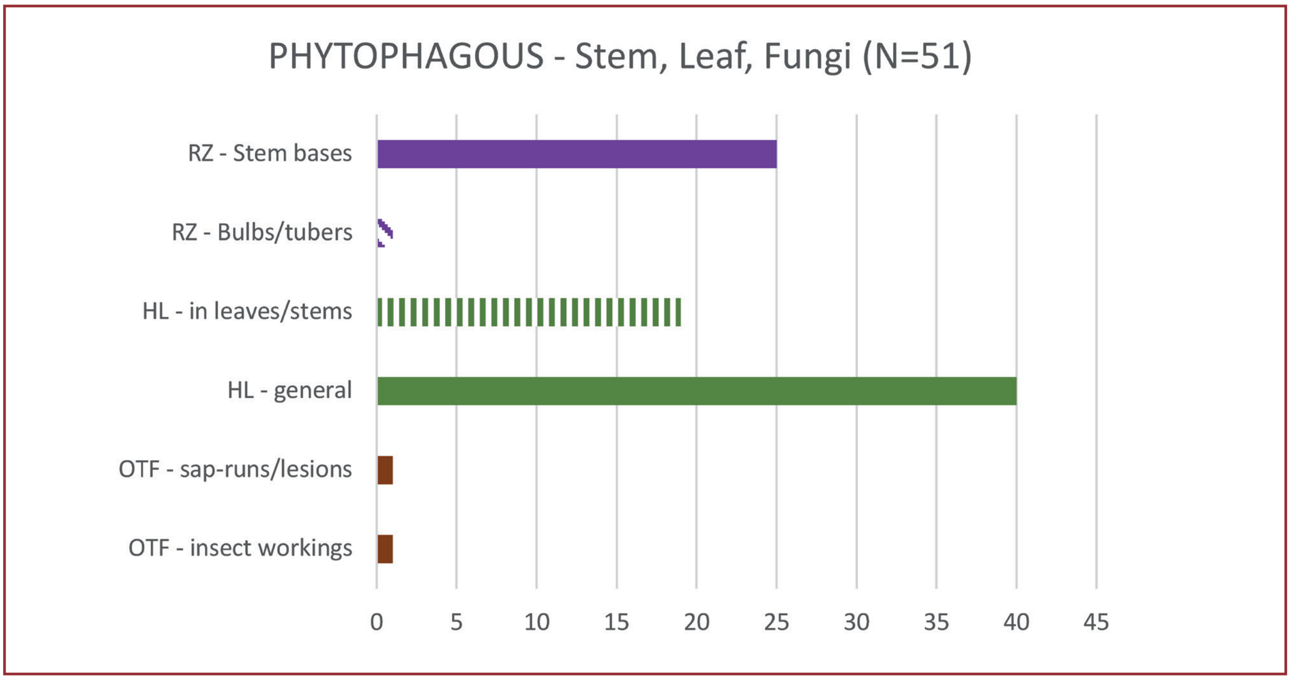




Figures 8 (above) and 9 (below). *Number of threatened species with Saprophagous or Zoophagous larval feeding traits, that are associated with each of the microhabitat types shown (WSG=water saturated ground; SSD=submerged sediment/debris; WP=water plants; RZ=root zone; Tmbr-Timber; OTF=overmature tree features; HL=Herb Layer; GSD=Ground Surface Debris). See Speight & Castello (2020) for further details.*



Figures 10. *Number of threatened species with Phytophagous (Stem, Leaf Fungi) larval feeding traits, that are associated with each of the microhabitat types shown (OTF=overmature tree features; HL=Herb Layer; RZ=Root Zone).*



Figures 11. *Number of threatened species with Phytophagous (Bulbs, Roots) larval feeding traits, that are associated with each of the microhabitat types shown (HL=Herb Layer; RZ=Root Zone).*

[Note that 13 of the 260 species assessed as threatened are not included in the version of the StN database used and so are missing from the analysis above. These are: Merodon orjensis, M. olympius, M. sacki, M. kozufensis, M. hirtus, M. medium, M. nitens, M. spineus, M. confinium, M. opacus, P. thracusi, P. bellierii, C. scintilla].

1

1. TOOLS, DATABASES AND EXPERTS

1.1 INTRODUCTION

The EU Pollinators Initiative (EPI) offers good opportunities for hoverfly conservation. A key action proposed within it is to establish a Pollinator Monitoring Scheme (EU POMS), including hoverflies as well as bees and butterflies, with indicators to enable evaluation of actions taken to tackle declines. The scheme lays out standard monitoring protocols, requirements, and estimated costs, as well as proposals for specialised monitoring of threatened species and for additional work in a range of areas. It is important that hoverflies are adequately covered by this scheme, as well as other pollinator monitoring schemes operating in Europe but there are some current challenges to their inclusion, and these are described here. Some will be addressed through existing or planned initiatives within the EU Pollinators Initiative. Efforts are made here to document those, as context for any identified gaps.

1.2 CHALLENGES RELATING TO TOOLS, DATABASES AND EXPERTS

1.2.1 GAPS IN IDENTIFICATION TOOLS FOR EUROPEAN HOVERFLIES

A complete set of identification tools would encompass thorough reviews of the species existing in each country (checklists, digital availability of museum data), proper identification literature (field guides, keys, online tools, and mobile device applications), information on distribution (atlases) and information on rarity (Red Lists). These tools take time to develop and will be subject to changes, requiring a permanent and regular updating mechanism to maintain high scientific standards.

For hoverflies, functional identification keys to the European genera partially exist, but generic keys are available in only a few European languages and more comprehensive illustration is needed (which can now be achieved photographically). A complete illustrated key to EU syrphid genera is in preparation in Germany (Mengual & Ssymank in prep). The IUCN EU Red List assessment project lists more species with phytophagous larvae as under threat than any other grouping, but of all European genera, the three large phytophagous genera are the least well served with identification keys at European level. For the genus *Cheilosia* the requirement is to construct a series of regional keys leading to an all-Europe key, partly via synthesis of available information and partly with revisionary work. Revisionary work on *Merodon* is still needed but following work during the last 20 years, it will soon be possible to aim for regional keys. The third genus, *Eumerus*, still requires a significant investment of human resources and time.

In overview, the requirements for European syrphid identification literature are a series of regional keys, together covering the syrphid fauna of at least the EU member states, with a view to synthesising these later into all-Europe keys (or, if more practical, a set of regional keys which include species of neighbouring countries). Two examples already exist, covering Fennoscandia and the Atlantic seaboard countries south to Belgium (inclusive). Keys to the syrphids of central Europe could be compiled immediately, while Mediterranean parts of the continent might need more comprehensive revision of the European *Eumerus* and *Merodon* species before their fauna could be treated.

1.2.2 COMMONLY USED MONITORING METHODS DO NOT WORK WELL FOR HOVERFLIES

The proposed EU POMS recommends prioritising a combination of transect walks and pan-trapping. This combination will generate a method-inherent bias in the results. This is because transects are highly dependent on experienced observers able to avoid systematically overlooking certain hoverfly groups either because they are small, fly only within the vegetation or have behaviours that differ from other hoverflies. Meanwhile, coloured water dish (or pan) traps collect only a particular subset of the hoverfly spectrum, which is quite different to that from, for example, Malaise traps. The EU POMS Technical Report states that, “as there is ongoing research into the representativeness of pan traps, their data cannot be used to estimate absolute abundance”. For regional and national Red-List assessment of the status of hoverflies, the results of the EU POMS will deliver sufficient data only for species with a wide spectrum of habitat associations which as a result will be well-represented in the selection of monitoring sites. Threatened species are more likely to be specialists and so less likely to be adequately covered.

1.2.3 TOO FEW HOVERFLY EXPERTS

One of the benefits of working on hoverflies is that many species are relatively easy to identify compared to those of other pollinator groups. This provides advantages when monitoring diversity and abundance in hoverfly genera or trends in common species. However, Europe currently lacks sufficient capacity to survey and monitor threatened hoverflies for conservation purposes, which requires a greater level of expertise. Furthermore, the identification tools required to train and equip new experts either do not exist or are not sufficiently accessible or up to date (see above). While only a small number of experts might theoretically be needed to produce reliable identification tools, such as keys, a far greater number of people will be required to ensure that, using those keys, syrphids can be effectively identified in all regions of the continent. Identifying reliably the syrphid fauna of a European country requires familiarity with 300 to 500 taxa in most of the Member States. Experience shows that someone starting with no knowledge of insects, or the identification literature requires 2 – 3 years to develop the expertise necessary to identify a substantial proportion of these 300 - 500 taxa reliably, assuming the necessary identification tools are available, and this is dependent upon the availability of periodic instruction from experts to reach the desired level of competence. Given the long lead-in time there is an urgent need to fund syrphid identification workshops in different parts of Europe. Courses are needed, potentially targeting different levels of knowledge, with a core team for checking difficult determinations. The EU POMS Technical Report provides an estimated breakdown of the number of hoverfly experts available in each European country and identifies major gaps.

1.2.4 LIFE-CYCLE REQUIREMENTS OF THREATENED (AND OTHER) HOVERFLIES ARE OFTEN POORLY KNOWN

Effective conservation will require more knowledge of the needs of hoverfly species throughout their life-cycle than is currently available, including their obligate associations with specific microhabitats and with other species. For the European syrphid species now recognised as threatened, although their larval microhabitats can at least be surmised from available data, more specific information on the requirements of the developmental stages are almost universally lacking. For instance, the phytophages that make up the bulk of the threatened species nearly all live out of sight, just below the ground surface, in the bulbs or stem-bases of herbaceous plants. But for most of those species the plant host of its larvae remains unknown. Without knowing its larval plant host, it is difficult to identify beneficial management measures. As a group, the developmental stages of syrphids with soil-inhabiting larvae, not just the phytophages among them, are poorly known. Investigations aimed at finding the unknown larvae of soil-inhabiting species are time-consuming and success is subject more to serendipity than to tried and tested methodology. There is need for significant funding aimed at both developing techniques for locating these larvae and at establishing the host plants of the threatened phytophages. Ideally this would also embrace the other threatened syrphids with soil-inhabiting larvae (e.g., *Chrysotoxum, Xanthogramma*).

While habitat association data are available for many European syrphid species, the absence of a pan-European habitat classification system until recently means that species habitat-association data from some parts of Europe are still, to a significant extent, incomplete. This is particularly the case for the Pannonian biogeographic zone and the Balkans. There are few habitat data for many of the recently described syrphid species from the Balkans, including those now recognised as threatened. Essentially, the syrphid fauna of a series of habitats from Southeast Europe remains uncharacterised. The same is true for Mediterranean-zone habitats of Italy, Spain, and Portugal. This issue can be addressed by Malaise trap surveys of the syrphid fauna of good examples of these poorly known habitat types. This approach has worked well in France and is underway in Switzerland and Spain. Ideally, it involves the active participation of botanical expertise in deciding choice of site and is dependent on the availability of specialist knowledge of syrphid identification – the need for reliable determination of the collected material from these reference surveys is paramount. It would be appropriate to bring this issue to the attention of EU bodies concerned with funding projects on biodiversity maintenance and management of protected sites, or more general research within the environmental sphere. Even within the implementation of the EU Habitats Directive (HD) the typical hoverfly species of Annex I habitats are not well known. For many taxa, systematic research will be needed before they can be covered by habitat assessment and site management across all biogeographic regions.

Synergies should be considered between EU pollinator monitoring and HD implementation, also with the view to reaching 2030 EU biodiversity targets.

The larvae of few of the syrphid species now categorised as threatened have been described. While the part of the ecosystem inhabited by the developmental stages of most of them has been deduced either from available information about closely related species, from emergence trapping of adults, or from rearing observations, information critical to identifying site-management options appropriate to improving the conservation status of the species is lacking. A clear example is provided by the species listed as threatened that have larvae feeding on plant tissues. Although it can be stated that they depend on certain herb layer plants, the actual plant species each of them requires is, in nearly every case, unknown. This is a less intangible problem than the physical and biotic parameters of water quality required by the aquatic larvae of some of the other threatened species, and is open to investigation, given the manpower and finance necessary to carry out the research. As species with larvae feeding in plant tissues comprise the largest single group of species regarded as threatened, development and employment of techniques to identify larval host plants of these species are a high priority for increasing the chances of survival of a majority of the Red-Listed hoverfly species. Recent advances in knowledge of larval host plants of phytophagous syrphids are typically a product of research undertaken for doctoral theses, each of which can evidently be expected to establish the host plants of two or three species, but rarely more. This approach moves very slowly, and to make any significant impact on the problem requires a major project undertaken by a research team.

1.2.5 DIFFICULTIES FACED BY HOVERFLY EXPERTS IN ACCESSING AVAILABLE RESOURCES FOR THE WORK NEEDED

At present many EU countries lack national organising entities that are able and willing to promote syrphid surveys, gather information and track funds. As a result, those countries are unable to benefit from what the EU could finance. An example is France, where there are several entomologists able to work with syrphids but there is no obvious umbrella structure under which they could operate that has enough money and administrative competence to be able to carry a “L’Instrument Financier pour l’Environment” (LIFE) - or other EU-financed project. In addition to having enough taxonomists to carry out surveys and other required work, it would be helpful to have in each EU member country, at least one structure able to organise, coordinate and distribute funds. In Germany, for example, this could become a task for the recently established National Red List Coordination Committee.

1.3 OPPORTUNITIES FOR FILLING GAPS RELATING TO TOOLS, DATABASES AND HOVERFLY EXPERTISE

1.3.1 EU INITIATIVES

The European Commission is supporting several projects to address challenges described in the previous section. The overall initiative is due to run until 2030 and includes several phases during which different projects or areas of work will be emphasised. Current projects are described below, with links to further information.

SPRING (Strengthening Pollinator Recovery through INdicators and monitoring): aims to support preparation for implementation of the EU Pollinator Monitoring Scheme EU POMS) by organising training to build capacity and through a pilot scheme which will involve monitoring at a small number of sites in every EU Member State. https://www.ufz.de/spring-pollination/

TAXO-FLY (Taxonomic Resources for European Hoverflies): is collecting taxonomic, morphological, and ecological data for all European hoverfly species, and will establish an open access EU Commission hosted website for this information. This project can provide the background for developing a series of identification keys. TAXO-FLY is under the direction of the University of Helsinki’s Finnish Museum of Natural History, Luomus. (https://www.helsinki.fi/en/news/biodiversity-loss/european-hoverfly-species-information-be-gathered-eu-funded-project/)

SAFEGUARD (safeguarding European wild pollinators) sits under Horizon 2020 Europe. The research project aims, among other things, to improve knowledge of EU-wide pollinator distribution (https://www.safeguard.biozentrum.uni-wuerzburg.de/).

The **STING** project (Science and Technology for pollinating Insects): is preparing training resources for hoverfly identification, and testing of planned EU pollinator monitoring. (https://knowledge4policy.ec.europa.eu/projects-activities/sting-project_en).

DEST (Distributed European School of Taxonomy) was established by prominent taxonomists and other international partners during the EU funded project European Distributed Institute of Taxonomy (EDIT: 2006 – 2011). One of these is dedicated specifically to the Syrphidae (though the latest version focused more generally on pollinators. DEST activities are under the umbrella of CETAF (Consortium of European Taxonomic Facilities). (https://cetaf.org/dest/courses/)

These projects will continue and new ones will be added, a large number of new researchers will be trained to take part in the pollinator monitoring scheme and each EU country will establish national centres for monitoring pollinators.

1.3.2 RED LIST OF TAXONOMISTS

Also EU supported, the Red List of Taxonomists[6] recognises the rarity of pollinator taxonomic expertise and aims to:

- detail information on the current number, location and profile of insect taxonomists;
- assess the status and future trends of insect taxonomic expertise in Europe;
- communicate materials designed to improve the understanding among policy makers, stakeholders and the general public of the role of a solid European taxonomic community in tackling the decline of insects.

1.3.3 BARCODING

Given the rapid developments in DNA barcoding techniques, comprehensive barcodes of the European fauna will be increasingly important for rapid analyses of large samples. DNA barcoding and metabarcoding (i.e., barcoding of mixed samples) approaches are increasingly used to analyse large samples and may also help to determine the identity of samples retrospectively. Barcodes are stored in the Barcode of Life Database (BOLD178)[7] as well as some other databases, but some scientists wait to complete comprehensive barcoding projects before transmitting data to the database, creating substantial delays. Several independent barcoding projects exist all over Europe, usually organised in the International Barcode Of Life (iBOL) consortium. Most projects are based in the northern part of Europe, and many rare and Mediterranean species are missing (EU POMS Report). Barcode libraries are increasingly complete, but the effort needed to obtain material for genetic analysis of rare species is much higher than anticipated. The latter may require collaborative efforts and specific projects able to support specialists to fill these gaps, by funding not only laboratory costs but also travel and collection. Also important is a full standardisation of DNA-sample treatment. This includes pre-fractioning of the samples, standard primers, analysis, and publication of possible barcode identification mistakes (e.g., no sufficient genetic gap distance, other non-European species with similar barcodes) as well as the development of smart systems to get at least results on relative frequency classes based on asymmetric sample splitting before applying meta-barcoding techniques. As costs come down, barcoding is expected to become an increasingly important method for surveying syrphids, because once set up it requires the help of fewer taxonomic experts.

Tools such as the nature application (App) "I-Naturalist" have proved highly successful for birds and flowering plants. In future, a mobile phone application providing for recognition of European hoverfly genera could be extremely useful. Assuming the output would be the name of the genus of the photographed syrphid, such an identification tool could be used all over Europe without associated, burdensome translation requirements. Further details of materials and tools currently available for hoverflies are included in the EU POMS Technical Report.

6 https://wikis.ec.europa.eu/display/EUPKH/European+Red+List+of+Taxonomists
7 https://www.boldsystems.org

1.3.4 MALAISE TRAPS

Malaise traps have well-known advantages for collecting certain hoverfly genera and species groups compared to pan-trapping (which is currently the EU POMS method of choice). Malaise traps do not attract hoverflies specifically, as the coloured pan-traps do, and as a result the recorded hoverfly spectrum differs considerably. Malaise traps are also easier to handle in the field.

To obtain adequate coverage of hoverflies, and especially of threatened species, it might be necessary to supplement the general methods of the EU POMS with Malaise traps, in a smaller subset of the whole sample, or even to use them for specific habitats which are not well covered. To accomplish this, adequate training in use of these traps would be essential, primarily in countries where Malaise traps are not commonly used. Standardisation and use of Malaise traps are well developed for monitoring purposes in Germany (Ssysmank *et al.*, 2018) and in France (Van Appelghem *et al.*, 2020). The expertise built there provides opportunities for uptake across the wider European region.

1.3.5 HOVERFLY-SPECIFIC DATABASES

IUCN EUROPEAN REGIONAL RED LIST OF HOVERFLIES

The IUCN European Regional Red-List includes all hoverflies native to or naturalised in Europe (890 species in total). Its geographic scope is continent-wide, extending from Iceland in the west to the Urals in the east, and from Franz Josef Land in the north to the Canary Islands in the South. It excludes the Caucasus region. Importantly, for each species, the Red List Database captures key information on known range and distribution, habitat and ecology, population status and major threats, as well as recommends for conservation action. Red List information provides valuable evidence to support conservation initiatives throughout Europe, including the designation of protected areas, reform of agricultural practices and land management, habitat restoration and rewilding, and pollution reduction schemes. The IUCN Red List data is readily searchable at: www.iucnredlist.org

STN

The Syrph the Net Database of European Syrphidae (Diptera) (StN) is a comprehensive, current, and centralised repository of information covering all species of hoverfly recorded from Europe and Turkey. The database is a set of spreadsheets into which are coded data on various species attributes, including macrohabitat, microhabitat, traits, range, and status. The macrohabitat categories correspond, where possible, with habitat categories used in CORINE and EUNIS (Devillers *et al.*, 1991).

At present StN has huge value to European work on syrphids due to its systematic database and organisation of the information on each syrphid species. A central premise of the StN database is that many syrphid species are closely associated with specific habitats, such that each habitat will have its own characteristic assemblage of syrphids. Scientifically testing this predictive ability more broadly and on a large-scale, would help to confirm and refine its utility in this area. For more information see: https://pollinators.ie/record-pollinators/hoverflies/syrph-the-net/

GOAL 1: SUFFICIENT TOOLS, DATABASES & EXPERTS FOR EFFECTIVE HOVERFLY MONITORING AND CONSERVATION IN EUROPE

Including:

- A complete set of identification tools for European syrphids at EU and country level, in appropriate languages.
- Syrphid-appropriate monitoring methods in place including specific monitoring of rare and threatened species.
- Enough experts to satisfy long-term monitoring needs.
- Good knowledge of the throughout-life needs of threatened (and other) syrphids.
- Europe-wide recognition & use of the IUCN Red List and StN databases.
- Enough national entities with the organisational capacity to connect large-scale EU funding with on-ground hoverfly expertise.

GOAL 1: RECOMMENDATIONS

Several recommendations from this discussion repeated or were closely aligned to those in the EU POMS Technical Report. They are included for context and indicated by shading, with additional notes where relevant.

1.1	A COMPLETE SET OF IDENTIFICATION TOOLS FOR EUROPEAN SYRPHIDS (SEE EU POMS TECHNICAL REPORT FOR FURTHER DETAILS)	
Note: the **TAXO-FLY** project is relevant to the actions below.		
Recommended action		**Current or potential leads and collaborators**
1.1.1	For the genus *Cheilosia,* synthesise available information, to construct a series of regional identification keys.	University of Novi Sad Faculty of Science, Serbia (UNSPMF); Finnish Museum of Natural History (LUOMUS); Helsinki (Sander Bot- Veldshop).
1.1.2	For the genus us *Merodon,* complete revisionary work and construct regional keys.	UNSPMF.
1.1.3	For the genus *Eumerus,* construct regional keys.	UNSPMF; Martin Speight (for Swiss species).
1.1.4	Complete hoverfly species habitat-association data for all of Europe with emphasis on threatened species and collate within StN (key gaps include the Pannonian biogeographic zone, the Balkans, and the Mediterranean zone habitats of Italy, Spain and Portugal).	HSG; UNSPMF; University of Nottingham School of Life Sciences; Entomological association Krefeld (EVKr).
1.1.5	Standardise DNA sample treatment, including pre-fractioning of the samples, standard primers, analysis and publication of possible barcode identification mistakes.	Zoological Research Museum Alexander Koenig (ZFMK); M. Sorg (EVKr).

1.1.6	**EU POMS:** complete a comprehensive pan-European gap analysis for hoverflies to prioritise species for collection and sequencing (for DNA barcoding project). [Underway as part of Taxonomic Resources for EU Pollinator Monitoring Scheme tender].	UNSPMF; LUOMUS Helsinki.
1.1.7	**EU POMS:** make comprehensive barcodes of all hoverfly species available on a single European online platform by 2026. [Missing species need to be collected (or museum or private collection material used) to close gaps in the database].	UNSPMF; LUOMUS; ZFMK.
1.1.8	**EU POMS:** Annotated, up-to-date hoverfly checklists available for all countries and taxa by 2023 (they may be included in field guides or other publications).	HSG; UNSPMF; NATURALIS Leiden; DE: German Red list Coordination Centre.
1.1.9	**EU POMS:** by 2025, develop a comprehensive European field guide and/or identification keys covering all European hoverfly species.	UNSPMF; Netherlands Nat. Research Institution for Biodiversity; NATURALIS Leiden; ZFMK; Hoverfly experts in Europe working with identification tools.
1.1.10	**EU POMS:** national (or regional) field guides for hoverflies available by 2026, so that laypersons in each country can obtain the necessary identification literature. (A2P note: for national complete keys in Germany this is a full-time task for 2-3 people for 4-5 years minimum, 2026 is not realistic for a complete species key; regional keys for smaller regions excluding high mountain zones and the Alps are more realistic.	UNSPMF; NATURALIS Leiden, other hoverfly experts in Europe working with identification tools.
1.1.11	**EU POMS:** by 2025, digitise and centralise access to type material and historic distribution data for hoverflies, from museums and private collections across Europe.	UNSPMF; LUOMUS, ZFMK, hoverfly experts in Europe working with identification tools.
1.1.12	**EU POMS**: by 2026, collate or develop hoverfly materials for inclusion in a proposed App for identifying all European pollinator species.	UNSPMF; LUOMUS Helsinki; ZFMK, hoverflies experts in Europe working with hoverflies; BioSense Institute.
1.1.13	**EU POMS**: Fund taxonomic experts and IT specialists to develop a pan-European platform for pollinators, which is constantly maintained and updated (e.g. coordinated by a European monitoring centre).	EU Commission (with taxonomic and IT experts)
1.2	HOVERFLY-APPROPRIATE MONITORING METHODS IN PLACE	
Recommended action		**Current or potential leads and collaborators**
1.2.1	Within the EU POMS, promote deployment of Malaise traps in parallel with pan-traps for better hoverfly coverage.	BfN.
1.2.2	Production/translation and distribution of a guide on how, why and when to put Malaise traps in the field, how to identify material and how to deal with the data.	BfN; EVKr; other entomological/ naturalist associations; museums.
1.2.3	Provide training in Malaise trap use in countries lacking this expertise.	BfN; other entomological/naturalist associations; field study centres.
1.3	ENOUGH EXPERTS TO SATISFY LONG-TERM MONITORING NEEDS	
Recommended action		**Current or potential leads and collaborators**

1.3.1	**EU POMS:** by 2022 a basic training course for hoverflies in each of: Atlantic Islands, Iberian Peninsula, France & Luxembourg, Italy & Malta, Greece, Cyprus, Bulgaria, Romania, Hungary, Slovenia & Croatia, Austria, Czech Republic & Slovakia, Poland, Germany, Belgium & Netherlands, Denmark, Sweden, Finland, Baltic States, Cyprus, and Ireland. **[Already part of the project SPRING: Strengthening Pollinator Recovery through Indicators and Monitoring).**	NATURALIS, Leiden; UNSPMF; LUOMUS Helsinki; ZFMK; Univ. Alicante; DEST/CETAF CETAF [Note: Such an initiative might benefit from the long-term experience of running such course by Roger Morris and Stuart Ball in the UK].
1.3.2	**EU POMS:** by 2024, establish one national reference collection of hoverflies for each country plus a pan-European one. [Note from A2P: timeframe is not realistic]	CETAF and other major scientific collections (public and private); entomology organisations; HSG.
1.3.3	**EU POMS:** by 2023, an advanced training course (covering taxonomy of difficult taxa) in each target region.	SPRING project leaders with taxonomic experts for difficult taxa, sourced through the HSG; DEST/ CETAF.
1.4	GOOD KNOWLEDGE OF THE LIFE-CYCLE NEEDS OF THREATENED (AND OTHER) SYRPHIDS	
Recommended action		**Current or potential leads and collaborators**
1.4.1	Canvas universities to attract interest in studying the life-histories of priority hoverfly taxa.	University of Nottingham School of Life Sciences; UNSPMF.
1.4.2	Develop techniques for locating the soil-inhabiting larvae of hoverflies and establish the host plants of the threatened phytophages and other threatened syrphids with soil-inhabiting larvae (e.g. *Chrysotoxum, Xanthogramma*).	University of Nottingham School of Life Sciences; NGOs e.g. UK Soil Association; UK Wildlife Trusts.
1.4.3	Identify the larval host plants of threatened phytophagous hoverflies by developing techniques and deploying them at scale through a research team.	UNSPMF University of Alicante; BioSense Institute.
1.5	EUROPE-WIDE RECOGNITION AND USE OF THE STN AND IUCN RED LIST DATABASES	
Recommended action		**Current or potential leads and collaborators**
1.5.1	Promote and use the IUCN Red List as evidence when planning and raising support for hoverfly conservation.	Martin Speight (ESSENTIAL FOR THIS SET OF ACTIVITIES); University of Bologna (Daniele Sommaggio); University of Nottingham School of Life Sciences (Francis Gilbert); UNSPMF, BioSense Institute; University of Alicante; all involved in planning and implementing hoverfly conservation.
1.5.2	Make StN open access, publicly available on the internet (especially important for amateurs).	
1.5.3	Organise training courses on the use of the StN database across member states for those working (professionally or as amateurs) with hoverflies.	
1.5.4	Include basic training on the use of the StN database as a part of certain curricula during BSc or MSc studies at the University, or as a part of a summer school, to promote the significance of this database among future generations of scientists and nature enthusiasts.	
1.5.5	Create video-tutorials showing examples of the use of the StN database.	
1.5.6	Large-scale testing of the predictive value of StN to confirm or refine this utility.	

1.6	ENOUGH NATIONAL ENTITIES WITH THE ORGANISATIONAL CAPACITY TO CONNECT LARGE-SCALE EU FUNDING WITH ON-GROUND HOVERFLY EXPERTISE	
Recommended action		**Current or potential leads and collaborators**
1.6.1	Identify and make available to syrphid experts, a list of entities in EU countries able to organise, coordinate and distribute EU funding for large-scale hoverfly work.	EU and national government agencies (e.g. in UK Natural England; JNCC; Forestry England; Wildlife Trust (Head Office)).
1.6.2	In countries lacking these entities, identify and encourage relevant organisations to take up this role.	EU and national government agencies.

2

2. LOSS AND DEGRADATION OF MICROHABITATS AND LOCAL POPULATIONS

2.1 INTRODUCTION

This section considers in detail the challenges to conserving hoverflies across Europe, emphasising the hoverfly larval feeding types most common among species recently assessed as threatened. These are split into three broad groups: saprophages, phytophages and zoophages, within which there are further sub-divisions, and a section is assigned to each. Several issues are common to all three groups, and these are described below. In some cases, these general challenges have a disproportionate impact on one or more of the different larval feeding types, or act on them in different ways or through different pathways. Attempts are made to explain this within the relevant larval feeding type section. Efforts have been made to reduce unnecessary duplication though some was unavoidable because of the highly inter-connected nature of many of the challenges identified.

2.2 GENERAL CHALLENGES AFFECTING HOVERFLY MICROHABITATS

2.2.1 FERTILISERS AND EXCESS NUTRIENT INPUT

This was considered a major issue for hoverflies as many hoverfly habitats, especially of rarer or threatened species, are dependent on low to medium nutrient levels. This is especially true for most open, species-rich grassland habitats, for all heathland habitats and for oligo- to mesotrophic waterbodies and all bog systems. Some recommendations relating to this issue are made under GOAL 2 (below) and it is considered in more detail through GOAL 4 and the associated text.

2.2.2 PESTICIDES

The potential effects of pesticides on hoverflies include impaired reproduction, fewer egg-laying sites, altered foraging patterns or success, reduced prey availability for larvae with zoophagous feeding traits, increased disease and parasite susceptibility, source-sink effects (landscape-scale population and community effects), trophic interaction effects and ecosystem services effects (Uhl & Brühl, 2019). Some recommendations relating to this are made under GOAL 2 (below) and further details of this challenge and its causes, along with additional recommendations, are included under GOAL 4 and the text that precedes it.

2.2.3 COMMERCIAL, INDUSTRIAL BEEKEEPING

Over the last half-century, beekeeping has reached agro-industrial proportions, such that the western honeybee (*Apis mellifera*) can now be considered a “massively introduced managed species” (Valido *et al.*, 2019). However, rather than benefiting or restoring pollinator biodiversity, high-density (commercial) beekeeping in the wrong areas can harm wild pollinator diversity, depressing densities of pollinators around apiaries in both natural habitats and crop lands, impairing pollination services and the reproductive success of plants, and spreading diseases to wild pollinators (Geldmann & Gonzalez-Varo, 2018; Valido *et al.*, 2019).

For example, Valido *et al.*, (2019) studied the influence of beekeeping on the functionality of plant-pollinator networks in Teide national Park (Tenerife, Canary Islands) and demonstrated several of these effects operating there; and a recent study in the Netherlands showed significant and large declines in the numbers of wild pollinators in heathlands in the vicinity of beehives (Smit *et al.*, 2021). Given that many *Eumerus* and *Merodon* species are mimetic and closely resemble bees, there is growing concern that commercial beekeeping will also generate significant changes in hoverfly communities.

Due to pollinator declines and honeybee die-offs in certain areas, honeybees are promoted in many places as a solution to ensuring pollination of commercial crops. Unfortunately, addressing the pollination challenge for agriculture has become entangled with the issue of what is best for conserving the biodiversity of pollinators (Ropars *et al.*, 2019, Ropars *et al.*, 2020). As a result, well-meaning conservation policies and initiatives are being influenced by a mixture of misinformation, misunderstanding, and intense lobbying from beekeeping and agricultural communities often focusing solely on *Apis mellifera* (Geldmann and Gonzalez-Varo, 2018; Valido *et al.*, 2019; Colla & McIvor, 2018). These misunderstandings persist in the media and among the public (Geldmann & Gonzalez-Varo, 2018). For example, honey from hives kept in 'natural areas' may be valued more by the public so that while protected areas are generally managed to be more pollinator friendly, managers may also introduce beehives, with potentially negative effects. In the St Katherine National Park in Sinai, an area without any native social bees, beehives have been introduced as a boost to the local economy. However, these can only survive the winter through the provision of supplementary sugar and affect pollination by native solitary bees (Norfolk *et al.*, 2018). In France, the initiative "Conservatoire de l'Abeille Noire" aims to preserve an old local form of the honeybee. Some national parks (e.g. Vanoise National Park) are acting with local partners to promote the conservation of this bee and are assigning the label "parc national" to resulting products (T. Lebard, pers. comm.).

Despite clear evidence that commercial beekeeping can pose a significant threat to wild pollinators as well as plant-pollinator interactions (Geslin *et al.*, 2017; Valido *et al.*, 2019) and though there is growing debate about the use of managed honeybees in natural and protected areas, and the effects that this practice may have on the integrity of native pollinator interactions (Henry & Rodet, 2018; Alaux *et al.*, 2019), the current lack of specific legislation allows beekeeping even in protected areas, in most countries worldwide (Torné-Noguera *et al.*, 2016). Moreover, some European countries have agri-environment schemes that provide funding to beekeepers to set up hives in natural areas.

Note that low-density beekeeping for local use has a long tradition and is probably not harmful to wild pollinators in landscapes with enough flower resources. The domesticated honeybee usually uses only "rewarding" nectar and pollen sources, which are communicated among workers in the hive, and this does not necessarily affect wild pollinators of other plant species.

2.2.4 CHANGING CLIMATE AND HYDROLOGY

In general, climate change increases the frequency and severity of extreme weather events, including wildfires, and exacerbates the negative impacts of human-mediated changes to hydrology (described below), all of which can damage important hoverfly microhabitats. Impacts of the changing climate on microhabitats of specific larval feeding types are covered under the relevant sections.

The alteration and simplification of waterways and the loss, reduction and degradation of small water body microhabitats, or water saturated ground, have implications for all three groups of hoverfly larval feeding types and this is discussed in more detail below.

STREAMS AND SEASONAL POOLS IN FORESTS

In forests, stream microhabitats are damaged by: the deepening of channels and the homogenisation of bank or edge profiles for drainage; canalisation; dredging to maximise flow through removal of bottom deposits and woody debris; and the removal of fallen timber either to reduce obstruction to water flow or for forest hygiene. Drainage removes microhabitat associated with seasonal pools. Also, general lowering of water tables in adjacent agricultural areas (for better harvests or earlier use of the soil) leads to disappearance of many water microhabitats in forests.

SMALL WATER BODIES ON ALLUVIAL FLOODPLAINS

Drainage, filling, and canalisation of streams involving re-routing, changing and homogenising edge profiles or deepening channels result in loss of microhabitats for these and other species. The dredging of streams and the removal of bottom deposits and vegetation also removes or degrades hoverfly microhabitats. Alluvial plains provide critical microhabitat for species including *Chrysotoxum lineare*, *Eumerus ruficornis*, *Merodon analis*, *Microdon myrmicae*, *Sericomyia nigra*.

SPRINGS AND FLUSHES (WATER SODDEN GROUND)

Springs and flushes occur where the water table reaches the surface of the ground. Flushes also often occur where the soils are saturated with water which seeps slowly downhill through the soil rather than in a distinct channel. Capping of springs occurs, especially in the mountains to supply water to holiday homes, in riparian woodland and in the Mediterranean zone, to supply water to homes, farming and livestock. The use of springs by livestock in montane or subalpine zones, causes soil disturbance and loss of natural structure and vegetation, with consequent loss of syrphid micro-habitats. Flushes are damaged through excavation to provide water for livestock and through drainage and filling.

SMALL WATER-BODIES IN OPEN HABITAT

Microhabitats associated with seasonal streams or rivers in open habitat are negatively affected by the compaction of bottom deposits through, for example, the use of river or stream beds for summer car parking. Pollution can be caused by use of rivers or stream beds for rubbish disposal, and micro-habitats are destroyed because of homogenisation of the channel profile through stone-lining. Microhabitats associated with pools and small standing-water bodies in open habitat are damaged through eutrophication or nitrification, destruction of the margin structure and marginal vegetation by over-stocking of the surrounding land with livestock, and through infilling, including use for rubbish disposal.

WATER ABSTRACTION

Water abstraction can be by industry or individuals, for agriculture, tourism, personal use or for livestock. Agricultural water abstraction is the main route through which surface and ground water are lost and the impact can extend as far as seven metres below ground. This is particularly problematic in the Mediterranean, but also in Central Europe in fertile alluvial plains for agriculture and around large cities for drinking water. Small streams are important resources for invertebrates and are easily impacted.

2.3 SPECIES WITH SAPROPHAGOUS LARVAL FEEDING TRAITS

This section considers forty-six of the 260 threatened species whose larvae obtain nutrients by consuming decomposing plant or animal material, with a few species that feed on sap-runs in living trees. Important microhabitats for these larvae include: overmature or “veteran” trees and their features (which are also sometimes found on stressed or damaged younger trees), and small water bodies such as mountain springs, seasonal pools in forests and small water bodies on alluvial floodplains (see Speight, 1989; Speight *et al.*, 2020). The challenges to these microhabitats are discussed in detail below.

2.3.1 LOSS, REDUCTION OR DEGRADATION OF VETERAN TREE MICROHABITATS

Microhabitats associated with overmature or “veteran” trees include trunk cavities, rot-holes, fallen timber and tree stumps. Their decline can arise through: the loss of entire veteran trees within standing forests; the replacement or loss of species that produce good veteran tree microhabitats (e.g. oak, willow, poplar, beech and other species); the loss or absence of hoverfly-friendly forestry practices; and the negative impacts of changing climatic conditions.

REMOVAL OF VETERAN TREES WITHIN STANDING FOREST

Entire veteran trees may be felled in parks, recreational forests and along roads, and in production forests: to protect the safety of the public or forestry workers; to avoid disease to commercial tree crops (veteran trees are perceived to be a source of disease); to improve forestry efficiency by realising economic benefits more quickly; and to produce firewood for the public or for foresters as extra income.

REPLACEMENT OR LOSS OF KEY TREE SPECIES

In western Europe we see the replacement of alien coniferous species by native tree species such as oak. However, elsewhere across Europe, oaks, willows, and poplars, which have a high likelihood of developing veteran tree microhabitats, are being replaced. Replacement with species such as *Tilia* or *Eucalyptus* results in complete loss of microhabitat for saproxylic syrphids (those feeding on dead wood).

Oaks are particularly important for saproxylic species because they are especially long-lived, they maintain the old wood parts in the crown and can live with rotting parts. Tree-holes tend to grow with the age of the tree and they develop a large variety of microclimatic and moisture conditions with different degrees of decomposing material (see papers and discussions on conservation measures of oak dominated forest habitats (9160, 9170 and 9190 under the EU Habitats Directive: Müller-Kröhling *et al.*, (2016), Ssymank, (2016), Ssymank *et al.*, (2019). Oaks are being replaced for economic reasons. They have a longer production time so are not favoured over faster-growing species. Also, infestations of oak processionary (*Thaumetopoea processionea*) and gypsy *(Lymantria dispar*) moths, whose caterpillars feed on oak leaves, can cause damage and lower timber production. Though otherwise healthy oak trees can survive infestation and regrow leaves later in the year, infested oaks may be cut and replaced by non-oaks. Sometimes, to combat mass infestation, there is large-scale aerial spraying of biological pesticides which targets the larvae of moths and butterflies but also has significant toxic effects on flies. Note that tree disease may favour hoverfly populations, for example Dutch Elm disease, and later the Bleeding Canker of Horse-Chestnut may have caused an upswing in sap-feeding hoverflies, notably *Brachyopa* (J. van Steenis pers. comm.).

Populus species such as *P. nigra* and *P. alba* used to exist on flood plains and in alluvial forests, but this habitat is severely diminished, as are the species associated with it. Poplars are now more likely to be found in some parts of riparian woodland. Planted species are often not the native poplars but can partly be used by saproxylic hoverflies. However, most riparian woodland is in central Europe and is dominated by *Alnus* and *Fraxinus* species, as well as sometimes *Salix alba* and *S. fragilis*, and poplars are rare in this habitat type.

DECLINE OR ABSENCE OF HOVERFLY-FRIENDLY FOREST AND WOODLAND MANAGEMENT

Old coppicing practices create good habitat for saproxylic hoverfly larvae because of the old trunks and the creation of fissures. However, coppiced forests of species such as *Carpinus* (hornbeam), *Castanea* (sweet chestnut) and various oaks, including Mediterranean species *Quercus frainetto, Q. cerris* and *Q. pubescens*, are being removed to make way for more lucrative forestry. A less entomologically useful form of coppiced forestry now occurs in the Mediterranean.

Transition zones or “ecotones” are important so that the adults of larvae that feed on dead wood can go on to feed on flowering shrubs and tall herbs (e.g. Van Steenis, 2016). However, forestry practices often preferentially remove shrub when it competes with wood production.

Succession planning for veteran trees is essential to the long-term viability of hoverflies with saproxylic larvae. Saproxylics can maintain populations for several years on a few, or even one, old tree (e.g. Van Steenis *et al.*, 2019). However, such populations are vulnerable if unable to move elsewhere when the tree dies or is removed. Microhabitat continuity, both on the same tree and within the same area (noting that most of these species are good fliers, so this can mean “within kilometres”), is essential. An absence of long-term thinking in forest and woodland management in Europe has led to situations in which there are old trees and very young trees but relatively little in between. In the Netherlands for instance, most forests are now 60 - 100 years-old (W. van Steenis pers. comm.). This can be expected to lead to long periods in which there are very few older trees in which saproxylic species can complete their life-cycle, and whole populations may be lost as a result. This situation results in part because there are now so few forest reserves in Europe that are not managed for timber production coupled with a lack of incentives for allowing trees to grow old. EU management contracts last for 5 - 10 years which is too short a timeframe to encourage long-term planning for the continuity of veteran trees.

REMOVAL OF VETERAN TREE FEATURES

Clearing trees uprooted by winds (windthrows) and removing all fallen or broken trees after major storms destroys important habitat for saprophagous hoverfly groups. Research has shown the arrival of a flush of species in the 2 - 3 years following heavy storms, which use these damaged tree parts (Van Steenis *et al.*, 2020). Fallen timber can be removed for forest hygiene and tidiness or along forest streams for better water flow. Removal is particularly common along roads and watercourses. Fallen timber may also be collected for firewood either by the public or by foresters to supplement income. Removal of tree humus from cavities, to use as potting compost, can destroy a microhabitat that can take decades to regenerate. Leaving the stumps of felled trees can enhance the larval habitat of several species like *Brachyopa* (see Van Steenis *et al.*, 2020), yet tree stumps are often removed, or may be treated with urea to inhibit decay organisms, while trunk cavities and rot-holes in urban parks or close to settlements are sometimes filled up with concrete or treated as wounds and sealed off. These practices should be prevented or minimised.

CHANGING CLIMATE, WEATHER EFFECTS AND FIRE

Premature death of trees *in situ* is occurring due to climate change effects, and the impact of this on veteran trees is accelerating in the Mediterranean following a succession of extreme weather events. Ancient trees are now dying prematurely because of drought. Climate change is influencing modern forestry towards promoting whatever species are most able to cope with the changes, even if non-native. Wet oak forest is threatened by water abstraction (both for drinking and irrigation) in combination with climate change. Root systems are adapted to the climatic situation of the soil, so when this changes it creates a cascade of issues.

Some natural fire cycles can be helpful for “veteranising” trees, creating microhabitats for saproxylic species. In the Boreal region, taiga forest vegetation needs natural fires from time to time, and these habitats are also partially managed with fire. Here, a certain frequency of natural fires is not in conflict with a high diversity of saproxylic hoverflies species, e.g. within the genera *Temnostoma* and *Spilomyia*, which can develop high population densities in these taiga habitats.

Conversely, frequent forest fires over larger areas in the Mediterranean pose a serious problem to both habitat and hoverfly conservation and may be increasing because of climate change. Dead wood for saproxylic hoverfly larvae needs to be moist so there are fewer of these species associated with Mediterranean microhabitats, however some that do occur there are quite threatened. Damaging impacts from fire are more likely in homogeneous managed forests, and those not actively managed for fires.

2.3.2 LOSS, REDUCTION OR DEGRADATION OF SMALL WATER BODY MICROHABITATS (OR WATER SATURATED GROUND)

Species with saprophagous larvae, and especially those with aquatic or sub-aquatic microphagous larvae, are impacted by activities that affect the hydrology of areas or the physical characteristics of waterways and their immediate surroundings. Changing hydrology also affects phytophagous and zoophagous species and so this topic is discussed in detail under the general section above (Changing Climate and Hydrology).

2.4 SPECIES WITH PHYTOPHAGOUS LARVAL FEEDING TRAITS

This section considers hoverfly species whose larvae are herbivorous, feeding on the tissues of living, non-woody plants. This is the dominant group of hoverfly species in Europe, encompassing the three most numerous genera: *Merodon*, *Cheilosia* and *Eumerus*. This group is mainly associated with forest and open ground macrohabitats (Speight *et al.*, 2020). Species were further separated into: 51 species that feed on stems, leaves and fungi (SLF); and 103 that feed on bulbs and roots (BR). These two sub-groups are phylogenetically and ecologically different and so are impacted in different ways by key threats, requiring different actions for their preservation.

2.4.1 ISSUES AFFECTING LARVAL MICROHABITATS

Hoverflies with phytophagous larvae are particularly sensitive because so many are highly specialised, often connected to a single genus or species of host plant. A diversity of phytophagous hoverfly species therefore requires a diversity of host plants. Issues leading to the loss, reduction, and degradation of favourable conditions for the phytophagous group are generally the same for both SLF and BR sub-groups, but the route of impact may differ both between them and across different regions.

2.4.2 REDUCTION IN HOST PLANT ABUNDANCE

While a diversity of host plant species is important, the size and density of host plant populations must be sufficient to support a sustainable hoverfly population. For example, *Cheilosia fasciata* (leaf miners) and *Portevinia maculate* (in tubers), both live as larvae in *Allium ursinum.* However smaller, isolated *Allium* patches are usually free of hoverfly larvae (no leaf-mines present). Similarly in dry habitats, low population densities of *Anthericum* species are not sufficient to support *Merodon rufus*. Fragmentation and loss of food plants affects both larvae and adults, which may share the same host plant species. Importantly, adults are likely to be key pollinators for their larval food plant such that the survival of the plant may correlate with the survival of the hoverfly species and vice versa.

2.4.3 FIRE

Fires can lead to direct loss of habitat and to overall degradation, with gradual loss of plant diversity and abundance. Fire impacts plant species differently. While sensitive and susceptible species may not survive burning, more resilient plant species may survive and become dominant, thereby changing species composition, and reducing overall diversity at fire-affected sites. Fires can also create favourable conditions for the establishment of invasive plants, reducing the diversity of native plant species. Additionally, fire can affect the long-term quality of soil because rains wash away organic matter more easily after fires. This impacts plant diversity by creating conditions suitable only for plants that can grow in poor-quality soils, reducing the quality of the subsequent herb-layer microhabitat.

Fires destroy above-ground microhabitats more severely than those below ground, presenting a major issue for the SLF subgroup. Larvae of threatened species feeding on bulbs and roots (BR) are generally less adversely impacted by fire partly because they are below the ground, but also because these species occur predominantly in the Mediterranean (76% occur there with 67% of them endemic to the region), where fires occur naturally and plant species have adapted to survive natural fire-cycles. Also, within the extant plant community of the Mediterranean, bulb plants are considered among the most valuable flora. However, the same level of resilience to fire has not developed in forest habitats and where fires occur there, phytophagous larvae of the BR sub-group are more severely impacted.

The occurrence of natural, accidental, and intentional fires is increasing, particularly in the Mediterranean and Alpine regions of Europe. In the Mediterranean, as well as in steppe areas, fire is deliberately used in agricultural management to clear remaining vegetation after harvest and to retain specific areas of agricultural land as grassland (essential for receiving some subsidies, for example, national subsidies in Serbia). Many rural areas in this region are becoming increasingly depopulated, resulting in a lack of manpower for mechanical land management and fire is used more frequently as an easier and quicker management technique, even though illegal in some countries, e.g., Serbia. Additionally, land abandonment has given way to afforestation and to a reduction in livestock, which would previously have played a key role in maintaining grassland areas. These changes can increase the fuel load of the vegetation and as a result the risk and severity of fires (Madrigal *et al.*, 2016). Where fire bans do exist, poor enforcement of the legislation can occur due to lack of capacity, difficulty in policing, political incentives and goals related to obtaining subsidies.

In the high-mountain zone of Europe (particularly the Alps), the number and frequency of accidental fires in coniferous forests is increasing. This is associated with a greater volume of visitors to the area for recreation. Furthermore, in the Central Alps, and especially on the southern slopes of the Alps, fires ignited by lightning have increased in frequency. With climate change and the increased incidence of hot and dry summers, these fires may assume a significant ecological role in the Alps (Conedera *et al.*, 2006).

Fifty-seven percent of threatened hoverfly species from the SLF phytophagous sub-group occur in the Alpine region of Europe, with 29% endemic to this area making increased fire incidence in this region a priority issue for the conservation of threatened hoverfly species.

2.4.4 OVERGRAZING

Overgrazing occurs in several habitat types across Europe's biogeographic regions, including forests, meadows, and grasslands. Different grazing species are sometimes dominant in particular regions, for example cattle and horses in many lowland areas, and goats and pigs in the Mediterranean and southern Europe.

CATTLE

Cattle grazing within forests is often used as a management technique to keep the mosaic forest habitat open and to increase meadow areas. Overgrazing within forests is a particular issue for the SLF sub-group (e.g. species from the genus *Cheilosia*) because the animals graze all plant species to the ground, removing the entire herb layer on which these species depend. Overgrazing negatively affects most *Cheilosia* species (Jovičić *et al.*, 2017). However, it is important to understand taxon-specific sensitivities, for instance findings show that *Cheilosia soror* might be less sensitive to overgrazing than most species of the genus.

PIGS

Hoverfly species of the BR larval sub-group are particularly affected by overgrazing by pigs. These animals dig up bulbs and tubers as well as consuming everything in the herb layer. In south-eastern Europe, though not only there, it was traditionally common practice to raise pigs within oak forests and, currently, overgrazing by pigs is a problem within oak forests in Corsica. Here, both the wild boars (*Sus scrofa meridionalis*), emblematic figures of the island with high quality meat, and the smaller Corsican pigs (known as "porcu nustrale") live freely. Corsican pigs, found in high numbers, are left to graze in the forest, driven by demand for artisanal pork produce. The number of pigs within forests (both wild boars and Corsican pigs) can be high and where pigs are found, no hoverflies are present. Historically, this has also been a problem in central Serbia, especially in low mountain areas. While today, this practice is less common, the damaging effects of former practices are still present (A. Vujić pers. comm.).

GOATS

Overgrazing in forests by goats is a common issue in the Mediterranean region and in the National Parks in southern France. Historically, this was a major force in modifying and shaping Mediterranean ecosystems, often resulting in the destruction of Mediterranean forests, especially when combined with wildfires (Papanastasis, 1998). Today the problem of over-grazing continues. For example, the Greek island of Ikaria is well known for its forest, but high numbers of goats graze there. For over twenty-five years Ikaria has faced serious overgrazing problems, with pastures stripped of vegetation, soil erosion, reduced soil fertility, a decline in biodiversity and the risk of desertification. A study by the Agricultural University of Athens confirmed that 'pastureland on the island of Ikaria can support only approximately 70% of the registered goats and sheep on the island'. The study also notes overexploitation in areas protected under Natura 2000[8]. Approximately 20 phytophagous species from the genus *Merodon* should be found in these forests, but surveys carried out by Novi Sad University particularly targeting this genus only detected three species (Vujić *et al.*, 2016).

ALPINE MEADOWS

Meadows (e.g., in the Alps) are deliberately enhanced by draining small rivers, which results in increased grazing and decreased species diversity.

[8] Source: https://www.europarl.europa.eu/doceo/document/E-7-2010-3279_EN.html

2.4.5 FOREST MANAGEMENT AND REFORESTATION

Undisturbed forest habitats can provide large areas of good-quality forest with a diverse herbal ground layer, and forest edges with a high diversity of flowering plants and increased levels of sunlight. Forestry management practices vary across Europe's biogeographic zones and there are many examples of intensive forestry practices that impact negatively on these conditions, including: monocultures of plantation trees (e.g. intensive poplar plantation forests in Serbia); clearing the herb layer (e.g. in the Balkans of south-eastern Europe); creating extensive drainage ditches to improve access for large machinery by drying the forest floor, making it less suitable for sensitive plant species (e.g. Sweden). Figure 11 below provides an example from the Czech Republic, of surface preparation for planting new trees. This area has been totally cleared of stumps and all vegetation, including *Galanthus nivalis* and *Leucojum vernum*, which are both protected bulb plants there.

Figure 12. *Surface preparation for tree planting in a protected forest area close to Olomouc. Credit: Libor Mazánek.*

Forest planting programmes that aim to create forest in regions where it was not originally present do not generally consider bulb hotspots when deciding where to plant trees. As a result, planting activities can destroy or reduce the diversity of bulb plants in the area. For example, the high grasslands of the Chelmos mountains in Greece have been replaced with planted forests, which has caused the destruction of many bulb plants that naturally occurred there (A. Vujić pers. comm.). This is a particular problem for the Mediterranean region where so many threatened BR species reside. High-alpine SLF species can be negatively impacted by afforestation since they rely on alpine meadow habitats.

Importantly, reforestation (or regeneration) programmes do not necessarily result in the recovery of hoverfly populations or species diversity. For example, in Montenegro, one half of the Sušica gorge remains as primary forest, whereas the other half was felled approximately 100 years ago for timber. The forest has recovered over the last 100 years, but hoverfly species diversity from the SLF sub-group is still half of what it would have been originally (A. Vujić pers. comm.), even though this forest patch is closely connected to the primary forest in the same gorge, emphasising the critical importance of protecting all remaining old forest.

2.4.6 CLIMATE CHANGE AND HYDROLOGY

Climate change in the Mediterranean region is predicted to result in warmer summers and less precipitation, causing drying and possible desertification of the land. It is projected that warming will be higher in the Mediterranean compared to the world average, making global warming an even greater threat to this region. The decrease in precipitation combined with the increased demand for water from tourism, agriculture and the growing human population are expected to lead to even more rapid loss of natural water supplies, and drying of natural habitats, and hence to increasing risk of fire. The combination of all these factors will impact on the extant flora, including bulb plants, and consequently on the phytophagous hoverfly species that depend on them, including the specialised genus *Eumerus,* which contains a high proportion of threatened species (Van Steenis *et al.,* 2017).

2.5 SPECIES WITH ZOOPHAGOUS LARVAL FEEDING TRAITS

This section considers threatened species whose larvae feed on living animals, predominantly aphids. The microhabitats with which zoophagous larvae are most closely associated are: the root zone (among roots of grasses or herbs and in association with colonies of root aphids, usually those tended by ants); the herb layer (mostly on tall strong herbs and low-growing non-woody flowering plants up to 0.5m in height); and trees (tree foliage, mature trees, understorey trees; shrubs, bushes and saplings; and one species that relies on overmature trees) (Speight *et al.*, 2020). Of the species associated with the nests of social insects, adult *Microdon major* and *Microdon myrmicae* have reduced mouthparts and do not visit flowers (Rotheray & Gilbert, 2011), and their larvae live in the nests of ants, where they eat the ant brood. The larvae of *Xanthogramma* and *Doros* species are aphid predators that probably live in ant nests (Hölldobler, 1929; Rotheray & Gilbert, 1999; Speight & Sarthou, 2017). *Doros destillatorius* may possibly be a predator of aphids in ant nests under oak bark (Speight *et al.*, 2020). Larvae of *X. aeginae* and *X. pilosum* are unknown (Nedeljkovic *et al.*, 2018).

Hoverflies with zoophagous larvae mostly use the ground surface (under or in terrestrial ground surface microhabitats such as tussocks and organic litter) and crevices and tunnels in the plant root zone, to shelter the life-cycle stage that overwinters (predominantly the larvae) from winter weather conditions. The species with larvae that live in the nests of social insects also overwinter there, in or close to the nests (Speight *et al.*, 2020) in organic debris close to the ground surface. These microhabitats are predominantly associated with forest (mostly deciduous and coniferous forest), and open ground macrohabitats (especially unimproved grassland) (Speight *et al.*, 2020), and gradual ecotones (or transition zones) between forest and open areas are also very important for both larvae and adults.

2.5.1 ISSUES AFFECTING LARVAL MICROHABITATS

In general, gradual rather than sharp ecotones between forests and meadows/grasslands/open areas support a higher hoverfly species diversity than is present in the forest or the open habitat itself. However, hoverflies with predatory larvae depend on the microhabitats of their prey. In many cases these relationships are unknown, making it difficult to develop a good understanding of the threats to which they are subject. This is in part because many of the known microhabitats (under bark, in social insect nests) are hard to survey.

2.5.2 LOSS OF GRADUAL ECOTONES BETWEEN FOREST AND MEADOWS

Intensification and mechanisation of agriculture, mechanised management in natural areas and mowing of roadside verges are some of the important mechanisms that lead to larger open areas with sharper borders. Loss of more gradual ecotones, including hedgerows, results in less diversity of the prey and plant species important to hoverflies. For example, it provides less (diverse) microhabitat for species with larvae living on trees and shrubs, bushes, or saplings, upon which most species with aphidophagous larvae rely. Sharper ecotones also result in a reduction of critical social insect species, such as the ant species that farm aphids in their nests, upon which some hoverfly larvae feed. Gradual ecotones also provide a richer variety in terrestrial ground-surface microhabitats important to this group of hoverflies, for overwintering or surviving dry periods. Adult hoverflies find a more continuous supply of pollen and nectar from plants typical of hedgerows and equivalent ecotones, than from those growing in improved or highly intensified meadows or grasslands.

2.5.3 LOSS OF MANY SMALL OPEN AREAS

The more traditional livestock grazing practices of tending small herds of sheep or goats result in many smaller open areas that are less intensively grazed and have gradual transition zones to forest. Over time more of these traditional small-scale livestock practices have been replaced with larger more intensively grazed herds, which has created larger overgrazed open areas with much sharper edges abutting the forest, more open forests, and a poorer plant diversity. In addition to this, many small open areas which were used in the past are abandoned because they do not meet the requirements of modern agriculture. These areas tend to disappear through rapid succession to closed forest of poor ecological quality. This is seen often in the Mediterranean (the most important biogeographical zone for this group of hoverflies), in Alpine areas and in many regions of central Europe. It is a smaller problem in

Northern Scandinavia. In some European countries (e.g. France) the EU financially supports grazing in proportion to the size of the herd and the surface grazed. This policy has encouraged farmers to keep larger herds on larger lands, incentivising the switch to more intensive agricultural practices. The EU supports traditional farming methods in Eastern but not in Western Europe, where such support is equally needed.

2.5.4 PESTICIDE USE

Hoverflies with zoophagous larvae may be particularly vulnerable to the effects of pesticides because these can affect the hoverflies themselves, across their entire life-cycle, and also their prey. There are many uncertainties about the scale of pesticide accumulation in the environment and in prey species, and about the impacts on the different life-stages of hoverflies with zoophagous larvae which makes it more difficult to recommend well-targeted action. Further information and recommendations on this subject are provided in GOAL 4 and associated text.

2.5.5 INVASIVE SPECIES: *HARMONIA AXIRIDIS* AND INVASIVE PLANTS

The multicoloured Asian ladybird, *Harmonia axiridis* is native to Asia, but has been introduced in many countries as a biological control agent against aphids (Adriaens *et al.*, 2003; Roy *et al.*, 2016). Through intraguild interactions (competition and predation) it may constitute an important threat to native aphid predators such as ladybirds (Adriaens *et al.*, 2003, Adriaens *et al.*, 2008; Roy *et al.*, 2008, Roy *et al.*, 2016) and hoverflies with aphidophagous larvae (Almohamad *et al.*, 2010, Ingels *et al.*, 2015). For example, females of the predatory hoverfly *Episyrphus balteatus* laid fewer eggs at sites with larval tracks from either conspecifics or *H. axiridis*, whereas the tracks of hoverfly larvae did not deter *H. axyridis* females from laying eggs (Almohamad *et al.*, 2010). These intraguild interactions can be complex and multifaceted. For example, in laboratory conditions, smaller, poorly nourished larvae of *H. axyridis* fed more on *Episyrphus balteatus* hoverflies than well-nourished ladybird larvae, and smaller larvae of *E. balteatus* were more susceptible to predation than well-fed hoverfly larvae (Ingels *et al.*, 2015). Although not known for certain, it is possible that rare hoverflies with zoophagous larvae are disproportionately affected by such strong intraguild predators.

Introduced, invasive plant species may replace natural plant communities, potentially reducing plant and hoverfly prey diversity. Though the impacts of the flowers of invasive plants on pollination networks appear to be small, there may be impacts on the availability of hoverfly prey. For example, the larvae of *Leucozona* (subgenus: *Ischyrosyrphus*), live on specialised aphid species like those linked to the flowers of Apiaceae, such as *Heracleum sphondylium* (hogweed or cow parsnip). Such species can lose their prey altogether if the aphid food plant is outcompeted. Relatively little is known about the scale of these impacts.

2.5.6 CLIMATE CHANGE

Longer warmer and drier periods will harm most hoverflies, but especially the aphidophagous larvae of zoophagous species, because aphids are highly sensitive to drier conditions. In addition, there may be a disconnect in phenological timing between aphid and hoverfly life-cycles. Multivoltine zoophagous hoverflies (i.e. those having two or more broods per year) often switch from tree/shrub aphids to the aphids of herbs (and vegetable crops) during the season, and hence the timing of phenological events may be more important to them than to hoverflies of other larval types. Many threatened zoophagous hoverflies are univoltine and tied to prey only available for short periods in the year. For these species, phenological mismatches may be critical to survival. Unfortunately, almost nothing is known about this.

Warmer winters can make it harder to overwinter successfully in a dormant state, particularly if breaking diapause requires a cold spell. Also, potentially, warmer winters could promote fungal infections or increase predation during the winter.

2.5.7 AGRICULTURAL POPULATION SINKS

Female syrphids can lay eggs in crops which are harvested before their aphid-feeding larvae can complete their development. For example: *Epistrophe eligans* is a univoltine species frequently found as larvae in cereal crops.

When the crops are harvested and the land ploughed within the same year, the *E. eligans* larval microhabitat is lost before hibernation can occur. Species most affected by this are those specialising in grass aphids (and hence cereal crops), such as *Episyrphus* and *Melanostoma.* All of the species mentioned are currently able to sustain their populations with reproduction outside crops. However, it is important to recognise that these sink effects exist, when considering habitat suitability for conservation purposes.

2.6 OPPORTUNITIES FOR PROTECTING, RESTORING OR CREATING MICROHABITATS

As described in the previous section, sustaining a diversity of hoverfly species in a landscape requires the ongoing presence and continuity of diverse microhabitats. Due to a range of natural resource management decisions and practices, these microhabitats continue to be lost even where macrohabitat is still present. This section considers the opportunities and options available for reversing these trends and supporting hoverfly conservation throughout Europe.

2.6.1 PRIORITISING WHERE TO PROTECT: PRIME HOVERFLY AREAS

Prime Hoverfly Areas (PHAs) are areas shown to be important both for hoverfly diversity and persistence and are identified through the application of a set of well-defined criteria (Vujić *et al.*, 2016). Such criteria-driven networks are well-recognised for their contribution to conservation of certain species and their habitats and priority areas already exist across Europe for birds, plants, and butterflies (Grimett & Jones, 1989; Anderson, 2002, Van Swaay & Warren, 2003). In many cases these areas have been integrated into national conservation planning and monitoring schemes (e.g. Plant Life International, 2010a, b). In Belarus, all Important Plant Areas (IPAs) are now protected by law (Darbyshire *et al.*, 2017), whilst in Croatia many IPAs were included in the expanded protected area network under the Natura 2000 scheme as part of their accession to the EU in 2013. So far, PHAs have been identified only for Serbia (Vujić *et al.*, 2016), where seventy percent (70%) of those identified to date are now protected.

In Serbia, only 22% of PHAs overlapped with Prime Butterfly Areas (PBAs) indicating that butterflies cannot be used as a proxy for all pollinators and different groups should be considered separately. However, there was high (72%) overlap with Important Bird Areas (IBAs) and with almost half of IPAs, so it should be possible to develop synergies.

Identification and protection of PHAs could be extended across the European region, in close collaboration with groups focused on species with similar needs and with other key area protection initiatives (such as Natura 2000) to improve the likelihood of success.

2.6.2 OPPORTUNITIES FOR PROTECTING GRASSLAND & WETLAND MICROHABITATS

Even the smallest fragments of undisturbed habitat in overgrazed areas can support an entire population of some hoverfly species, or significant proportions of them. There are existing practices within the EU through which small habitat patches can be protected. For example in France, under the Mesures Agro-Environnementales et Climatiques (MAEC) management actions can be taken by (for example) shepherds, such as delaying first grazing, cutting small trees to maintain open lands, avoiding wetlands, or putting resting places in less sensitive habitat, for which they can be compensated by the EU. Currently this scheme is available only for Natura 2000 sites and is focused on species on the EU Habitat Directive, which does not include any hoverflies. However, where these measures are taken in favour of promoting good conservation status for an Annex I Habitat, including its typical species, hoverflies can also be considered to some extent. Alpine grasslands and wetlands are especially fragile and vulnerable to the impacts of overgrazing and dung. Most are EU Annex I Habitats, and hoverflies form part of their typical species for assessment of “Specific Structures and Functions (including typical species)”. This mechanism can therefore provide an avenue for conserving hoverfly species, and remnant habitat patches of value to them, at least in some areas.

2.6.3 THE EU 2030 BIODIVERSITY TARGETS

The largest network of protected sites in the EU Natura 2000, based on sites of the EU Habitats Directive (HD) and the EU Birds Directive (BD) is designed to be a "coherent" ecological network of protected sites. Currently the EU is launching a "Pledges" process to reach the 2030 EU biodiversity targets. The protected areas target for 2030 is to designate 30% of the terrestrial area as protected (and managed) sites, and 10% as "strictly" protected[9]. Within this process there are opportunities to review existing national protected areas systematically, and threatened species should be considered within this. Red-listed hoverflies (nationally and EU Red Listed) as well as Prime Hoverfly Area analyses, could be important inputs into this process, to support supplementation of existing protected areas measures or to enhance their status to strict protection regimes.

The EU Biodiversity Strategy[10] includes information about buffer zones around Protected Areas and encourages margins for pollinators around agricultural areas.

2.6.4 EU POLLINATOR GUIDANCE DOCUMENTS

These lay out guidance to national governments, local authorities, and to the forestry, agriculture, and nature conservation sectors, on how to protect and encourage pollinators. The current focus is largely on bees and butterflies but there are opportunities to expand this to cover the needs of hoverflies.

2.6.5 PROTECTED AREA NETWORKS

Protected Area (PA) networks, including and especially the Natura 2000 network, should be some of the most readily mobilised vehicles for the conservation of hoverflies. Prime Hoverfly Areas (PHA) could be identified here and protected and managed so that both larval and adult forms are provided for. Newly identified, biodiversity rich PHAs outside existing PAs should be protected and added to the national network.

Starting with the larger PAs with their own management bodies, and using StN, and Red List databases as well as other tools and resources, hoverfly inventories can be established, priority species confirmed, their conservation needs identified and addressed, and population trends monitored. As part of this effort, planned management measures to enhance or maintain the conservation status of habitats or vegetation types within existing PAs could be systematically screened, optimised and reviewed for pollinator conservation, including hoverflies.

2.6.6 HOVERFLY-FRIENDLY FORESTRY AND WOODLAND MANAGEMENT, AND REFORESTATION

OPPORTUNITIES FOR PROTECTING VETERAN TREE HABITATS

In the UK there is a long-term citizen scientist project to map old trees, including the development of predictive tools to identify where other old trees might be so that they can be protected. There is potential to extend this across Europe.

Within forestry practices there are strategies and initiatives that enable a proportion of trees to get much older than the average harvesting age and that produce at the same time a continuous age distribution of trees to support habitat succession. Whole trees or tree groups within a forest stand can be "bought" or agencies otherwise compensated for leaving them to age naturally while those around them are felled. An example of this is the practice of "îlot de senescence" in France, though at presence trees are left for only 30 years or so, which is not long enough to secure veteran tree succession. However, with an extended period of protection this practice could be valuable for maintaining veteran tree habitats.

Old-style coppicing, coppice with standards (i.e., with spacing that enables mature trees to grow to an advanced age), or mixed extensive forest-grazing systems, can enhance the quality and continuity of veteran tree micro-

9 https://ec.europa.eu/environment/system/files/2022-01/SWD_guidance_protected_areas.pdf
10 https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm -

habitats. Coppice with standards has the additional advantage of partly compensating for a drier climate which may become increasingly important in parts of Europe as the climate changes. Thinning the tree canopy to leave standards largely reduces the rainwater interception in the tree layer, and both natural regrowth and a better water supply for the old trees saves veterans and promotes tree continuity even in situations where annual precipitation is well below 500 mm/yr.

OPPORTUNITIES FOR PROTECTING ALL HOVERFLY HABITAT IN FOREST AND WOODLAND

Some larger forests have areas set aside as wilderness areas or non-intervention zones, in which there is no forestry. It is essential that last remaining large and old-growth forests be maintained without any timber activities (Peterken, 1993) to provide strongholds for saproxylic species in general, as well as a refuge for the more demanding, highly adapted species.

2.6.7 HOVERFLY-SENSITIVE AGRICULTURE

In addition to some government agencies there are many farmer groups and NGOs with a specific interest in improving outcomes for nature in agriculture (e.g., Farm Clusters, FWAG & LEAF in the UK) and these provide an opportunity to promote and expand hoverfly-friendly practices through methods such as organic farming, integrated pest management and farming with alternative pollinators (FAP) (see Box 2).

BOX 2: Farming with Alternative Pollinators (FAP) - a win-win strategy for farmers and insect conservation. By Axel Ssymank & Stefanie Christmann.

Farming with Alternative Pollinators (FAP) was developed by Stefanie Christmann within BMU*-funded projects and has been tested in Uzbekistan and Morocco under different field conditions and with different crops, and since 2020 also in Turkey, Jordan, Palestine, Egypt and Algeria. In principle, 75% of the field is used for the main crop, while 25 % of the field is used for habitat enhancement measures for wild pollinators through marketable habitat enhancement plants (MHEP) and nesting support (Christmann *et al.*, 2021, 2017). By better and continuous pollination in combination with biocontrol, the harvest and benefit to farmers can be much higher than with conventional farming with a 100% main-crop field, and is self-sustaining without any payment of subsidies. This FAP approach has been tested with hundreds of smallholders, and trials have started in large-scale farming. Based on trials since 2013, the FAP-induced incentive (higher income per area) is higher the more degraded the surrounding agro-ecosystem is, e.g. in regions with large fields of cereals.

Hoverflies help in a mixed-pollinator community with wild bees to complete pollination of all flowers of the target crop under different weather conditions throughout the whole flowering period. At the same time, hoverflies with zoophagous larvae have an important role in biocontrol of crop pests, allowing reductions in pesticide use.

Under good conditions (e.g. the presence of old trees on the farm, or within less than ca. 300 m in more fragmented landscapes) even rare xylosaprophagous hoverfly species such as *Myolepta difformis* (EN in the EU) or the rare *Mallota cimbiciformis* can live in FAP fields, as shown in two FAP trials with different main crops (*Vicia faba; Solanum melongena)* in the Kenitra region near Rabat (Morocco). Here, *Myolepta difformis* was attracted by the MHEP *Coriandrum sativum.*

Organic farming (where no specific measures of habitat enhancement occur) can also support high densities of hoverflies, but mainly of relatively common species of zoophagous larvae, that benefit from feeding on aphids (and coccinellids).

* BMU is the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety, now BMUV and including consumer protection.

Phytophagus species are known to be impacted by specific agricultural practices such as pesticide use and ploughing, and Box 3 describes the evidence for this gathered from olive groves in the Mediterranean region, along with recommendations for beneficial changes. Goal 4 includes additional text on the impacts of pesticide and fertiliser use, and Goal 5 includes text on agriculture policy.

BOX 3: Impact of agricultural practices on *Merodon* species, in olive groves on Lesvos.
By Marina Janković.

Some phytophagous species develop in plants connected with olive groves. Two agricultural practices often applied in these plantations can be extremely harmful: the use of pesticides, and ploughing.

These impacts have been evaluated through a study of the three types of olive groves on Lesvos:

i. Olive groves with intensive use of pesticides. Pesticides affect phytophagous species both directly and indirectly. Herbicides reduce the population of bulb plants, indirectly decreasing the abundance and diversity of hoverfly species connected to them. Meanwhile insecticides, which are often applied 2 – 4 times per year (Taxidis *et al*. 2015), contribute directly to the declines within these plantations. Frequent monitoring of these olive groves has shown that usually, no phytophagous hoverfly species are present. Though sometimes up to five species of *Merodon* can be detected, this is significantly fewer than expected in this type of habitat (A. Vujić pers. comm.).

ii. Olive groves with ploughing. Farmers usually cultivate their olive groves by ploughing 15cm and disk harrowing 10cm (Taxidis *et al*., 2015). This practice greatly affects the host plants of many phytophagous hoverfly species due to the destruction of the bulbs, which often grow at this depth. However, ploughing may have some benefits for ground-nesting bees, by creating open, bare ground, loosening compacted soils or changing the predator community (Ullman *et al*., 2020). Up to now, 13 phytophagous *Merodon* species have been detected during frequent monitoring of this type of olive grove (A. Vujić pers. comm.).

iii. Olive groves without agricultural interventions. Here, the habitat for hoverfly species is undisturbed since there is no ploughing and pesticides are not used. The number of species detected in these olive groves (29) is far greater than in the other two treatments, supporting the claim that these two agricultural practices have a negative impact on phytophagous species diversity. Of the 29 species, 16 are found exclusively in undisturbed olive groves (A. Vujić pers. comm.).

Recommendation: keep the use of pesticides to an absolute minimum and leave unploughed at least one-third of an olive grove, to ensure that this type of plantation provides suitable habitat for both bees and hoverflies.

OPPORTUNITIES FOR BIOLOGICAL CONTROL

Many aphids are crop pests and aphidophagous hoverfly larvae therefore have a potentially significant role to play in natural biological control (Rotheray & Gilbert 2011; Rojo *et al*., 2003). This presents a good opportunity for building greater awareness of the value of hoverflies to the agriculture sector, and as a result, for encouraging hoverfly-friendly measures in an around crops.

2.6.8 HOVERFLY-FRIENDLY LIVESTOCK GRAZING

As a result of these effects, conservationists traditionally consider livestock grazing incompatible with maintaining high biodiversity in Mediterranean ecosystems (Tsoumis, 1985). However, extensive low-density grazing over larger areas, all year round, without closed fencing and preferably with a mix of pasturing animals (cows, horses, sheep, goats etc.), is an effective conservation management measure in many different habitats. Done well, it can maintain high plant and animal diversity, which also sustains diverse hoverfly communities. Several of these projects exist across Europe. In Germany, there is a manual on natural extensive pasturing systems and Natura 2000 protected areas (Bunzel-Drüke *et al*., 2019), wherein all aspects are discussed in detail, with practical examples of suitable breeds of animals, animal health and care, and the potential for effective management of all Annex I habitats of the EU Habitats Directive, using pasturing.

In some regions of Europe, forest management practices have been improved, resulting in positive impacts for saprophagous species (e.g. in the Netherlands, changes in forestry management have been made to conserve veteran trees and leave dead trees standing, benefiting hoverfly species with saprophagous larvae). However, these measures have no positive impact on phytophagous species because the measures do not result in improvements to the quality of the herb layer, or bulb and root microhabitats at ground level, on which these species rely. Ground-layer microhabitats and plant species in the forest important for these phytophagous species are often omitted in forestry management, which is generally focused on timber trees.

At the other end of the spectrum, abandoning grazing and management entirely also results in the loss of small open areas, through rapid succession to closed forest. The rewilding movement may allow greater focus on the most appropriate level and type of grazing for wildlife-friendly landscapes, which could benefit the kinds of habitats required by hoverflies.

2.6.9 HOVERFLY-SENSITIVE FIRE MANAGEMENT

Fire is commonly used as a conservation practice to keep areas open. Timing of fire management, weather conditions and the amount of accumulated plant biomass, especially in the litter and topsoil layer, make big differences to fire intensity and duration. In well planned and executed fire management the temperature in the soil can remain low just a few millimetres below ground and the litter will quickly burn down, presenting little or no threat to phytophagous hoverfly larvae with bulb and root feeding traits. Further, where fire is not used to burn large areas at once, and deliberately ensures part of the habitat is left to support recovery, other hoverfly groups can also be sustained. This style of managements is and was used, for example, for large heathland areas with *Calluna* (heather) and supports good insect populations. Similarly, there are methods for limiting fire spread and damage in forest and woodland, using fire breaks and selecting a planting mix that includes species that show more fire resistance, which includes some oaks

Different types of habitat respond differently to fire and to fire management methods. Some are highly sensitive to it and as a result can change their plant composition completely over time. Often, the impacts on insects are not considered. To establish the justification for its use, long-term monitoring of insects in the areas where fire is used as a conservation tool is required, to examine the effect on insect populations. Hoverfly-friendly fire management may be designed or tailored for different habitats, where their fire response is well understood.

2.6.10 LANDSCAPE MANAGEMENT PLANNING

Landscapes in Serbia that have experienced changes in aggregation, isolation/connectivity and landscape diversity are known to have lost *Cheilosia* species richness (Popov *et al.*, 2017) and this pattern of loss is well-recognised eslewhere. Landscape-scale management planning, which addresses a range of ecosystem processes, conservation objectives and land uses, can benefit species such as hoverflies with their complex resource and habitat requirements which change during their life-cycle and may be spatially separated. Planning at the landscape scale rather than for a single land-use system within the landscape, recognises the interdependence of the multiple systems operating and provides an opportunity for "joined-up" conservation that incorporates elements of critical importance to hoverflies. These include: optimal proportions of different land-use types to encourage sufficient abundance of suitable macrohabitats; a diverse mosaic of favourable microhabitats; corridors and gradual "ecotones" or transition zones between habitats; and adequate buffer zones around sensitive areas to prevent contamination from other systems.

In Europe nearly all habitats are now managed mostly for food, and thus future land management strategies should seek to achieve a balance between food production and biodiversity conservation, which will benefit from landscape-scale planning.

CORRIDORS AND TRANSITION ZONES

Within a landscape-scale approach, narrow strips of land such as hedgerows, and the areas under power lines or alongside canals and railway lines, can provide habitat refugia and corridors for invertebrates. In the UK, canal-side and railway planting of *Berberis vulgaris* is supporting the barberry carpet moth (*Pareulype berberata*)[11] and in France, the open areas created under power lines have proved valuable for rare butterflies (e.g. *Coenonympha oedippus*, *Maculinea alcon*) and could also be good for phytophagous hoverflies.

Care must be taken to ensure good, ongoing management of this strips. For example, if land under power lines is left for several years without cutting, it results in an area less ecologically valuable, potentially leaving only brambles and dead small wood sticks instead of open areas with wildflowers.

2.6.11 RESTORATION OF LOCAL POPULATIONS USING INTENSIVE MANAGEMENT METHODS

260 species were identified as threatened during the IUCN Red List assessment process. This document lays out activities that would be valuable in supporting the major larval feeding traits represented among these taxa, through habitat protection and management at sites or areas where those species are known to persist. However, for some threatened taxa this approach may not be enough, or may not act swiftly enough, to reverse declines and drive recovery. For these taxa, more intensive interventions may be needed, which might include:

- creating artificial habitats to support local populations while habitat is restored;
- reintroducing species to areas from which they have been lost;
- research to increase understanding of species-specific needs (e.g., identifying host plants),
- establishing *ex situ* populations to support these and other activities.

The IUCN's Guidelines on the Use of *Ex situ* Management for Species Conservation[12] consider these and other intensive management interventions and are a valuable resource for identifying instances where more intensive population management methods may be required to support the conservation of individual species, at specific locations. As an example of a more intensive approach, Box 4 describes the methods used to restore a local population of the Pine Hoverfly, *Blera fallax*, in Scotland.

BOX 4. Use of intensive management methods to restore the Pine Hoverfly to the Cairgorms in Scotland. By Gabrielle Flinn.

In the UK, the Pine Hoverfly, *Blera fallax*, is known from only two sites in the Cairngorms National Park in Scotland. Lack of larval habitat is considered the primary threat, which has resulted from the loss of veteran Scots Pines, *Pinus sylvestris*, that have holes and cavities containing wet decay with associated microbes on which the larvae filter-feed. In Scotland, this species is an iconic champion for the return of the Caledonian pine forest and has been the subject of extensive conservation efforts in recent years.

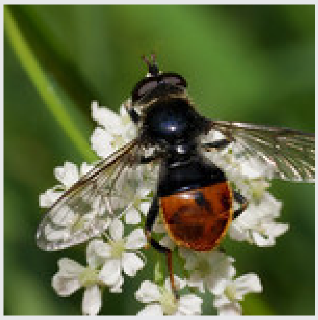


Photo: Frank Vassen - *Blera fallax*

The project uses two intensive management methods to safeguard and encourage Scottish populations. Firstly, it expands the amount of larval habitat available by boring holes in pine stumps in suitable clear fell areas. These holes collect water and create the wet, decaying conditions preferred by these larvae. This also benefits other hole-breeding hoverfly species such as *Callicera rufa*, *Myathropa florea*, *Speghina clunies*, *Xylota segnis*, and other types of hole-dwelling flora and fauna. This technique was pioneered for *Callicera rufa* in 1994 and proven effective for attracting *B. fallax* by Dr. Ellen Rotheray (University of Sussex).

[11] https://naturebftb.co.uk/the-projects/barberry-carpet-moth/
[12] https://www.cpsg.org/iucn-ssc-ex-situ-guidelines

Secondly to supplement and expand wild numbers, and using protocols developed by Dr. Rotheray, the Royal Zoological Society of Scotland has successfully maintained a captive breeding programme, having reared the Pine Hoverfly through a full breeding cycle including mating, female oviposition and larval rearing using “Hoverfly Lagoons” filled with water-saturated pine sawdust.

The project is a collaboration that includes: the Malloch Society, Royal Society for the Protection of Birds (RSPB), Forest and Land Scotland, Nature Scot, Cairngorms National Park Authority, and the Royal Zoological Society of Scotland (RZSS).

Note the project has also involved annual surveys by local experts and trained volunteers, under the auspices of an EU funded project, ‘Rare Invertebrates in the Cairngorms’. Local citizens are considered essential for the conservation management of the species, both for gathering critical data and for raising awareness about the need for these conservation efforts.

2.7 GOALS AND RECOMMENDATIONS

GOAL 2: ADEQUATE PROTECTION, MANAGEMENT & RESTORATION OF PRIORITY HABITATS AND POPULATIONS

Ensuring:

- Prime Hoverfly Areas are identified and protected.
- Priority micro-habitats for hoverflies are protected, restored and established.
- Habitat mosaics, ecotones and connectivity are promoted and restored.
- Biodiversity conservation is a significant product of forestry and agriculture.
- Biodiversity values are prioritised in Protected Areas.
- Where needed, intensive management methods are applied to retore and support local populations of priority species.

GOAL 2: RECOMMENDATIONS

Goal 2 is focussed on the larval microhabitat requirements most prevalent among species classified as threatened, though the measures described will also benefit non-threatened species with similar needs. The recommendations are not spatially explicit. That is, they do not specify priority sites or areas where it is most important to act for specific threatened taxa. This level of detail is for consideration at national, sub-national and local levels, for which useful information may be drawn from the IUCN Red List database, from StN and from local experts.

The recommendations in this section are separated into different land-use systems (forest and woodland management, Protected Areas, grazing systems and agriculture) because although there is some overlap, in general they involve relatively discrete groups of potential implementers, resources and decision-making bodies. It was generally agreed that agricultural systems are less important for threatened hoverfly species which are unlikely to occur or persist there (though see BOX 2). However, it was considered important to include a section on these systems because of their influence on the quality of microhabitats in surrounding areas, and on landscape connectivity. Additional recommendations of relevance to those involved in these land-use systems are included in Goals 3, 4 & 5.

2.1	GENERAL RECOMMENDATIONS FOR ALL OR MULTIPLE SYSTEMS			
Larval types benefitting are denoted in last 3 columns: S=Saprophagous; P=Phytophagous; Z=Zoophagous				
Recommended action	**Current or potential leads and collaborators**	S	P	Z

2.1.1	Identify Prime Hoverfly Areas across Europe using the methods identified by Vujić *et al.*, (2016).	UNSPMF; NATURALIS; PA networks; groups of hoverfly experts in European countries.	X	X	X
2.1.2	Seek synergies with other species groups and with other initiatives (e.g. Natura 2000, IBA, IPA, PBA) to increase chances of successful management and protection of PHAs.	UNSPMF (Birdlife International; IUCN; Butterfly Conservation Europe (BCE); those with interest in old trees).	X	X	X
2.1.3	Establish and contribute to an IUCN veteran tree conservation task force to map and promote protection of veteran trees across Europe. [Proposal submitted]	UNSPMF, BioSense Institute, HSG, Lichen SG, Mollusc SG, Global Tree SG, The Woodland Trust & Ancient Tree Forum in UK, national forestry and woodlands management agencies).	X		
2.1.4	Develop landscape rather than single system management:				
	■ pursue optimal proportions of different land-use types to encourage abundant, suitable macrohabitats that will support hoverfly requirements;		X	X	X
	■ avoid planning of infrastructure such as roads, paths etc. along forest borders which will destroy ecotones;	National, regional & local policy makers and implementers; local planning authorities; NGO landowners/managers; Protected Area managers.	X	X	X
	■ restore semi-natural ecotones (transition zones), especially in intensively used and heavily modified landscapes (e.g. hedgerows, mown strips under powerlines, canal, railway and road side planted strips etc).			X	X
2.1.5	Reduce or remove excess nitrogen deposition, pesticides and seed coatings (see also GOAL 4).	Government agencies for agriculture and environment.	X	X	X
2.1.6	Create buffer zones of sufficient size to protect sensitive areas from excess nitrogen deposition, pesticides and seed coatings.	Government agencies (agriculture & environment; Protected Area managers; NGO landowners/ managers.	X	X	X
2.1.7	Manage risks where natural/accidental fires are a concern:				
	■ Enforce fire ban legislation.	Local policy makers and implementers; local fire and rescue authorities; NGO landowners/ managers; Protected Area managers.		X	X
	■ Maintain management of accumulating biomass to restrain the frequency, intensity and scale of fires (e.g. on abandoned lands), while still supporting diverse microhabitats.			X	X
	■ In forest/woodland, maintain natural fire breaks and plant a species mix that includes fire-resilient species (e.g. some oaks).	Local policy makers and implementers; NGO landowners/ managers; NGO conservation implementers; Protected Area managers.	X		
	■ In local communities, explore and where possible address the drivers of damaging fire frequency/intensity/ scale.		X	X	X
2.1.8	Where fire is used for management, ensure practices limit damage and support biodiversity:				

	■ carefully consider the timing, weather conditions and accumulated biomass, especially in the litter and topsoil;	Government Agencies (e.g. through guidance materials to relevant sectors); NGO landowners/ managers and NGO conservation implementing organisations; Protected Area managers.		X	X
	■ ensure fire management strategies are tailored to the known fire sensitivity or response of the habitat-type targeted, including the microhabitat features;			X	X
	■ do not burn large areas at once, ensuring part of the habitat remains to support recovery.			X	X
2.1.9	Protect and restore natural hydrology and especially small water bodies:				
	■ Stop drainage;	Government Agencies responsible for hydrology and waterbodies; NGO landowners/managers and NGO conservation implementing organisations; Protected Area managers.	X	X	X
	■ Reduce water abstraction;		X	X	X
	■ Protect springs, flushes and small water bodies in open areas from livestock damage such as compaction and disturbance of soil/ vegetation;		X	X	X
	■ Prevent canalisation of streams, homogenisation of edge profiles, dredging and other methods of removing bottom deposits and woody debris.		X	X	X

2.2 RECOMMENDATIONS FOR PROTECTED AREA SYSTEMS

Current or potential leads and collaborators

- National & local policy makers/implementers;
- Protected Area/Landscape managers; NGO landowners/managers;
- Hoverfly experts (e.g. UNSPMF; HSG; experts in national & local conservation NGOs; entomological organisations e.g. BfN & EVKr);
- Farmers operating within PAs; farm conservation-directed partnerships and charities (e.g. in UK - Local Nature Partnerships (LNPs) and Farm Clusters; UK Farming & Wildlife Advisory Group (FWAG); Game and Wildlife Conservation Trusts;
- Specialist NGOs (e.g., UK Centre for Ecology & Hydrology).

Recommended action		S	P	Z
2.2.1	Manage Prime Hoverfly Areas for their biodiversity conservation value.		X	X
2.2.2	Starting with large, well-managed PAs with their own management bodies, such as national parks and biosphere reserves:	X	X	X
	■ develop inventories of hoverflies as a standard procedure;	X	X	X
	■ identify priority species for each PA based upon the Red List status (European as well as national or regional) and national responsibilities for protecting these species;	X	X	X
	■ identify the main threats to these priority species in the respective PA;	X	X	X
	■ develop and implement the necessary conservation measures to improve their status (including intensive management methods where needed – see IUCN Guidelines on the Use of Ex situ Management for Species Conservation);	X	X	X
	■ monitor population trends of the priority species as feedback for planning;	X	X	X
	■ in planning management measures to enhance or maintain the conservation status of any habitats or vegetation types within existing PAs, systematically screen, optimise and review for pollinator conservation, including hoverflies.	X	X	X
2.2.3	Manage throughout for good hoverfly microhabitats: spatial and temporal mosaics, microhabitats for both larvae and adults, with good connectivity and gradual ecotones.	X	X	X

2.2.4	Maintain or restore water levels.	X	X	X
2.2.5	Develop and implement specific "biodiversity-farming" in and around PAs.			
	■ Ensure arable areas inside PAs are managed to support biodiversity (see section on agricultural, grassland and grazing systems), and without intensive fertilisation, pesticides or seed coatings;			X
	■ Ensure buffer zones of appropriate size around PAs to protect from agricultural run-off;			X
	■ Ensure forestry areas inside PAs support biodiversity (see section on forestry and woodland systems);	X	X	X
	■ Carefully consider the number and distance between beehives in PAs, and in border zones around them (noting the > 3km foraging range of honeybees).			X
2.3	RECOMMENDATIONS FOR FORESTRY AND WOODLANDS SYSTEMS			

Current or potential leads and collaborators

- National & local policy makers/implementers;
- Government, NGO and private organisations who manage forests and woodlands (e.g. UK Woodland Trust); forestry sector;
- Organisations with an interest in old trees (e.g. UK Woodland Trust and Ancient Tree Forum);
- Protected Area/Landscape managers;
- Hoverfly experts (e.g. UNSPMF; HSG; experts in national & local conservation NGOs; entomological organisations e.g. BfN & EVKr).

Recommended action		S	P	Z
2.3.1	Protect existing forest. There is no guarantee that hoverfly (and other) diversity will return to new forest.	X	X	X
2.3.2	Support the inclusion in forests of tree species recognised for their saprophage-friendly mature tree features:	X		
	■ allow trees like *Salix* and *Populus* to grow up naturally;	X		
	■ promote and actively manage oak forest.	X		
2.3.3	Protect existing veteran trees microhabitats and ensure their continuity long-term:			
	■ register and protect known veteran trees;	X		
	■ give important (parts of) forests a higher protection by rendering them nature reserves, forest reserves or other national designation, to make sure trees are not cut or removed;	X		
	■ leave groups of trees standing around individual veteran specimens, to protect them from high winds and reduce risks to the public and forestry workers;	X		
	■ leave windthrows and a percentage of storm-damaged fallen or broken trees, to natural forest succession;	X		
	■ leave tree stumps in place after felling and discourage wood shredding;	X		
	■ plant or manage future veterans of oak trees in the vicinity of existing old growth forest to enlarge suitable forest stands (e.g. oak rejuvenation under *Pinus* afforestation close to (mixed) oak forests);	X		
	■ compensate land managers for leaving stands of forest to mature and grow old naturally ensuring that larger areas are maintained than in current practice;	X		
	■ reduce or prevent clearance of deadwood and living trees from in, and around, waterways.	X		
2.3.4	Before any new forestation, identify and protect important hotspot areas of bulb-plants to preserve the bulb and root microhabitats.		X	X
2.3.5	Protect and restore the natural hydrology, especially the integrity of small water bodies:			
	■ retain small water bodies wherever possible, especially in forests, avoiding drainage measures and keeping or restoring water levels to those of natural forest.	X		

2.3.6	Where otherwise lost or inadequate, create artificial microhabitats to support local populations:			
	■ where appropriate, create artificial rot-holes in trees as support for saproxylic hoverfly larvae in areas where veteran trees and their features are lost (see Box 4);	X		
	■ encourage syrphid-friendly methods for cleaning livestock shed run-off (e.g. through a series of shallow pools with aquatic vegetation).	X		
2.3.7	Protect and restore ecotones, and encourage habitat mosaics and spatial and temporal habitat continuity within and around forests:			
	■ support and promote natural vegetation at the forest and water's edge;	X		
	■ include areas with meadows to increase forest edge habitats;	X	X	X
	■ protect and encourage the herb layer;		X	X
	■ stop drainage;	X	X	X
	■ allow less run-off from agriculture;	X	X	X
	■ reduce foot traffic in sensitive areas;	X	X	
	■ use grazing to open up small areas while preventing overgrazing;		X	X
	■ incorporate ground layer microhabitats into forestry and woodland management plans (e.g., prevent clear-cutting and ensure spatial and temporal habitat continuity).	X	X	

2.4 RECOMMENDATIONS FOR GRASSLAND, GRAZING SYSTEMS AND AGRICULTURE

Current or potential leads and collaborators

- National & local policy makers/implementers;
- Conservation-directed partnerships and charities focused on farms and grazing systems (e.g. in UK - Local Nature Partnerships (LNPs) and Farm Clusters, UK Farming & Wildlife Advisory Group (FWAG)); Game and Wildlife Conservation Trusts;
- Protected Area/Landscape managers; NGO landowners/managers;
- Hoverfly experts (e.g. UNSPMF, HSG, experts in national & local conservation NGOs, entomological organisations e.g. BfN & EVKr); research and data organisations (e.g. National Biodiversity Networks);
- Specialist NGOs (e.g. UK Centre for Ecology & Hydrology).

Recommended action		S	P	Z
2.4.1	Preserve even the smallest fragments of undisturbed habitat in overgrazed areas (such as woodland fragments), as these can support the entire, or significant proportions of, populations of some species.	x	x	x
2.4.2	Support habitat heterogeneity and continuity in grasslands or grazing systems:			
	■ Designate bulb-plant hotpots (as these are not visible at all times of the year), for preservation as part of land management;		X	X
	■ Establish optimal numbers of grazing animals for specific areas of land, to ensure grazing levels are sustainable and overgrazing does not occur;		X	X
	■ Delay first grazing/mowing date on grasslands until after peak bloom;		X	X
	■ Reduce fertiliser input, to allow low competitive plant species and late flowering plant species to develop.		X	X
2.4.3	Promote good biodiversity outcomes from agriculture			
	■ Adopt a working principle that agriculture should not negatively impact surrounding areas;	X	X	X
	■ Encourage and engage in cooperative planning for biodiversity outcomes across landscapes (e.g. through vehicles such as the UK Farmer Clusters);	X	X	X
	■ Encourage spatial and temporal heterogeneity in all modern agricultural management techniques (e.g. maintaining flower strips for 2-3 years at a time, not completely mowing areas, leaving part of the ecotones intact each year, protecting and installing hedgerows etc.);		X	X
	■ Reduce/remove reliance on pesticides and nitrogen fertilisers (see GOAL 4).	X	X	X

3

3. LACK OF AWARENESS ABOUT HOVERFLIES AND HOVERFLY-FRIENDLY BEHAVIOUR

3.1 CHALLENGES

Improving understanding among the public about various roles biodiversity plays in different ecosystems is essential to achieving systemic change in human behaviours that would lead to encouraging sustainable living. When it comes to insects, some orders are favoured due to their charismatic appearance (e.g. butterflies) or appreciation for their (known) ecosystem services (e.g., bees), while unfortunately many are disliked.

A recent study exploring the reasons behind the universally acknowledged truth that people like bees and dislike wasps (Sumner *et al.*, 2018), recognises a lack of appreciation for their role in ecology and in the economy as the root of this «unfair treatment». Bearing in mind that socio-psychological factors (such as a person's attitude or identity) drive the behaviour of individuals, nature and biodiversity conservation activities will often rely on well-informed individuals and groups for their success. Therefore, investing effort in increasing awareness and understanding of hoverflies is likely to play a valuable role in their conservation. See Box 5 for a working example from Serbia.

BOX 5. Raising public awareness: "Biology Night", Novi Sad, Serbia. By Marija Miličić.

To bring hoverflies closer to the wider public (primarily children, but also adults), in Novi Sad, every year a workshop is organised in the Department of Biology and Ecology, as part of a "Biology Night". During this workshop, all visitors have the opportunity to learn about the significant roles hoverflies play in the ecosystem and the threats they are facing, how to recognise them and how to differentiate hoverflies from bees and wasps. There are fun activities such as quizzes and puzzles, and visitors learn how to build "hotels" for insects to attract different pollinators to their gardens or apartment terraces. This is only one example of activities that can be conducted to raise public knowledge and appreciation of hoverflies. Knowledge, and a sense of familiarity, are steppingstones to increased engagement of individuals in conservation efforts for hoverflies through, for example, participation in citizen science projects.

3.2 OPPORTUNITIES

It is particularly important to focus on environmental education in early childhood by offering stories about hoverflies as main characters that will resonate with children. This can help them to explore the unique characteristics, behaviours and roles hoverflies play, while at the same time addressing their potential confusions and misconceptions about these insects. These stories could use hoverflies as case studies to learn about how nature works, including understanding the impact that hoverfly species have on the ecosystem and human well-being, as well as the impact humans have (directly or indirectly) on species and their habitats. Focusing more on native nature on their doorstep, schools should use all opportunities to boost each nature connection journey, prioritising environmental awareness-raising at an early age. Educating children about the complexity of the environment needed for hoverflies is also a powerful way to advocate for a diverse variety of habitat types.

Biodiversity is essential for sustainable development and human well-being, and people should be aware of human activities that could harm biodiversity and ecosystem function. Besides children then, environmental education should also be a crucial part of formal and informal adult education, aimed at creating collective action in solving the biodiversity crisis. To shift the world onto a resilient path, responsible citizenship seeks mechanisms to enable everyone to gain the knowledge and skills for achieving sustainable development by 2030, from local to global level (United Nations (UN), Agenda for Sustainable Development).

Next to environmental knowledge, connectedness to nature also has a great role in influencing environmental behaviour – people with a strong sense of connection to nature engage in a greater number of pro-environmental behaviours, which in turn generates happiness and overall well-being (Martin *et al.*, 2020). With this in mind, there are many simple nature activities and pathways to nature connectedness which could contribute to pro-nature conservation behaviour (Richardson *et al.*, 2020), such as creating a garden with plants that will support hoverfly communities, joining conservation projects or simply enjoying nature outdoors are great learning tools that also bring associated benefits for people's health and wellbeing.

Messages about the importance of biodiversity and the environments on which it depends should be delivered in creative ways tailored to specific audiences. The general public should be informed about the beneficial roles hoverflies play in ecosystems (particularly in pollination and biological control), which will help in overcoming the lack of appreciation of these insects. Attention should be also given to specific activities that the public can engage in, specifically in urban areas, to create new habitats or preserve existing ones. Additionally, people should learn about threats affecting hoverfly diversity and how they can help to curb them. One way to accomplish this is to increase public engagement through citizen science projects dealing with hoverflies or their habitats (see Box 6). Such projects could involve the public in monitoring species or participating in conservation actions, directly affecting their knowledge, skills, and behaviour. Moreover, citizen science records of hoverflies could be extremely valuable for scientific research, as shown in a recent study on phenology of Danish hoverflies (Olsen *et al.*, 2020), where data collected by amateurs on 37 species of hoverflies were included in the analyses.

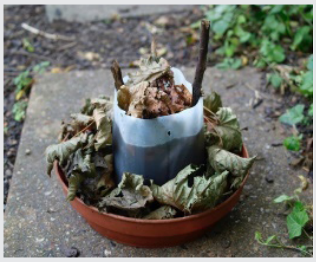
Importantly, those working in the fields of agriculture and forestry should have a good understanding of the vital ecosystem services that depend upon the conservation of biodiversity and be strong partners in safeguarding it. Working with conservationists, they can design and manage their systems to minimise the negative impacts on natural communities.

Box 6. The Hoverfly Lagoons Project: increasing public involvement in conservation efforts. By Dr. Ellen Rotheray.

Encouraging enthusiasts and the public to collect data on hoverfly distribution has long been practised in the UK. Since 1980, the British Hoverfly Recording Scheme members, supported by a small team of local advisors, have been tasked with collecting adult records, biological data, and information about immature stages. Digital technologies have made aiding and confirming the identification of adult hoverflies easier and more efficient. In 2013, a Facebook group was set up by Stuart Ball and Roger Morris, with a team of administrators, for identifying hoverflies from photographs sent in by its 5,400 members. Through this, more than 80,000 hoverfly records are now obtained every year. In 2015, the UK Hoverfly Larval Facebook group was founded, to focus on the immature stages of hoverflies. In the same year, a citizen science organisation, the Buzz Club (www.thebuzzclub.uk), came into being under the stewardship of Prof. Dave Goulson and his lab at the University of Sussex, with the aim of encouraging the public to take part in UK-wide experiments on garden pollinators. Tasked with designing experiments for the Buzz Club, the Hoverfly Lagoons project was born, so named to convey a more positive image for a small, stagnant, microbe-rich water body (essentially a container with decaying vegetation and rainwater). The idea was inspired by conservation management work for the Pine Hoverfly (see BOX 4.), which included designing artificial rot-holes using containers, most of which failed to attract the target species but were instead occupied by many other semi-aquatic hoverfly species occurring in Scotland. Six years on and the Hoverfly Lagoons project has:

- ✓ confirmed seven species utilising this artificial habitat in UK gardens;
- ✓ recorded up to 285 larvae per lagoon;
- ✓ documented population booms of *Syritta pipiens* in 2018 and 2020;
- ✓ encountered the previously unknown pupal stage of *Rhingia rostrata* (in press).



What's more, research investigating the utilisation of this micro-habitat has indicated a positive effect on local crop pollination (unpublished data). In terms of public engagement, the Facebook group has achieved a lot through encouraging its nearly 1000 members to look out for, identify and rear hoverfly larvae. The Hoverfly Lagoons project has raised awareness through a ripple effect in social media and blogs, attracting interest from news and gardening websites reaching as far as the United States and New Zealand. The project currently boasts 151 United Kingdom (UK) - wide volunteers collecting monthly data from May until October. With the related blog which facilitates engagement (www.hoverflylagoon.co.uk) and continued efforts to inspire through social media and the Facebook pages, citizen science involvement is steadily climbing, schools are becoming interested, and with new discoveries each year it's certainly proved its value.

GOAL 3: A CULTURAL SHIFT TOWARDS HOVERFLY-FRIENDLY ATTITUDES AND BEHAVIOURS

Achieved through:

- Specific training and guidance materials for land-users especially in agriculture and forestry (also hydrology and flood prevention management) and Protected Areas, covering hoverfly pollinator friendly practices.
- Elevated public recognition: of hoverflies (as distinct from other species); of their benefits as pollinators and biocontrol agents; of a broader range of their microhabitats; and of behaviours that support or damage them.
- A cultural shift to including, not competing with, biodiversity.
- Increased public involvement in local and regional conservation efforts.

GOAL 3: RECOMMENDATIONS

Some of the recommendations below are directed towards integrating hoverfly information and requirements into existing or planned pollinator guidance and materials, targeted at a range of landowner/manager sectors. These guidance documents and materials are considered a priority. In addition, there are recommendations aimed at generally elevating hoverfly awareness and knowledge among the public and education sectors, with examples of successful initiatives to encourage uptake.

3.1	GENERAL
Current or potential leads and collaborators	
■ EU Commission (through Pollinator Initiative); ■ National/local government agencies; NGOs involved with pollinators; biodiversity planning and implementation bodies; ■ NGO campaigning and advocacy organisations (e.g. Buglife & CPRE in UK, WWF); ■ HSG; entomological organisations; museums; Zoos and Zoo Associations (e.g. European Association of Zoos and Aquaria (EAZA) Terrestrial Invertebrate Taxon Advisory Group (TITAG); ■ Education organisations (schools, universities; field centres).	
Recommended action	
3.1.1	Use the EU pollinator public wiki[13] which lists current pollinator projects around the EU, searchable by education and awareness raising, to communicate projects and to find and connect to others working on awareness raising for pollinators.
3.1.2	Broaden EU Pollinators Initiative communication materials beyond (mainly) bees and butterflies to give appropriate space to hoverflies.
3.1.3	Capitalise on the value of hoverflies as a group that can provide useful advocates and indicators for a diversity of habitat types. Most habitats can be represented by hoverfly species.
3.2	SPECIFIC TRAINING AND GUIDANCE MATERIALS COVERING HOVERFLY-FRIENDLY PRACTICES, FOR LAND-USERS, ESPECIALLY IN AGRICULTURE, FORESTRY (ALSO HYDROLOGY AND FLOOD PREVENTION MANAGEMENT) AND PROTECTED AREAS

[13] https://wikis.ec.europa.eu/display/EUPKH/EU+Pollinator+Information+Hive

Current or potential leads and collaborators	
■ EU Commission (through Pollinator Initiative); ■ National and local government and non-government authorities responsible for managing forests, woodland, Protected Areas, agriculture and grazing (e.g. ONF (National Forests Office) in France); ■ National and local government agencies involved with pollinators; biodiversity planning and implementation bodies; ■ Natura 2000 Committees; ■ Bodiversity-focused agriculture organisations (e.g. FWAG, Farm Clusters & LNPs in the UK). ■ Research, data & advisory organisations (e.g. UNSPMF, HSG, CIEEM, entomological organisations, museums); ■ Non-government nature protection/management or advocacy organisations (e.g. Buglife, Woodland & Wildlife Trusts, Ancient Tree Forum, CPRE in the UK, CIEEM, Zoos and Zoo Associations e.g. European Association of Zoos and Aquaria (EAZA) Terrestrial Invertebrate Taxon Advisory Group (TITAG)). ■ Organisations with an interest in veteran trees (e.g. HSG, Lichen SG, Mollusc SG, IUCN Veteran Tree Task Force, UK Ancient Tree Forum); ■ Education organisations (schools, universities; field centres).	
Recommended action	
3.2.1	**EU Pollinator and Biodiversity Guidance** documents for national governments and local authorities and for the forestry, agriculture and nature protection sectors and agencies, include a dedicated section on **identifying, protecting and managing PHAs.**
3.2.2	**EU Pollinator Guidance documents** for national governments, local authorities, forestry, agriculture, nature protection and urban & rural development sectors, include sections on **protecting, restoring, and establishing microhabitats for hoverflies**, emphasising those of most importance to species identified as threatened.
3.2.3	**EU Pollinator Guidance documents** for agencies responsible for large grazing complexes, include a section promoting the identification, **protection and management of remnant habitat patches** (i.e. small refugia such as woodland sites within grassland-dominated landscapes) that are important for hoverflies.
3.2.4	**Ensure EU Pollinator Guidance** documents for national governments, local authorities, forestry, agriculture, and nature protection, promote **planning for habitat diversity at the landscape scale** (i.e. across multiple systems) and emphasise the **protection, restoration and establishment of habitat mosaics, ecotones and connectivity**.
3.2.5	**Provide EU guidance to PAs** on risks to other pollinators from honeybees including recommendations on the number and distance between beehives.
3.2.6	Survey PA managers to measure the extent of their awareness of and access to guidance on identifying, managing and protecting key micro-habitats for both larval and adult hoverflies, e.g. including translations. Act on the results.
3.3	ELEVATED PUBLIC RECOGNITION: OF HOVERFLIES (AS DISTINCT FROM OTHER SPECIES); OF THEIR BENEFITS AS POLLINATORS AND BIOCONTROL AGENTS; OF A BROADER RANGE OF THEIR MICROHABITATS; AND OF BEHAVIOURS THAT SUPPORT OR DAMAGE THEM
Current or potential leads and collaborators	
■ EU Commission and IUCN social media channels; HSG; EU Pollinator Initiative; ■ UNSPMF (as part of the European Commission financed SPRING project); NGOs working on pollinator projects; conservation-directed farm partnerships (e.g. UK LNPs, Farm Clusters); ■ Government agencies (agriculture, grazing, forestry, Protected Areas, conservation); ■ Research and data organisations; academia (schools, universities, colleges); NGO landowners/managers; Protected Area/landscape managers; media organisations; businesses (e.g. food retail); ■ Educational organisations e.g. UK Field Studies Council, Naturalist Associations; NGO campaigning organisations (e.g. Buglife); Online Facebook Groups (e.g. UK Hoverfly Facebook Group); natural history museums, National Biodiversity Networks.	
Recommended action	

3.3.1	Mount an EU Pollinator Initiative communication campaign to highlight the distinction between hoverflies and other pollinators, targeting the pollinator scientific community, policy makers, forestry and agriculture, schools and journalists, and illustrating the importance of a range of hoverfly microhabitats, communicating the major threats faced by species occupying them and behaviours that support or damage them.
3.3.2	Provide a series of illustrated national guides in storytelling form and in several native languages, with information about various hoverfly genera found in those countries, their habitats and the ecosystem services they provide.
3.3.3	Promotion of hoverflies using hashtag **#HoverflyRevolution** in all hoverfly-related posts on social networks.
3.3.4	Raise knowledge about hoverflies and their significance through formal and informal education, at all levels, through curriculum – relevant materials covering: ■ how hoverflies are integral to our health; ■ case studies using hoverflies to teach people about how nature works; how we have an impact on nature (using hoverflies as an example).
3.3.5	Develop and implement school and adult-learning curricula to raise awareness of the ecological importance of habitat heterogeneity, specifically focusing on the relationship between hoverfly species diversity and quality and quantity of natural habitats.
3.4	A CULTURAL SHIFT TO INCLUDING, NOT COMPETING WITH, BIODIVERSITY
Current or potential leads and collaborators ■ Government agencies; regional/local policy makers and implementers; conservation-directed farm partnerships and forums (e.g. LNP and Farm clusters); NGO landowners/managers; Protected Areas/ Landscape managers; ■ Government agencies; relevant networks/forums e.g. UK Ecosystem Services Network, Farm Clusters, National Biodiversity Networks; ■ Universities and other research organisations with citizen science programmes; ■ Field centres, natural history museums, zoos and zoo associations (e.g. EAZA TITAG).	
Recommended action	
3.4.1	Enhance opportunities for nature experiences and for making nature's value visible, by organising virtual field trips. (e.g. for the general public, community-based organisations, city planners, infrastructure providers etc.).
3.4.2	Demonstrate biodiversity value in qualitative and quantitative terms and draw attention to the ecosystem services hoverflies provide (e.g. especially in agriculture).
3.4.3	Increase public willingness to act for biodiversity protection on a regional level by encouraging their participation in regional citizen science projects which bring science and the public closer together.
3.4.4	Ensure PA visitors understand behaviours that are good or bad for nature (specifically hoverflies) at that site. Provide tourist brochures and information boards at the entrance of PAs, or where researchers are working, displaying information about threats and pro-environmental behaviours (see Box 7).

BOX 7. Example: public information panel displayed by researchers at a field site

Insect research on Hoverflies (Diptera, Syrphidae)

- Hoverflies are important pollinators of agricultural crops and wild plants.
- They are declining rapidly due to intensification of agriculture, extensive bee-keeping, extreme weather, habitat loss due to dam-building, overgrazing and other human impacts.
- This loss will pose a threat to the survival of individual species but also to ecosystems and eventually to agricultural crops.
- Our research here is increasing knowledge of the habitat and habits of these species, of species composition, and of possible threats to them.

Helophilus trivittatus (Fabricius, 1805).

Sphiximorpha petronillae Rondani, 1860.

Brachyopa maculipennis Thompson, 1980.

Callicera macquarti Rondani, 1844.

Syrphidae in trees (SIT) is hosting the Syrphidae Foundation.
Donations for protection of the species are welcome.

For more information: https://www.syrphidaeintrees.com/syrphidae-foundation/

4

4. PESTICIDES AND NITROGEN

4.1 INTRODUCTION

The known and assumed damage to hoverflies from widespread pesticide and fertiliser use is reported in GOAL 2 and the text section that precedes it, which describes factors influencing the loss and degradation of hoverfly larval microhabitats. More detail about this is provided below.

Reshaping the culture of pesticide and fertiliser use across Europe will require significant changes to policy and to economic incentives at the EU and national levels, as well as to management principles, priorities, and methods at the level of individual sites. It will have significant implications for the agriculture and forestry sectors, as well as for the management of Natura 2000 sites and other legally protected areas. Much of this is beyond the scope of this plan, which is focused on the specific needs of hoverflies, and especially on species recently assessed as threatened. Nevertheless, the topic is included here because the issues described have such a huge impact on the future of hoverflies in Europe that their absence would have left an obvious gap.

4.2 CHALLENGES

4.2.1 FERTILISERS AND EXCESS NUTRIENT INPUT

Many hoverfly habitats, especially of rarer or threatened species, are dependent on low to medium nutrient levels. This is especially true for most open, species-rich grassland habitats, for all heathland habitats and for oligo- to mesotrophic waterbodies and all bog systems.

Excess nutrient input can result from any kind of fertiliser. Today, these are usually nitrate or ammonium based, applied either directly or transported by wind, soil erosion or surface water, from adjacent crops or intensive grasslands to the species rich semi-natural open habitats. In addition to fertiliser input, in many regions of Europe, quite high concentrations of nitrogen come from aerial deposition, both as nitrogen oxide (NOx) from combustion, cars, heating etc., and as ammonia (NH_3), mainly from intensive agriculture, through fertiliser use and intensive animal rearing. Both NOx and ammonia have direct toxic effects on plants and animals, but the main threat comes from a change in the dynamics of plant growth and competition (see Box 8 below), with nitrogen deposition causing faster growth of plants and trees, speeding up vegetational succession and resulting in loss of plant diversity.

The critical load of nitrogen is the level of nitrogen input which still allows for continuity of the habitat without degradation, species loss or eventual loss of area. For many habitats including their typical hoverfly species, critical loads of nitrogen are relatively well known and range between 10 - 20 kg of nitrogen per hectare per year. However, there are large regions in Europe which exceed these loads by 20 to 40 kg/ha/yr, leading to rapid degradation and loss of plant species, which is detrimental to specialised phytophagous hoverfly groups such as *Cheilosia*, *Merodon* and *Eumerus*, as well as more specialised zoophagous groups. In addition, the groups associated with ant nests disappear (*Chrysotoxum*, *Xanthogramma*, *Microdon*) and all rare or threatened aquatic hoverfly groups which need oligo- to mesotrophic water conditions are affected, for example bog species like *Parhelophilus consimilis*, *Orthonevra*, and many *Neoacia* and *Melanogaster*-species. Even some eutrophic wetland habitats suffer from excess nutrients.

Box 8. The impacts of excess fertiliser and nitrogen deposition on important habitats for threatened hoverflies. By Axel Ssymank.

Fertiliser in grasslands accelerates growth of dominant grasses, making them more competitive and leading to early mowing. As a result, less competitive herbs slowly vanish, and late-flowering herbs are unable to produce seeds. The resulting change, from a flowering meadow to a pure grass crop, or from high to low diversity grassland (e.g. from 40 - 60 plant species per 100 m^2 to only 15 - 20 species), results in a major loss of flower resources for adult hoverflies, a shortening of the flowering period, and the loss of plant species needed by phytophagous larvae, or those that support the aphid species suitable for the zoophagous larvae of specialised hoverflies such as *Leucozona* species.

While the degradation caused by low fertiliser inputs can be gradual and slow, high fertiliser loads can destroy the original habitat completely. Restoration is then difficult and can take several decades.

Many habitats of specialised (and threatened) hoverflies, such as heathland habitats and bogs, need medium to very low nutrient levels and are often already heavily influenced by airborne nitrogen deposition (nitrate and ammonium) which can be higher than their critical loads, and in some cases even beyond the limit where management with grazing or mowing can compensate. Taking measures to reduce nutrient inputs is therefore essential, particularly in these more sensitive areas.

4.2.2 PESTICIDES

The potential effects of pesticides on hoverflies include impaired reproduction, fewer egg-laying sites, altered foraging patterns or success, reduced prey availability for larvae with zoophagous feeding traits, increased disease and parasite susceptibility, source-sink effects (landscape-scale population and community effects), trophic interaction effects and ecosystem services effects (Uhl & Brühl, 2019). Some pesticides can also affect the nitrogen-fixing capabilities of the leguminous plants used to reduce reliance on synthetic nitrogen fertilisers (Fox *et al*., 2007), the over-use of which is another challenge to hoverflies (see above) (though noting that planting or sowing nitrogen-fixing legumes can negatively contribute to excess nitrogen in low nutrient ecosystems (Ssymank, pers. comm.)).

Studies on pesticide residue levels in individuals of flower visiting insects is currently only available for bees, and mostly honeybees. While such studies have concentrated largely on neonicotinoids, honeybees contain levels of all the major classes of pesticides and multiple compounds have been found in different bumblebee species, as well as in many bumblebee individuals. However, there is almost no information on pesticide effects on non-bee groups of flower-visiting insects (Uhl & Brühl, 2019). However, the assumption that pesticides are one of the major players in hoverfly decline is supported by data showing extremely high pesticide residues in some protected areas in NW-Germany (Buijs & Mantingh, 2020) in locations where Hallmann *et al*., (2017) found dramatic insect declines including those of hoverflies.

Use of pesticides is widespread. As a result of direct application to crops, unintentional redirection into adjacent non-target areas (e.g. field edge structures, managed flower strips etc.), and exposure of air space, pollen and nectar, stem and leaves, soil and water sources, pesticides can contaminate many of the habitats of flower-visiting insects in the agricultural landscape (Simon-Delso *et al*., 2017; Uhl & Brühl, 2019). In some regions pesticides were found to carry up to 10 km away from agricultural land, on the wind (Buijs & Mantingh, 2020).

Forestry practices include the use of helicopter treatments to remove oak processionary caterpillar, gypsy moth and other species considered pests, for example in pine plantations. Though this is usually forbidden, it is possible to get special permits (Ssymank pers. comm.) The extent of application allowed is more restricted in forestry than it is in agriculture, where there are no such rules.

Seed coatings (containing pesticides) applied in one area dissolve and wear off into the soil, then move into adjacent wetlands or rivers, affecting aquatic larvae. Pesticides are also directly added to water bodies to prevent mosquitos from hatching. These pesticides are strong and can be lethal to a diversity of species.

Photo: application of Reslin (a pyrethroid insecticide) against mosquitoes on a football field close to Olomouc in the Czech Republic. The insecticide cloud moves under the tree canopy and into the protected area, exterminating both mosquitoes and other flying insects, more than 400 m from the place of application (Credit: Libor Mazánek)

In south-eastern Netherlands, good-quality forests occur in the valleys, but above them, large areas are used for agriculture, which uses a lot of pesticides. Agricultural run-off into forest habitats is causing degradation and loss of ground-layer microhabitats. Here, sensitive species are unable to survive and the forest floor is dominated by nettles (*Urtica* sp.), which are difficult to remove. It is possible that throughout Europe, many such places carry 50% or fewer of their original complement of hoverfly species (Van Steenis, pers. comm.) The run-off also damages the springs and streams in those valleys and most waterbodies will suffer from nutrients and pesticides that arrive either through run-off or through aerial spraying from surrounding agricultural land. In Bavaria, studies involving butterflies have shown that on the southern slopes of river valleys, warm winds carry pesticides to high meadows from the valley bottom (Habel *et al.*, 2016).

Insects themselves can carry pesticides deposited in one area across into neighbouring areas and there are many examples of this. Dry meadows used to be continuous in valleys but are now in patches in between crop fields. Pollinators flying out of these patches are sprayed, and carry the pesticide back into the patch before dying. Similarly, bees can nest in the soil of ploughed fields, moving back-and-forth from there to feed from flowers. Their typical foraging distance is 200-3000m, while most native pollinators usually need their floral resources within less than 500m distance (W. van Steenis, pers. comm.), providing an indication of the size of buffer zone required around sensitive areas to keep them free of pesticides. Current buffer-zone requirements are not adequate. In the EU, farmers are not allowed to spray within 10 m or 50 m of water bodies, but this will not prevent pesticide spread by insects.

As of 10 December 2021, there are 454 different pesticides approved for use in the European Union. We know very little about the effects of single pesticides on insects, and the combined effects of low levels of several pesticides are not studied at all. Other important gaps include: whether and which types of agriculture are important sources of pesticide pollution; the scale of pesticide accumulation in the environment, in the prey and food species of larval hoverflies, and in the different life-stages of hoverflies; the scale and nature of the impact of pesticides on hoverfly populations; and the potential differences between the various types of pesticides and their occurrence in protected versus non-protected areas, different countries, geographic regions or areas.

NATURA 2000 SITES

Within Natura 2000 sites all Annex 1 Habitat sites are strictly protected such that no degradation of quality is allowed. However, there are often crops within and adjacent to the Natura 2000 site, from which pesticides and nitrogen deposits can spread, causing slow degradation.

4.3 OPPORTUNITIES

4.3.1 INTEGRATED PEST MANAGEMENT

According to the US Environment Protection Agency, Integrated Pest Management (IPM), "…is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life-cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment. The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, organic food production applies many of the same concepts as IPM but limits the use of pesticides to those produced from natural sources, as opposed to synthetic chemicals".

4.3.2 INCREASING KNOWLEDGE ABOUT PESTICIDE IMPACTS

Currently there are large-scale research projects, Diversity of Insects in Nature Protected Areas (DINA), being carried out in Germany using numerous Malaise-trap transects from intensive crops into nature conservation areas, to analyse insect decline and pesticide accumulation from adjacent areas. All insects will be deoxyribonucleic acid (DNA) meta-barcoded, and thus this will also give valuable data on hoverflies.

4.4 GOALS AND RECOMMENDATIONS

GOAL 4: PROTECTED AREAS FREE OF TOXIC SUBSTANCES AND BETTER RULES FOR THEIR APPLICATION OUTSIDE

Specifically:

- Pesticides and harmful fertilisers in sprays and seed coatings are phased out inside and around sensitive areas.
- Pesticide use is rare and carefully targeted; it is not applied as a precaution; and the harmful effects of nitrogen deposition from all sources, everywhere, is significantly reduced.
- Integrated Pest Management is the default method for managing pests outside protected areas.

GOAL 4: RECOMMENDATIONS

The recommendations below, the result of a brainstorm of ideas during the 2020 workshop, refer to some of the EU initiatives that could lead to transformative change in this area, and identify some additional areas for work or development that would support hoverflies more specifically. See also recommendations in GOAL 2.

4.1	PESTICIDES AND HARMFUL FERTILISERS IN SPRAYS AND SEED COATINGS ARE PHASED OUT INSIDE AND AROUND SENSITIVE AREAS;

Current or potential leads and collaborators

- European Parliament (pesticide policy);
- National governments (pesticide policy);
- Government agencies (including science & research);
- Agricultural boards;
- NGO landowners/managers (particularly agricultural land owners/managers);
- Health and safety regulators;
- Protected Area/Landscape managers;
- Natura 2000 site committees and managers.

Recommended action	
4.1.1	Ban pesticides and seed coatings from sensitive protected areas (e.g., Natura 2000 sites).
4.1.2	Ensure that the test for admission of pesticides and seed coatings to the market considers long-term effects within semi-natural ecosystems and is based on the most sensitive organism groups (Currently these tests investigate only direct, immediate toxicity such as Lethal Doses, and ignore long-term effects in ecosystems, such as disorientation and subsequent death of pollinators by neonicotinoids. For hoverflies, only *Episyrphus balteatus*, a very quickly reproducing species, with low sensitivity to toxic substances, is tested).
4.1.3	Ensure sensitive areas and PAs are surrounded by buffer zones of adequate size, in which there is no use of pesticides in either sprays or seed coatings, or via Genetically Modified Organisms producing toxins themselves (note: the EC SUR Proposal is relevant to this).
4.1.4	Ensure strong provisions for prohibiting the use of pesticides in ecologically sensitive areas in the EU law, building on the Commission's proposal for a Regulation on the sustainable use of plant protection products[14].
4.2	PESTICIDE USE IS RARE AND CAREFULLY TARGETED; IT IS NOT APPLIED AS A PRECAUTION; AND THE HARMFUL EFFECTS OF NITROGEN DEPOSITION FROM ALL SOURCES, EVERYWHERE, IS SIGNIFICANTLY REDUCED;
Current or potential leads and collaborators ■ European Commission; ■ European Food Safety Authority; ■ European Parliament; ■ National & local governments; ■ Health and safety regulators; ■ NGO campaigning organisations; ■ Research and data organisations; ■ Biodiversity-supporting farm partnerships and forums (e.g. UK LNPS and Farm Clusters, Organic Farmers and Growers, Linking Environment and Farming (LEAF)); ■ Innovative agriculture-focused organisations (e.g. Organic Research Centre, Koppert Biological Systems, UK ADHB & FWAG); ■ NGO landowners/managers; ■ Protected Area managers; ■ National Biodiversity Networks.	
4.2.1	Extend the prohibition of pesticides that is already in place in some States.
4.2.2	Eliminate EU subsidies for pesticides and fertilisers.
4.2.3	Advocate for changes in economic incentives to:
	■ encourage use of crop varieties bred for resilience to certain pests to reduce reliance on pesticides;
	■ prevent application of pesticides or seed-coatings on more than 50% of the production surface per year without exceptions, to allow for insect population recovery, and only if no toxic residues from previous years remain on the fields;
	■ only allow pesticides and seed-coatings which are fully biodegradable and will leave no residues after one year;
	■ transition to agricultural systems that use fewer pesticides or harmful fertilisers while maintaining productivity (e.g. organic farming and Farming with Alternative Pollinators (FAP));
	■ protect and encourage semi-natural structures such as hedgerows to help filter out nitrogen influences, and other strategies to limit run-off and aerial dispersal.
4.2.4	Create buffer zones of sufficient size (500 m - 3km) to protect sensitive areas from excess nitrogen deposition, pesticides and seed coatings (see EU Biodiversity Strategy and Pollinator Action Plan for information).
4.2.5	Reduce atmospheric nitric oxide (NOx) originating from combustion (heating, cars etc.), and atmospheric ammonium, originating mainly from fertilisers and livestock breeding.
4.2.6	For oligotrophic habitats (bogs, heathland, many types of species rich grasslands etc.), ensure that total nitrogen input is well below their specific critical loads for nitrogen and below critical levels for ammonium.
4.2.7	Promote integrated pest management as the default method for managing pests outside Protected Areas:

[14] https://food.ec.europa.eu/system/files/2022-06/pesticides_sud_eval_2022_reg_2022-305_en.pdf

	■ Use a combination of techniques such as biological control (e.g. aphidophagous hoverflies), habitat manipulation, modification of cultural practices, and resistant varieties;
	■ use pesticides only after monitoring indicates they are needed according to established guidelines;
	■ treat with the goal of removing only the target organism;
	■ Select and apply pest control materials in a manner that minimises risks to human health, beneficial and non-target organisms, and the environment.

5. GAPS IN POLICY SUPPORT FOR HOVERFLIES

5.1 INTRODUCTION

Hoverflies are rarely explicitly considered in government policies and, where included under the broad banner of "pollinators", their specific needs are often not adequately addressed.

5.2 CHALLENGES

5.2.1 POTENTIAL UNDERESTIMATION OF HOVERFLY POPULATION DECLINES AND ENDANGERMENT

Insect declines in Europe have been widespread and dramatic in the recent past (see Box 9.) Recent studies in Germany (Ssymank *et al.*, 2021) and the Netherlands (Barendregt *et al.*, 2022) show declines of 80% in species numbers over the past 30 or 40 years. This pattern is also noted in Belgium (see the Red List, Flanders) and England (Ball & Morris, pers. comm.). Note that in the Netherlands, most of the species involved have zoophagous larval feeding traits.

BOX 9. Insect decline and hoverflies. By Axel Ssymank.

The decline of insects is not new and has been documented in many national and regional red lists. However, the coverage of insect groups has often been incomplete, with the declines of butterflies and deadwood beetles often better documented than flies. The Entomological Society Krefeld, in Germany, has been collecting data for over 30 years, mainly in North Rhine Westfalia, with a precisely defined, standardised Malaise trap method (Ssymank *et al.*, 2018), which has allowed the statistical calculation of trends in comparison with historical material. Hallmann *et al.* (2017) calculated a decline of more than 75% in only 27 years in the biomass of flying insects, based on material collected in the middle of protected areas, the majority being EU Natura 2000 sites. This was the starting point for global awareness of insect decline and political debate. The study was able to exclude changes in land management, vegetation, and climate as possible reasons, because of excellent vegetation and photo documentation, even of the historic traps. Looking into the detail, the declines have not resulted from the loss of one group of large insects, because the analysis showed similarly high rates of decline in different insect groups, independent of body size. Hoverflies from traps were analysed in a case study of the Wahnbachtal river area, to illustrate the close relationship between general insect biomass decline, abundance, and species richness. Eighty-nine percent fewer hoverflies were present, and local loss of species diversity was 23%, between 1989 - 2014 (Hallmann *et al.*, 2021). Moreover, hoverfly species with an average frequency of occurrence showed unexpectedly high rates of decline, which means that many currently Near Threatened or still Least Concern species are on the verge of becoming Vulnerable, Endangered or Critically Endangered. Still unpublished analyses show that species groups connected to aquatic habitats, or that have contact with soil as larvae, are at higher risk. At species level there can be large differences, even between closely related species. For example, *Pyrophaena granditarsa* was abundant in the historical material but is now presumed extinct locally, while *P. rosarum* is much less affected, with relatively low rates of decline. Additional studies from southern Germany on migrating hoverflies show a 90% decline over the past 50 years (Gatter *et al.*, 2020), confirming that hoverfly decline is not only a regional phenomenon. Further, recent data on pesticide residues in the protected areas of the Hallmann-study reveal toxic concentrations of a mix of pesticides at all these sites (Buijs & Mantingh, 2020) implicating this as a potential causal factor.

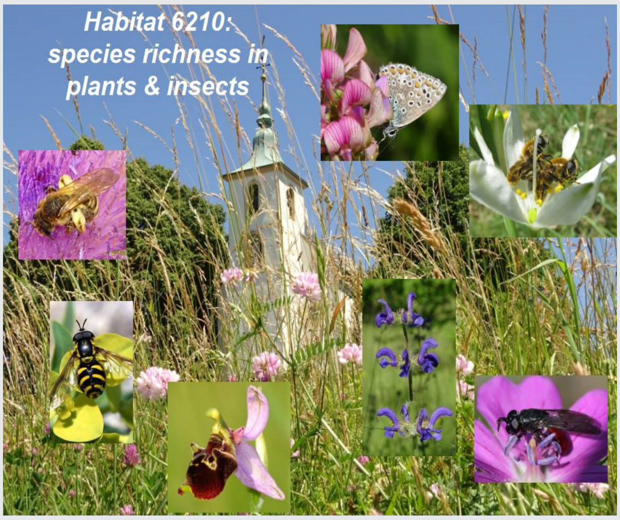
Many of the affected species have been picked up through the Red List assessment process and classified as threatened, but not all. Hoverfly Assess to Plan (A2P) workshop participants noted that a recent, dramatic decline is one of the criteria that can qualify a species for a threatened category. However, the decline must have occurred in the immediate past, defined as a period of three generations or 10 years, whichever is the longer. As a result, there are several shorter-lived hoverfly species categorised as Near Threatened or Least Concern, despite significant recent declines and current occupation of only a fraction of former range. These species also need conservation action. Should the recently observed declines continue in larger parts of Europe, many of the species now assessed as Least Concern would become Near Threatened, Vulnerable, or even more severely under threat at a European level. Identifying these species and targeting them for action alongside threatened taxa with which they overlap in distribution and specific conservation needs, would be an efficient way to reverse declines and prevent them from moving into a threat category in future.

5.2.2 INSUFFICIENT KNOWLEDGE TO CARE FOR HOVERFLIES AT SITE LEVEL

Whether driven through EU, national or local policy measures, what happens for hoverflies will be heavily dependent on-site management practices and success there can only be achieved through attention to habitat-typical species (see Box 10 below).

BOX 10. Example of the complexities of hoverfly conservation in dry calcareous grasslands (EU Habitat 6210). By A. Ssymank.

Dry calcareous grasslands belong to the most species-rich protected habitats in the continental biogeographic region. They support up to 100 plant species per 100 m² and in Germany alone include around 250 typical plant species and well over 1,000 typical insect species (Ssymank *et al.*, in prep). They are perhaps best known for their orchids but focusing management on these alone risks losing much of the insect diversity. Typical and threatened hoverfly species of these dry grasslands do not rely only on the rich flower buffet but also have specific larval habitat requirements. For example, the larvae of *Eumerus tricolor* and *Merodon rufus* are phytophagous, feeding on bulbs and rhizomes of specific host plants, of which a minimum density is required to sustain populations. Meanwhile, *Microdon devius* larvae live in ant nests, feeding on ant broods, like the well-known Blue Butterflies (*Maculinea* spp.). Many of the typical zoophagous species of the genera *Chrysotoxum* and *Xanthogramma* live on root aphids partly tended by ants, and rely on ant nests.



To support these diverse hoverfly needs, good management of dry, calcareous grasslands:

1) **combines sympathetic mowing practices and/or low-density grazing with little or no fertiliser use, to maintain ant populations and a diversity of plant life including both low growing and late flowering species;**

2) **supports spatial and temporal mosaics of all management measures, to sustain refuges for immature life-stages and an ongoing supply of nectar and pollen for adults.**

There is often insufficient knowledge of the needs of individual species to do this. This knowledge must be expanded, through provision of information materials to site managers. This is currently missing from most EU Member States and other European nations. Recommendations for the types of guidance needed are included under GOAL 3.

5.2.3 EU COMMON AGRICULTURAL POLICY

The EU Common Agricultural Policy provides a range of subsidies, some intended to support species such as hoverflies. In some cases, these are not sufficiently informed by species' biology and as a result can have the opposite effect to that intended. Similarly, though the EU Farm to Fork Strategy[15] includes important areas for attention, it does not necessarily go far enough in its advice to create the desired effect for species such as hoverflies. Some examples of these challenges are described in previous sections.

5.3 OPPORTUNITIES

5.3.1 THE EU HABITATS DIRECTIVE

Under the Habitats Directive there are two broad routes though which species at risk can be effectively conserved. One is by listing them on Annexes II or IV, which triggers an obligation to protect them either at certain sites (Annex II species within Natura 2000 sites) or more broadly (Annex IV, strictly protected species wherever they occur), as well as an obligation to monitor and report on their status at regular intervals to demonstrate there has been no deterioration in condition. Currently no bees or hoverflies are listed on these Annexes. However, a recent fitness check of the Birds and Habitats Directives[16] concluded that this omission does not constitute a serious obstacle to achieving the Directives' general objectives. Furthermore, amending the Annexes of species and habitats that are triggers for the selection of Natura 2000 sites could have significant implications for the configuration of the network and is not recommended at this time.

The second route through which species at risk can be protected, is by listing the taxa as typical of one or more of the habitats at risk that are listed on Annex I. Monitoring of those habitats should then incorporate monitoring of associated typical species, and the management of those habitats should include measures to support healthy populations of those associated typical species.

Some hoverflies are already included as typical species of Annex I habitats and so receive attention through this route. More could be added and there is value in doing so for a select group with good bioindicator properties.

5.3.2 SUBSIDIES AND INCENTIVES

The EU Common Agricultural Policy (CAP) has the potential to provide a mechanism and incentives for agriculture to be a biodiversity producer. For example, farmers can currently receive money from the EU for setting aside flower strips which are potentially beneficial to hoverflies. Unfortunately, CAP currently promotes annual measures and so these strips can be moved or ploughed over in year two, which destroys their longer-term value and helps common species but not rarer ones. If funding were contingent on a more permanent life for these strips (at least 2 - 3 years), their value could be significantly increased.

In the UK, Brexit may provide an opportunity to change the way that Common Agricultural Policy (CAP) farming subsidies work. A recent 25-year environment plan and associated legislation plan includes payments to farmers for taking action that benefits the environment, through a type of biodiversity restoration. These work through the adoption of a principle called, "no net loss of natural capital", that is incorporated into planning processes for land management. There are subsidies for public good and for the adoption of this natural capital principle. This will be a positive change for the UK with potential benefits for hoverflies, and it would be valuable to have similar changes at the EU level. In addition, there is a big trend towards rewilding areas of land, including many former farms, and this can be very helpful for hoverfly conservation by kick-starting the process of creating more space for nature and more connections between natural areas across the landscape.

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[15] https://ec.europa.eu/food/farm2fork_en

[16] https://ec.europa.eu/environment/nature/legislation/fitness_check/docs/nature_fitness_check.pdf

5.3.3 NATIONAL POLICY FRAMEWORKS FOR SPECIES

Individual nations have a key role to play in supporting hoverfly conservation through national policy frameworks, supporting and acting on key research. In Serbia, there are some 30 - 40 species on the strictly protected list and 40 on the protected list. This is the only country in Europe that has this, along with three sites protected just for hoverflies. Lessons learned from the Serbian model could be extended to other nations across Europe. Further details are provided in Box 11.

BOX 11: Serbia: a Champion for Hoverflies in Europe.
By Ante Vujić, Marija Miličić and Marina Janković.

Intensive hoverfly research in Serbia starting from the mid-20th century provided ample information about the distribution and diversity of this insect group throughout the country, with 418 species recorded. A combination of traditional taxonomic approaches and integrative taxonomy in recent years has helped reveal the hidden diversity of this Dipteran family. Thanks to this, and to continuous monitoring from 2005, today more than 65,000 hoverfly occurrence records exist for Serbia.

The foundation for legal protection of hoverflies in Serbia was set by the passing of the Law on Nature Protection in 2009. This document represents the framework for the legal protection of species and their habitats. The Rulebook on the proclamation and protection of strictly protected and protected wild species of plants, animals and fungi is the by-law which regulates in detail the legal protection of species and habitats. A panel of experts for each group of organisms listed in the Rulebook was gathered prior to passing the by-law and the result of their work is 2,633 strictly protected wild species listed in Appendix I of the Rulebook, and 860 protected wild species listed in Appendix II. The significance of hoverflies as biodiversity components was recognized through the inclusion of 33 species on the list of strictly protected species, and 44 species as protected in the mentioned Appendices. The revision of the Rulebook is currently in progress and the list of strictly protected and protected hoverfly species will be broadened by the addition of 130 species.

Through the nationally financed project 'Conservation strategy for protection of hoverflies (Insecta: Diptera: Syrphidae) in Serbia' (running from 2010-2020), Prime Hoverfly Areas (PHA) were defined based on the presence of hoverfly species of conservation interest detected in these areas. Originally, 38 areas were designated as PHAs, while recently 7 additional areas were proposed for addition to the list. A significant number of these areas are already part of the Protected Area network in Serbia, while the rest will be proposed for protection in the future based on their significance for hoverflies. Additionally, three habitats in Serbia were already legally protected because they represent significant habitats for hoverflies.

These examples are a testimony to the significance of hoverflies from both economic and ecological perspectives, but also a reminder that continued research is the only way to establish the basis for their conservation.

5.3.4 EU POLLINATORS INITIATIVE: GUIDANCE DOCUMENTS FOR BIOINDICATOR SPECIES

It would not be practical or efficient to attempt to provide management guidance for all species, or even for all threatened species of hoverfly. However, materials could be developed for a carefully selected subset of hoverfly taxa whose effective management at sites will contribute to securing good conditions for other species reliant on the same habitat features. These species could be targets for monitoring and their presence used as a proxy indicator for others.

Due to their diverse array of specific needs, hoverflies are good candidates for signalling specific qualities of different habitats. For example, there are hoverflies that are intimately associated with the sap-runs typical of wounded trees in old forests, so their presence there can be an astute indicator of forest management practices (e.g. *Brachyopa*, *Sphiximorpha* and *Myolepta* species). Similarly, *Spilomyia* is a tree-hole species. *Populus tremula* (Aspen), a softwood pioneer species, is often eliminated from forests but is key to the persistence of some species and has specific hoverflies associated with it that will signal its presence (*Hammerschmidtia ferruginea*). *Sphiximorpha* *petronillae* is a good example of an indicator species, as on the single tree where it was found in Serbia there were also *Brachyopa grunewaldensis*, *Brachypalpus* (undescribed species), *Criorhina floccosa*, *C. pachymera*, *Psilota atra* and *Sphiximorpha subsessilis* (see Van Steenis *et al.*, 2019). *Sphegina* and *Riponnensia* species require semi-aquatic conditions and there are wetland species that can signal upwellings in grassland (i.e. *Orthonevra elegans*). See Boxes 11 and 12 for details of potential indicatospecies.

Box 12. Potential indicator of forestry management practice #1: Sphiximorpha petronillae - associated with sap-runs.
By Jeroen van Steenis (From: Steenis *et al.* 2016; Steenis *et al.* 2019; Aracil *et al.* 2021.)

Habitat. Thermophilous forests with clearings containing old senescent trees, mainly *Quercus cerris*, *Q. pubescens* and *Q. frainetto,* and humid *Castanea*-*Laurus*-*Quercus* forest.

Larval habitat. Sap-runs on *Quercus* trees in association with the European velvety tree ant (*Liometopum microcephalum* (Panzer, 1798)). Larvae have not been found but there are records of females ovipositing near sap-runs on these trees.

Adults. Rarely found visiting flowers. Males sit motionless for hours on tree trunks with sap-runs. Females are seen ovipositing in cracks in the bark some distance from the actual sap-run and the ants tend to walk close to the sap-run.

Accompanying species. On a single tree in Novi Sad, Serbia, the following accompanying saproxylic hoverfly species were found: *Brachyopa bicolor*, *B. grunewaldensis*, *B. insensilis*, *Brachypalpus* new species, *B. valgus*, *Criorhina floccosa*, *C. pachymera*, *Psilota anthracina* and *Sphiximorpha subsessilis*. Also, within the same area: *Brachyopa silviae*, *Brachypalpus laphriformis* and *Ferdinandea cuprea*.

Causes:

1) **Forestry practice.** Timber logging is the primary cause of habitat loss. Also, overprotective measures in city parks or around footpaths and open areas in the forest, such as using tree pruning sealer on trimmed trees.
2) **Tourism and leisure.** Much of the remaining suitable forest is near urbanised areas, in forest parks that are less affected by the normal forestry practice of clearcutting. However, here there is a tendency to remove dead wood and senescent trees to minimise the possibility of harm to people. Mowing meadows rigorously and even using herbicides or pesticides are other examples of threats.

Solutions: protect remaining forests and support the retention of senescent trees and their features in forestry practice. Protect areas from pesticides.

Further research is required: to establish the true relationship between sap-runs, and trees with the European velvety tree ant and the ant hunter wasp (*Tracheliodes curvitarsus*). Investigate all areas in which these two species have been found, to see whether *Sphiximorpha petronillae* is also present.

Main threat: habitat loss. **Below: *Sphiximorpha petronillae*, female egg laying behaviour, Novi Sad, Serbia. With two workers of the European Velvety tree ant on the right. Photo: Jeroen van Steenis**

Box 13. Potential indicator of forestry management practice #2: *Spilomyia diophthalma* – associated with rot-holes. By Jeroen van Steenis (from: Steenis, 2000, 2016; Pennards, 2021).

Habitat. Mixed coniferous, *Abies*-*Picea* and deciduous forest, *Tilia*-*Quercus*-*Fraxinus* with overmature trees.

Larval habitat. Females have been collected near rot-holes in living *Populus tremula*. Larvae of other species of this genus are found in rot holes in deciduous trees indicating that this species is also dependent on these rot-holes.

Adults. Frequently visiting flowers, especially large umbellifers. They also settle on foliage and tree trunks. Males exhibit territorial behaviour when visiting flowers, and females have been caught in traps on dead *Populus tremula*.

Accompanying species. In Sweden, the following saproxylic species were found in the same forest meadow of 0.9 ha in which *Spilomyia diophthalma* is frequently collected: *Blera fallax*, *Brachypalpoides lentus*, *Brachypalpus laphriformis*, *Ceriana conopsoides*, *Criorhina ranunculi*, *Pocota personata*, *Sphegina sibirica*, *Spilomyia manicata*, *Xylota abiens* and *Xylota sylvarum*.

Main threat. Loss of quality and quantity of forest habitat.

Causes:

1) **Forestry practice.** Timber logging, especially of deciduous trees in mixed forests, is the primary cause of habitat loss.
2) **Tourism and leisure.** The removal of deadwood and old standing trees, and rigorous mowing of meadows, reduces habitat quality in city parks or forests near cities. Conversely, too little management of these areas causes shrubs and trees to intrude into meadows, also degrading habitat.
3) **Agriculture.** The intensification of agriculture, especially in the Alpine countries reduces hydration of the surrounding forests causing a shift in tree composition away from vital deciduous species. Pesticides penetrate forests and accumulate in rot-holes negatively impacting larval survival. Overgrazing by cattle and sheep within forestry, can lead to declines in suitable flowering herbs and increase mortality rates of adults.

Solutions. Protect remaining forests and support practices that retain senescent trees and their features, and the maintenance of forest meadows. Protect areas from pesticide impacts.

Left: *Spilomyia diophthalma,* female on Wild Angelica, *Angelica sylvestris,* Estonia. Photo: J. Devalez.

GOAL 5: POLICY SUPPORT FOR HOVERFLIES IN EUROPE THAT AIDS CONSERVATION ACTION

- More hoverflies are listed as typical of one or more of the habitats at risk, in Annex I of the EU Habitats Directive, as well as in national threatened species' lists.
- Well-targeted policies, subsidies and incentives support conservation of priority hoverfly microhabitats.
- Near Threatened and Least Concern species that have undergone significant range-contractions are targeted for attention.

GOAL 5: RECOMMENDATIONS

Current EU legislation, policies and strategies provides a framework for biodiversity conservation that many species and their habitats can benefit from. Well-targeted changes to the way in which hoverflies are dealt with under these instruments would provide a powerful tool for the conservation of rare as well as common hoverfly species. In addition, many initiatives critical to successful hoverfly conservation will be best addressed at the national level, with specific protections delivered through the agencies responsible for on-ground site protection.

5.1	GENERAL POLICY-RELATED RECOMMENDATIONS	
Recommended action		**Potential implementers & collaborators**
5.1.1	Link EU habitat restoration efforts and management with the requirements for the main pollinators such as hoverflies.	EU; IUCN staff involved in Hoverflies initiative and HSG; government agencies.
5.1.2	Address the main pollinator groups (including hoverflies) in the EU-Pledges process for the EU protected area and conservation status targets under the EU-Biodiversity Strategy 2030.	
5.1.3	Promote more forest wilderness areas without any interventions across all different types of European habitats throughout their whole range and include these in the 10% target on strictly protected areas for 2030. Starting with Natura 2000 sites.	
5.2	HOVERFLIES ARE LISTED AS TYPICAL OF ONE OR MORE OF THE HABITATS AT RISK, IN ANNEX I OF THE EU HABITATS DIRECTIVE, AS WELL AS IN NATIONAL THREATENED SPECIES LISTS.	
Recommended action		**Potential implementers & collaborators**
5.2.1	Discuss with relevant actors the listing of more hoverfly taxa as typical of one or more of the Annex I Habitats at risk, on the EU Habitats Directive.	UNSPMF; HSG; Natura 2000 site managers.
5.2.2	Raise awareness that many hoverflies represent «typical species» of Annex I habitats protected under The EU Habitats Directive and include them in habitat assessments and site management for Natura 2000.	
5.2.3	Develop species-specific site management advice for a select list of species representative of specific habitats (e.g. dry grassland, bogs or wetlands, different forest types etc.), to inform changes to site management of benefit to these and other taxa.	

5.2.4	Add threatened hoverfly species to national protected species lists to provide a legal mandate to protect them at the national level.	HSG; national government agencies; regional/ local policy makers and implementers.
5.3	WELL-TARGETED POLICIES, SUBSIDIES AND INCENTIVES SUPPORT CONSERVATION OF PRIORITY HOVERFLY MICROHABITATS.	
Recommended action		**Potential implementers & collaborators**
5.3.1	Promote subsidies in Europe for farmers adopting the “no net loss of natural capital” principle.	Government agencies; Ecosystem Services Networks; AHDB/ farm clusters /FWAG (in UK).
5.3.2	Extend nature-supporting provisions for graziers and farmers in Natura 2000 sites to support hoverfly conservation.	Natura 2000 site committees; government agencies.
5.3.2	Expand support and extend the time period for, maintaining stands of aging trees across Europe, beginning with Natura 2000 sites.	Natura 2000 site committees, national forestry management bodies.
5.3.3	Increase «defend» across Europe, especially in the alpine grassland and wetlands, and include in MAEC and other equivalent national initiatives.	EU; national government agencies.
5.3.4	Critically review the current implementation of agri-environmental measures under the CAP and recommend changes useful for hoverflies (e.g., ensure that incentives to create field margins for pollinators require them to be in place for more than the current 1 year.	IUCN SSC Invertebrate Sub-committee (for hoverflies and other taxa) with government departments/agencies; agriculture boards.
5.4	NEAR THREATENED AND LEAST CONCERN SPECIES THAT HAVE UNDERGONE SIGNIFICANT RANGE-CONTRACTIONS ARE TARGETED FOR ATTENTION.	
Recommended action		**Potential implementers & collaborators**
5.4.1	Support identification of Near Threatened and Least Concern species likely to progress to a threatened category in the next 10 years. Recommend additional measures to support their needs if not covered here.	UNSPMF; HSG; other experts.
5.4.2	Intensify research on hoverfly and insect decline in different regions of Europe and in different landscape settings to improve understanding of possible exceptions and major factors likely to prevent further decline.	Regional and national hoverfly experts, government and non-government research organisations.

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APPENDIX 1. SPECIES INCLUDED IN A2P SUBSET

Larval Feeding trait	Species name	RL	Range	In EU 27	EU 27 Endmic	European Biogeographical Regions
Saprophagous (sap)	*Callicera scintilla*	CR	Maj.Eur	Y	N	Mediterranean
Saprophagous (sap)	*Brachyopa minima*	CR	Endemic	Y	Y	Mediterranean
Saprophagous (sap)	*Myolepta difformis*	EN	Maj.Eur	Y	N	Mediterranean
Saprophagous (sap)	*Sphiximorpha euprosopa*	EN	Maj.Eur	Y	N	Mediterranean
Saprophagous (sap)	*Sphiximorpha petronillae*	EN	Endemic	Y	N	Mediterranean
Saprophagous (sap)	*Psilota nana*	EN	Endemic	Y	N	Continental, Mediterranean
Saprophagous (sap)	*Primocerioides regale*	EN	Endemic	Y	N	Mediterranean
Saprophagous (sap)	*Ceriana glaebosa*	EN	Endemic	Y	Y	Mediterranean
Saprophagous (sap)	*Chalcosyrphus pannonicus*	EN	Maj.Eur	Y	N	Continental, Mediterranean, Pannonian
Saprophagous (sap)	*Callicera fagesii*	EN	Maj.Eur	Y	N	Atlantic, Continental, Mediterranean
Saprophagous (sap)	*Chalcosyrphus nigripes*	EN	Maj.Eur	Y	N	Northern
Saprophagous (sap)	*Callicera macquarti*	EN	Maj.Eur	Y	N	Atlantic, Continental, Mediterranean
Saprophagous (sap)	*Brachyopa quadrimaculosa*	EN	Maj.Eur	Y	N	Mediterranean
Saprophagous (sap)	*Sphegina limbipennis*	EN	Endemic	Y	Y	Atlantic, Continental, Mediterranean
Saprophagous (sap)	*Brachyopa silviae*	EN	Endemic	Y	N	Continental, Mediterranean
Saprophagous (sap)	*Brachyopa bimaculosa*	EN	Endemic	Y	Y	Continental, Mediterranean
Saprophagous (sap)	*Sphegina sublatifrons*	EN	Endemic	Y	N	Continental
Saprophagous (sap)	*Sphegina atrolutea*	EN	Endemic	Y	Y	Alpine
Saprophagous (sap)	*Sphegina varifacies*	EN	Endemic	Y	Y	Atlantic, Continental
Saprophagous (sap)	*Brachyopa grunewaldensis*	EN	Endemic	Y	N	Continental, Mediterranean
Saprophagous (sap)	*Brachyopa maculipennis*	EN	Endemic	Y	N	Continental, Pannonian
Saprophagous (sap)	*Brachyopa vernalis*	EN	Endemic	Y	Y	Mediterranean
Saprophagous (sap)	*Spilomyia triangulata*	VU	Maj.Eur	Y	N	Alpine, Continental
Saprophagous (sap)	*Callicera spinolae*	VU	Maj.Eur	Y	N	Atlantic, Continental, Mediterranean, Pannonian
Saprophagous (sap)	*Chalcosyrphus eunotus*	VU	Maj.Eur	Y	N	Alpine, Atlantic, Continental, Pannonian
Saprophagous (sap)	*Spilomyia digitata*	VU	Maj.Eur	Y	N	Continental, Mediterranean
Saprophagous (sap)	*Callicera rufa*	VU	Maj.Eur	Y	N	Alpine, Atlantic, Continental, Mediterranean, Pannonian
Saprophagous (sap)	*Brachypalpus chrysites*	VU	Maj.Eur	Y	N	Alpine, Continental, Pannonian
Saprophagous (sap)	*Callicera aurata*	VU	Maj.Eur	Y	N	Alpine, Atlantic, Continental, Mediterranean, Northern
Saprophagous (sap)	*Temnostoma sericomyiaeforme*	VU	Endemic	Y	N	Northern
Saprophagous (s-t)	*Parhelophilus crococoronatus*	EN	Endemic	Y	Y	Mediterranean
Saprophagous (s-t)	*Palumbia bellierii*	EN	Endemic	Y	Y	Mediterranean
Saprophagous (aq)	*Eristalis tecta*	CR	Endemic	N	N	Continental
Saprophagous (aq)	*Anasimyia femorata*	EN	Endemic	Y	N	Mediterranean
Saprophagous (aq)	*Myathropa usta*	EN	Endemic	Y	Y	Macaronesian
Saprophagous (aq)	*Sericomyia bequaerti*	CR	Maj.Eur	Y	N	Continental
Saprophagous (aq)	*Riponnensia daccordii*	CR	Endemic	Y	Y	Mediterranean
Saprophagous (aq)	*Chrysogaster simplex*	EN	Maj.Eur	Y	N	Mediterranean, Black Sea, Anatolian
Saprophagous (aq)	*Chrysogaster mediterraneus*	EN	Maj.Eur	Y	N	Continental, Mediterranean
Saprophagous (aq)	*Riponnensia longicornis*	EN	Maj.Eur	Y	N	Northern
Saprophagous (aq)	*Melanogaster jaroslavensis*	EN	Endemic	N	N	Steppe
Saprophagous (aq)	*Neoascia unifasciata*	EN	Endemic	Y	N	Continental
Saprophagous (aq)	*Orthonevra montana*	EN	Endemic	Y	N	Continental

Saprophagous (aq)	*Melanogaster curvistylus*	EN	Endemic	Y	N	Continental
Saprophagous (aq)	*Chrysogaster rondanii*	EN	Endemic	Y	N	Atlantic, Continental
Saprophagous (aq)	*Orthonevra plumbago*	EN	Endemic	Y	N	Continental, Northern, Pannonian
Saprophagous (aq)	*Riponnensia morini*	EN	Endemic	Y	N	Mediterranean
Saprophagous (aq)	*Neoascia balearensis*	EN	Endemic	Y	Y	Macaronesian
Saprophagous (aq)	*Melanogaster nigricans*	VU	Endemic	Y	N	Continental, Mediterranean
Zoophagous	*Paragus thracusi*	CR	Endemic	Y	Y	Mediterranean
Zoophagous	*Eupeodes biciki*	CR	Endemic	Y	N	Northern
Zoophagous	*Platycheirus meridimontanus*	CR	Maj.Eur	N	N	Mediterranean
Zoophagous	*Platycheirus altomontis*	CR	Endemic	Y	Y	Alpine
Zoophagous	*Cryptopipiza notabila*	EN	Maj.Eur	Y	N	Northern
Zoophagous	*Heringia adpropinquans*	EN	Endemic	Y	Y	Macaronesian
Zoophagous	*Pipiza carbonaria*	EN	Endemic	Y	N	Continental
Zoophagous	*Pipiza laurusi*	EN	Endemic	Y	N	Continental, Mediterranean
Zoophagous	*Pipiza luteibarba*	EN	Endemic	Y	N	Mediterranean
Zoophagous	*Claussenia hispanica*	EN	Endemic	Y	Y	Mediterranean
Zoophagous	*Pipizella thapsiana*	EN	Maj.Eur	Y	N	Macaronesian, Mediterranean
Zoophagous	*Paragus constrictus*	EN	Maj.Eur	Y	N	Alpine, Atlantic, Continental
Zoophagous	*Paragus glumaci*	EN	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Pipizella nataliae*	EN	Maj.Eur	Y	N	Black Sea, Anatolian
Zoophagous	*Pipizella cantabrica*	EN	Endemic	Y	Y	Atlantic
Zoophagous	*Pipizella elegantissima*	EN	Endemic	Y	Y	Continental
Zoophagous	*Paragus majoranae*	EN	Endemic	Y	N	Continental, Mediterranean
Zoophagous	*Paragus medeae*	EN	Endemic	Y	Y	Pannonian, Black Sea
Zoophagous	*Pipizella nigriana*	EN	Endemic	Y	N	Alpine
Zoophagous	*Pipizella bispina*	EN	Endemic	Y	N	Alpine
Zoophagous	*Pipizella lyneborgi*	EN	Endemic	Y	Y	Mediterranean
Zoophagous	*Doros destillatorius*	EN	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Chrysotoxum parmense*	EN	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Chrysotoxum gracile*	EN	Maj.Eur	Y	N	Continental, Mediterranean
Zoophagous	*Chrysotoxum lineare*	EN	Maj.Eur	Y	N	Atlantic, Continental, Northern, Pannonian
Zoophagous	*Epistrophe leiophthalma*	EN	Maj.Eur	Y	N	Alpine, Continental, Mediterranean
Zoophagous	*Xanthandrus babyssa*	EN	Endemic	Y	Y	Macaronesian
Zoophagous	*Epistrophella coronata*	EN	Endemic	Y	N	Mediterranean
Zoophagous	*Syrphus auberti*	EN	Endemic	Y	N	Alpine
Zoophagous	*Melanostoma wollastoni*	EN	Endemic	Y	Y	Macaronesian
Zoophagous	*Melanostoma incompletum*	EN	Endemic	Y	Y	Macaronesian
Zoophagous	*Eupeodes vandergooti*	EN	Endemic	Y	Y	Mediterranean
Zoophagous	*Xanthogramma aeginae*	EN	Endemic	Y	Y	Mediterranean
Zoophagous	*Xanthogramma pilosum*	EN	Endemic	Y	Y	Mediterranean
Zoophagous	*Platycheirus abruzzensis*	EN	Maj.Eur	Y	N	Continental
Zoophagous	*Platycheirus caesius*	EN	Endemic	Y	N	Alpine, Atlantic
Zoophagous	*Microdon major*	EN	Endemic	Y	Y	Atlantic, Continental
Zoophagous	*Platycheirus muelleri*	EN	Endemic	Y	Y	Alpine, Continental, Mediterranean
Zoophagous	*Triglyphus escalerai*	EN	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Paragus coadunatus*	VU	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Paragus oltenicus*	VU	Maj.Eur	Y	N	Mediterranean
Zoophagous	*Pipizella obscura*	VU	Maj.Eur	Y	N	Northern
Zoophagous	*Pipizella siciliana*	VU	Endemic	Y	Y	Mediterranean
Zoophagous	*Pipizella brevis*	VU	Endemic	Y	N	Alpine
Zoophagous	*Pipizella calabra*	VU	Endemic	Y	Y	Alpine, Continental
Zoophagous	*Pipizella zloti*	VU	Endemic	Y	N	Continental, Mediterranean
Zoophagous	*Paragus ascoensis*	VU	Endemic	Y	Y	Mediterranean
Zoophagous	*Paragus sexarcuatus*	VU	Endemic	Y	Y	Mediterranean
Zoophagous	*Chrysotoxum orthostylum*	VU	Maj.Eur	Y	N	Continental
Zoophagous	*Chrysotoxum cisalpinum*	VU	Maj.Eur	Y	N	Alpine, Atlantic, Continental, Mediterranean

Zoophagous	*Chrysotoxum triarcuatum*	VU	Endemic	Y	Y	Macaronesian
Zoophagous	*Microdon miki*	VU	Maj.Eur	Y	N	Continental, Northern, Pannonian
Zoophagous	*Sphaerophoria potentillae*	VU	Endemic	Y	N	Atlantic, Continental, Northern
Zoophagous	*Microdon myrmicae*	VU	Endemic	Y	N	Atlantic, Continental
Zoophagous	*Platycheirus islandicus*	VU	Endemic	N	N	Arctic, Northern
Zoophagous	*Rohdendorfia alpina*	VU	Maj.Eur	Y	N	Alpine
Zoophagous	*Trichopsomyia lucida*	VU	Endemic	Y	N	Atlantic, Continental, Mediterranean
Phytophagous BR	*Merodon orjensis*	CR	Endemic	N	N	Continental
Phytophagous BR	*Merodon cabanerensis*	CR	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon planiceps*	CR	Maj.Eur	Y	N	Mediterranean, Anatolian
Phytophagous BR	*Merodon longisetus*	CR	Maj.Eur	Y	N	Northern
Phytophagous BR	*Merodon sapphous*	CR	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon arundanus*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon longispinus*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon andriotes*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon olympius*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon sacki*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus bicornis*	CR	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus tenuitarsis*	CR	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus banaticus*	CR	Endemic	Y	N	Pannonian
Phytophagous BR	*Eumerus nivariae*	CR	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus pannonicus*	CR	Endemic	N	N	Pannonian
Phytophagous BR	*Eumerus azabense*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus bifurcatus*	CR	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon dzhalitae*	EN	Endemic	N	N	Black Sea
Phytophagous BR	*Merodon quercetorum*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon hoplitis*	EN	Endemic	Y	Y	Continental
Phytophagous BR	*Merodon balkanicus*	EN	Endemic	Y	Y	Alpine, Continental
Phytophagous BR	*Merodon luteomaculatus*	EN	Endemic	Y	N	Mediterranean
Phytophagous BR	*Merodon dobrogensis*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon kozufensis*	EN	Endemic	Y	N	Continental
Phytophagous BR	*Merodon adriaticus*	EN	Endemic	Y	N	Mediterranean
Phytophagous BR	*Merodon puniceus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon hirtus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon calcaratus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon testaceus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon robustus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon rufipes*	EN	Maj.Eur	Y	N	Black Sea, Steppe
Phytophagous BR	*Merodon ambiguus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon pumilus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon velox*	EN	Maj.Eur	Y	N	Mediterranean, Anatolian
Phytophagous BR	*Merodon segetum*	EN	Maj.Eur	Y	N	Continental, Mediterranean
Phytophagous BR	*Merodon eques*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon flavicornis*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon medium*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon erymanthius*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon naxius*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon nitens*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon antonioi*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon spineus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon toscanus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon atricapillatus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon abruzzensis*	EN	Endemic	Y	Y	Continental
Phytophagous BR	*Merodon nisi*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon megavidus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon peloponnesius*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon confinium*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus truncatus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus sinuatus*	EN	Maj.Eur	Y	N	Arctic, Continental, Pannonian

Phytophagous BR	*Eumerus ruficornis*	EN	Maj.Eur	Y	N	Atlantic, Continental, Mediterranean, Northern, Pannonian
Phytophagous BR	*Eumerus ovatus*	EN	Maj.Eur	Y	N	Continental, Mediterranean, Pannonian
Phytophagous BR	*Eumerus hungaricus*	EN	Maj.Eur	Y	N	Alpine, Continental, Mediterranean, Pannonian, Black Sea
Phytophagous BR	*Eumerus subornatus*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus aurofinis*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus tauricus*	EN	Maj.Eur	Y	N	Pannonian, Black Sea, Steppe
Phytophagous BR	*Eumerus dubius*	EN	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus longicornis*	EN	Endemic	Y	Y	Continental, Pannonian
Phytophagous BR	*Eumerus purpurariae*	EN	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus santosabreui*	EN	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus canariensis*	EN	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus montanum*	EN	Endemic	Y	N	Mediterranean
Phytophagous BR	*Eumerus torsicus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus rubrum*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus phaeacus*	EN	Endemic	Y	N	Mediterranean
Phytophagous BR	*Eumerus gibbosus*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus niehuisi*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus vandenberghei*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus karyates*	EN	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus claripennis*	EN	Endemic	Y	N	Continental, Mediterranean
Phytophagous BR	*Merodon crypticus*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon teruelensis*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon euri*	VU	Endemic	Y	N	Mediterranean
Phytophagous BR	*Merodon confusus*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon gallicus*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon virgatus*	VU	Endemic	Y	N	Alpine, Continental
Phytophagous BR	*Merodon alexandri*	VU	Endemic	N	N	Steppe
Phytophagous BR	*Merodon vladimiri*	VU	Endemic	N	N	Continental
Phytophagous BR	*Merodon desuturinus*	VU	Endemic	Y	N	Continental
Phytophagous BR	*Merodon latifemoris*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon papillus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon hamifer*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon luteihumerus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon femoratoides*	VU	Maj.Eur	N	N	Mediterranean, Black Sea, Anatolian
Phytophagous BR	*Merodon luteofasciatus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon ottomanus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon opacus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Merodon caerulescens*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon rubidiventris*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Merodon rojoi*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus niveitibia*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus armatus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus crassus*	VU	Maj.Eur	Y	N	Mediterranean
Phytophagous BR	*Eumerus latitarsis*	VU	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus purpureus*	VU	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus hispidus*	VU	Endemic	Y	Y	Macaronesian
Phytophagous BR	*Eumerus grallator*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus minotaurus*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus hispanicus*	VU	Endemic	Y	Y	Mediterranean
Phytophagous BR	*Eumerus etnensis*	VU	Endemic	Y	Y	Macaronesian, Mediterranean
Phytophagous BR	*Platynochaetus macquarti*	VU	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia varnensis*	CR	Endemic	Y	Y	Continental, Black Sea
Phytophagous (SLF)	*Katara connexa*	CR	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia katara*	CR	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Ischyroptera bipilosa*	CR	Endemic	Y	N	Alpine

Phytophagous (SLF)	*Cheilosia subpictipennis*	EN	Maj.Eur	Y	N	Alpine, Continental, Pannonian
Phytophagous (SLF)	*Cheilosia pictipennis*	EN	Maj.Eur	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia paralobi*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous (SLF)	*Cheilosia schnabli*	EN	Maj.Eur	Y	N	Continental, Mediterranean, Pannonian, Black Sea
Phytophagous (SLF)	*Cheilosia rodgersi*	EN	Maj.Eur	Y	N	Mediterranean
Phytophagous (SLF)	*Cheilosia montana*	EN	Endemic	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia herculana*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia andalusiaca*	EN	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia griseifacies*	EN	Endemic	Y	N	Continental, Pannonian
Phytophagous (SLF)	*Cheilosia alpestris*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia gagatea*	EN	Endemic	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia balkana*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia aristata*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia hercyniae*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia morio*	EN	Endemic	Y	N	Alpine, Continental, Northern, Pannonian
Phytophagous (SLF)	*Cheilosia nivalis*	EN	Endemic	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia beckeri*	EN	Endemic	Y	Y	Alpine
Phytophagous (SLF)	*Cheilosia barbafacies*	EN	Endemic	N	N	Continental
Phytophagous (SLF)	*Cheilosia insignis*	EN	Endemic	Y	N	Alpine, Continental, Pannonian
Phytophagous (SLF)	*Cheilosia ingerae*	EN	Endemic	Y	N	Northern
Phytophagous (SLF)	*Cheilosia pedemontana*	EN	Endemic	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia impudens*	EN	Maj.Eur	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia pedestris*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia pini*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia pilifer*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia vujici*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia kerteszi*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia crassiseta*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia tonsa*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia laeviventris*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia clausseni*	EN	Endemic	Y	Y	Alpine
Phytophagous (SLF)	*Cheilosia laeviseta*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia clama*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia alba*	EN	Endemic	Y	N	Continental
Phytophagous (SLF)	*Cheilosia lenta*	EN	Endemic	Y	N	Alpine, Continental, Pannonian
Phytophagous (SLF)	*Cheilosia latigenis*	EN	Endemic	Y	Y	Alpine
Phytophagous (SLF)	*Cheilosia vangaveri*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia loewi*	EN	Endemic	Y	N	Alpine, Continental, Pannonian
Phytophagous (SLF)	*Cheilosia venosa*	EN	Endemic	Y	N	Alpine
Phytophagous (SLF)	*Cheilosia faucis*	EN	Endemic	Y	N	Alpine, Continental
Phytophagous (SLF)	*Cheilosia lucense*	EN	Endemic	Y	Y	Atlantic
Phytophagous (SLF)	*Cheilosia iberica*	EN	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia thessala*	EN	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia limbicornis*	EN	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Pelecocera nigricornis*	EN	Endemic	Y	Y	Mediterranean
Phytophagous (SLF)	*Cheilosia reniformis*	VU	Maj.Eur	Y	N	Northern
Phytophagous (SLF)	*Psarus abdominalis*	VU	Maj.Eur	Y	N	Alpine, Atlantic, Continental, Mediterranean, Pannonian

Sap=saproxylic; s-t=semi-terrestrial; aq=aquatic; BR=bulb and root zone; SLF=stems, leaves and fungi

APPENDIX 2. WORKING GROUP PARTICIPANTS AND ADDITIONAL CONTRIBUTORS

Name	Relevant Affiliation or Role	Country
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