European Red List of Insect Taxonomists

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European Commission
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PENSOFT

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Prof. Georgi Zlatarski Street 12
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Executive summary

Insects play a significant role in the functioning of healthy ecosystems and human well-being. By providing vital services such as pollination, matter decomposition, and bio-control, they greatly influence the living world. Our ability and expertise to recognise insect species and biodiversity are fundamental for their conservation. However, there is increasing concern regarding our capacity to identify insects and describe and name new insect species. This capacity has traditionally been provided by taxonomists, working in museums, institutes or universities. This *European Red List of Insect Taxonomists* provides the first assessment of the status of taxonomic expertise capacity in Europe. Based upon a quantitative analysis of taxonomic papers published in scientific journals during the last decade as well as an online questionnaire, a detailed overview is given of the taxonomic capacity for each insect order and for each EU country. This *European Red List of Insect Taxonomists* is a call to the community of experts to bring their expertise into the public focus, and a call to society at large to acknowledge the role of taxonomy and support its sustainability in the long term.

Overall, taxonomic capacity is threatened or eroded for 41.4% and 34.5% of the insect orders at the European and EU levels, respectively. The degree of erosion of taxonomic capacity is calculated as a Red List Index following Butchart et al. (2007), ranging between 0 (taxonomic capacity fully eroded) and 1 (all taxa covered by adequate capacity). There is substantial variation in the number of insect orders covered by taxonomists among countries: the highest Red List Index RLI is found in Czechia, followed by Germany and Russia. The lowest RLI is found in Albania, Azerbaijan and Belarus, and among the EU countries - Luxembourg, Latvia, Ireland and Malta. The number of insect orders covered by taxonomic expertise in each country correlates well with the Red List Index. The four largest insect orders (Coleoptera, Diptera, Lepidoptera, Hymenoptera) were all covered by >80% of the countries (in the case of Coleoptera and Lepidoptera even by >90%), but Adequate Capacity is only attained in 26% (Coleoptera) to 58% (Hymenoptera) of all countries.

Three sets of recommendations – on strategic actions, science and societal engagement, are provided, with the aim of ensuring the long-term sustainability of taxonomic expertise in Europe.

Strategic recommendations providing the framework to foster taxonomy:

a. Provide targeted and sustainable funding specifically directed at increasing taxonomic capacity across Europe;

b. Integrate the valuable role of taxonomists into policy formulation and implementation at the EU and national level.

The Red List of Insect Taxonomists project provides:

- Detailed information on the current number, location and productivity of insect taxonomists.
- A methodology for assessing the status of taxonomic expertise capacity similar to the established IUCN Red List of Threatened Species™ process, potentially applicable to any taxonomic group at different geographical scales.
- An assessment of the status and future trends of insect taxonomic expertise.
- Recommendations for strengthening taxonomic expertise across Europe.

Science recommendations reinforcing the far-reaching impact of taxonomy:

c. Ensure the continuous overview of the available taxonomic capacity, for example, by periodic re-assessment of the Red List of Taxonomists. Expand the approach to other biodiversity groups.

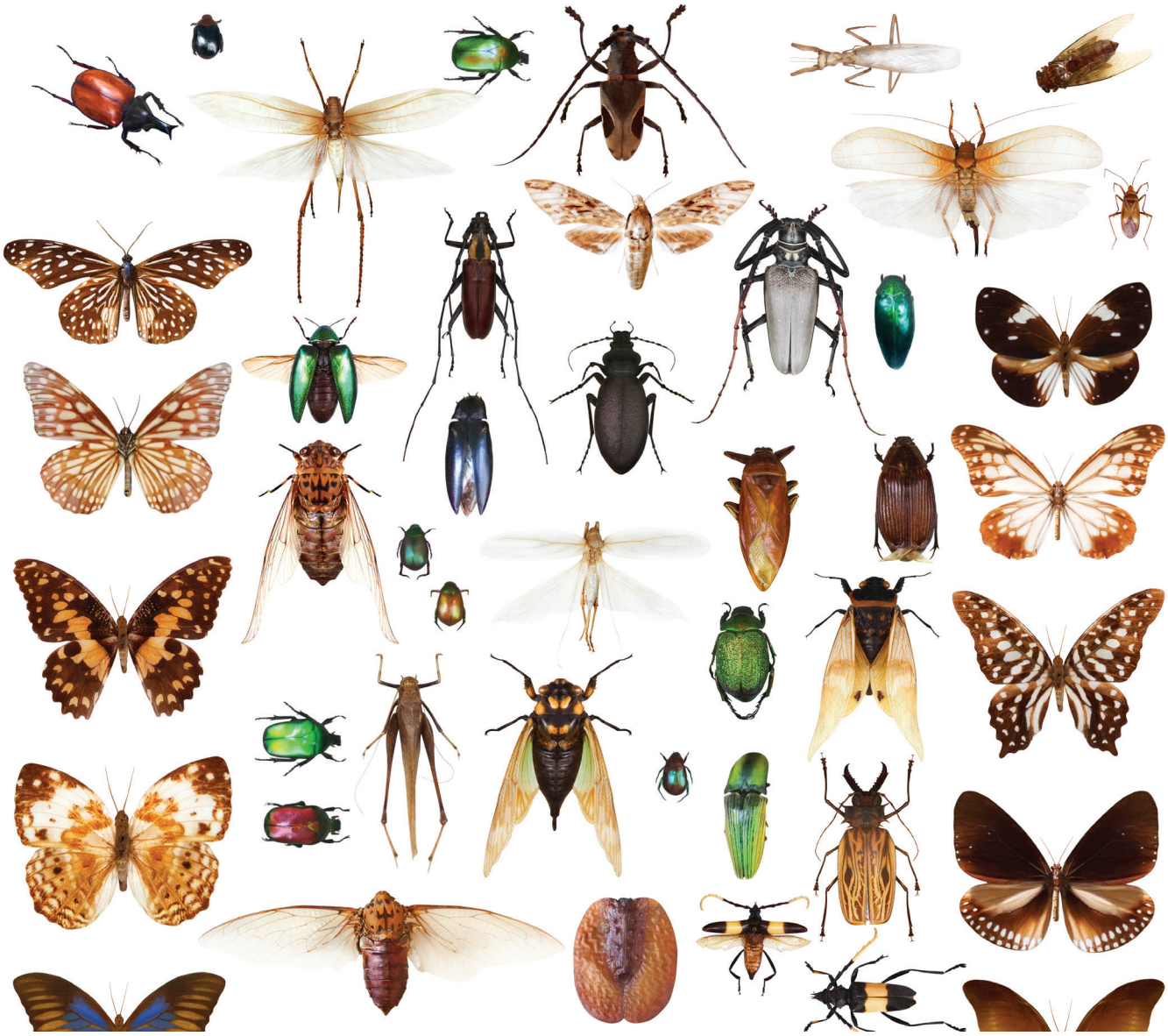
d. Increase the taxonomic capacity through dedicated knowledge exchange, education, training and development opportunities for professional taxonomists.

e. Promote networking among taxonomists by maximising the use of modern technologies in research, publishing and knowledge exchange.

Societal recommendations engaging society in taxonomy:

f. Increase the recognition and awareness of the importance of taxonomic expertise by using effective means of communication with the public.

g. Engage with citizen science initiatives to maximise the synergies between their efforts and taxonomic expertise in efficient research and monitoring of biodiversity.



Compilation of different insect orders. Photo: GVS/stockadobe.com

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Entomologist examining a small insect under a microscope. Photo: anton_shoshin/stockadobe.com

1 Background

1.1 The EU response to the insect biodiversity crisis

As a consequence of multiple human actions, more species are threatened with global extinction now than ever before (IPBES 2019). In response to this global biodiversity crisis, the EU has adopted an ambitious Biodiversity Strategy[1] for 2030 that outlines a comprehensive long-term plan to protect nature and reverse the degradation of ecosystems across the EU. Through a set of specific targets, objectives and commitments the EU Biodiversity Strategy for 2030 strengthens the ambition for the conservation of insects through nature protection and restoration, and more specifically through its commitment to reverse the decline of pollinating insects. In June 2022, the Commission published a proposal for a Nature Restoration Law which further reinforces the ambition to bring back nature, including insects, into all ecosystems[2].

In 2018, the European Commission adopted a Communication on the first-ever EU initiative on wild pollinators. The initiative sets strategic objectives and actions for the EU and its Member States to address the decline of pollinators, namely improving the knowledge of pollinator decline, tackling its causes and raising awareness, and engaging society at large[3].

Over recent decades, Europe's wild pollinators have declined in occurrence, abundance and species richness (Potts et al. 2010). Many of them are threatened due to unsustainable land use, intensive agriculture and pesticides, invasive alien species, environmental pollution and climate change (IPBES 2016). In 2017, a German study (Hallmann et al. 2017) found that flying insect biomass had declined by over 75% in just 27 years, with wild pollinators, in particular, facing a vast array of threats driving their decline.

To assess the risk of extinction of insects in the EU the European Commission initiated assessments of the status of certain taxa according to the IUCN Red List Criteria at the regional scale (IUCN 2012a). To date, several insect groups such as butterflies (Van Swaay et al. 2010), bees (Nieto et al. 2014) and saproxylic beetles (Nieto and Alexander 2010, Cálix et al. 2018) have been assessed. The *European Red List of Hoverflies* (ca. 900 species) is nearly complete and in December 2020 the European Commission kick-started the *European Red List of Moths*.

The IUCN *European Red List of Bees* (Nieto et al. 2014) revealed that around one in ten European bee species face extinction. However, data on distribution and population trends of more than 56% of bee species in Europe (55% in the EU) was insufficient to allow a Red List assessment (i.e. they were assessed as Data Deficient). This means that the proportion of threatened bee species across the European region could range from 4% (if not all DD species are threatened) to 60.7% (if all DD species are threatened; Nieto et al. 2014). This knowledge gap highlighted the vital need for more effective research and monitoring of this important species group. For many other insect groups, the available data are even less adequate to reveal their status and trends in Europe.

In parallel with the decline of insect species, there is also a worrying decline in insect taxonomic expertise, which hinders conservation efforts. To address this problem, in December 2020 the European Commission launched work on the first-ever European Red List of Taxonomists.

1.2 The importance of insect taxonomy

Taxonomy - the science of discovering, describing, naming, and classifying organisms - not only produces fascinating insights into the characteristics of life on Earth, but above all, it provides the basis for many other research fields, including ecology, evolutionary biology, and genetics (Mayr 1969). Moreover, it provides a basic under-

[1] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

[2] https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en

[3] https://ec.europa.eu/environment/nature/conservation/species/pollinators/policy_en.htm.

Taxonomy is indispensable for:

- **Conserving and sharing the benefits of biodiversity:** To date, about 1.8 million species of an estimated 8 million species have been described (IPBES 2020). Knowledge of species and their distributions is central to their protection and provides new opportunities for life sciences to understand the benefits of biodiversity.
- **Responding to climate change:** distributions of species are known to shift as a consequence of climate change. Taxonomic collections help to understand the spatial distributions of species, allowing extinction, pest and disease risks to be predicted and supporting ecosystem adaptation measures.
- **Managing Alien Invasive Species (IAS) and pests:** IAS and pests pose one of the major threats to biodiversity and food security. Managing these risks calls for trained taxonomists able to provide information about the species and rapid identification tools to managers and society.
- **Facilitating trade:** when an unknown insect is found in an agricultural shipment, global commerce is slowed and shipments are held at great cost pending identification. Rapidly available taxonomic support saves money.
- **Improving human, animal and plant health:** taxonomy is fundamental for correct diagnoses and treatment, prediction of disease vectors and regulation and quality control of trade in medicinal plants.

Source: BioNET™ Website: http://www.bionet-intl.org

standing of components of biodiversity, which is necessary for effective decision-making about conservation and sustainable use[4].

With around one million described species and perhaps as many as 5.5 million extant species globally (Stork 2018), insects are the largest class of animals, representing three out of four described animal species. Insects are widely distributed, occupying terrestrial and freshwater habitats throughout the planet and they play an indispensable role in ecosystems by driving key processes such as pollination, decomposition, soil fertility and forming an essential part of food chains.

Monitoring the distribution and abundance of insects also depends on the availability of up-to-date and precise data underpinned by the taxonomic knowledge required to define and identify species. While the existing knowledge clearly demonstrates an alarming decline of biodiversity, the knowledge gaps are still considerable (Hochkirch et al. 2020). The EU Biodiversity Strategy for 2030 stresses the importance of filling these gaps promptly. For this, strong taxonomic expertise will be necessary. In Europe, taxonomic expertise is primarily found in research institutions such as natural history museums and universities. European museums play a vital role in insect taxonomy globally as they host a large proportion of type material of insects (e.g., ca. 50% of all Orthoptera species; Cigliano et al. 2022). Therefore, Europe has a high responsibility for maintaining taxonomic knowledge and building capacity also outside Europe.

[4] CBD https://www.cbd.int/gti/importance.shtml

1.3 Assessment of insect taxonomy capacity

The pool of taxonomic experts in Europe has been shrinking for decades (Green 1998, Audisio 2017) leading to a shortage of trained taxonomists and curators and the impact these deficiencies have on our ability to conserve, use and share the benefits of biological diversity (Global Taxonomy Initiative[5]). The dual phenomenon of the decline of insects and that of insect taxonomists has been acknowledged in the context of the European Red List (Nieto et al. 2014). Several attempts have been made to date to take stock of the taxonomic capacity in Europe, in the context of EU-funded projects such as Fauna Europaea, EDIT, and PESI's Taxonomic Experts & Networks Database[6] under FP7. They provided the first European scale survey of taxonomists containing European information service expertise and contact information for European taxonomic experts, networks and societies.

Decisive action is needed to reverse this negative trend of taxonomic capacity. To devise effective interventions, it is necessary to map and accurately identify the current and newly emerging gaps in expertise. This assessment aims to undertake such work for insects (class Insecta).

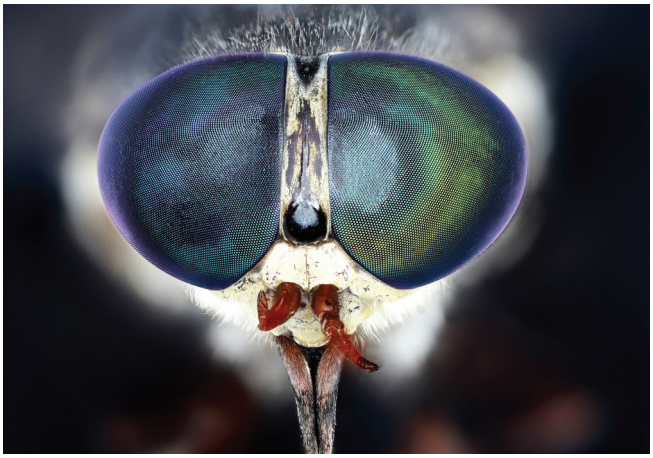
[5] https://www.cbd.int/gti

[6] http://www.eu-nomen.eu/portal/index.php

Tiger Beetle (*Cicindella campestris*). Photo: Vitalii Hulai/ stockadobe.com

Neon Cuckoo Bee (*Thyreus wallacei)*. Photo: USGS/ unsplash.com

Green Skipper Butterfly (*Astraptes habana*). Photo: vmenshov/ stockadobe.com



Pale Giant Horsefly (*Tabanus bovinus*). Photo: Macroscopic Solution/stockadobe.com

2 Objectives of the assessment

The overall goal of the project is to assess the available taxonomic expertise on insects at the European and EU-level (27 EU countries), as well as a detailed analysis at national level. The specific objectives are to:

- Obtain detailed information on the actual number, location and profile of insect taxonomists. Analyse the results to detect trends, gaps and potential risks of erosion insect taxonomic expertise.

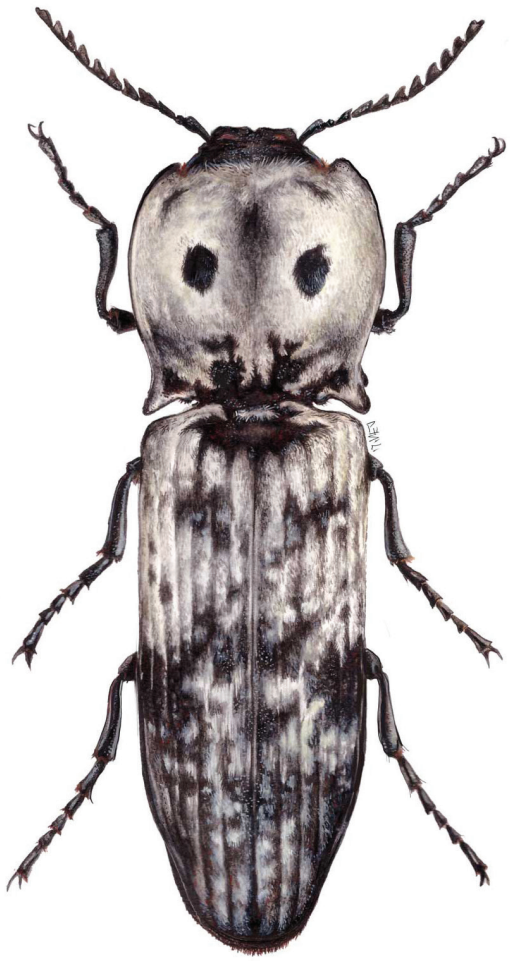
- Assess the level of threat to potentially lose the taxonomic capacity for insect orders across the European region and at the EU level. Evaluate further the situation for certain orders and families of insects known to play an important role as pollinators at the EU level and for individual EU countries.

- Develop recommendations for strengthening the taxonomic expertise in Europe based on expert analysis and consultation.

- Develop communication materials designed to improve the general understanding among policymakers, the interested parties and the general public of the need for a strong European taxonomic community in order to tackle the decline of insects and safeguard their essential contribution to the biodiversity and functioning of our ecosystems.

This study aims to produce a set of meaningful recommendations that may guide future actions to overcome detected gaps, breaches, shortages and needs in the current capacity of taxonomic expertise on insects and in the European landscape.

The study will contribute to well-grounded decision-making processes to secure taxonomic capacity over time as a means to biodiversity sustainability.



Calais parreysii, a Near Threatened species of click beetles (Elateridae) (The IUCN Red List of Threatened Species 2017) Illustration: Denitsa Peneva

3 Methodology

The IUCN Red List of Threatened Species™ is a globally recognised tool to assess the conservation status of species, based on a highly authoritative and objective methodology for classifying species by their extinction risk (IUCN 2012b, 2022). Red List assessments of species fundamentally rely on the work of taxonomists, whose availability and qualification are fundamental to properly assess the threat status.

The available capacity for insect taxonomy was investigated through a novel approach based on the principles of the Red List. Assessment of taxonomic expertise was conducted at two geographic levels, the European and EU levels. Our objective and robust approach to assess the status of active taxonomists relied on a query in Web of Science (Core Collection) conducted for the 2011-2020 period to obtain numbers of taxonomic publications with authorship from Europe or from the EU for each insect order as well as major families of larger insect orders. The distributions of the insect taxa in question were not considered as these are not aligned to political borders and taxonomic research on any insect group requires a solid knowledge of related non-European taxa. A bespoke terminology of Red List categories was developed (equivalences to the IUCN Red List are shown in Figure 1). The assignment to these categories was based on the number of taxonomic papers on the respective insect group published between 2011 and 2020 (per number of described species). For assessments below the European level, the calculation was corrected by GDP to reflect the economic capacity of each country (see online Annex[7] for further details). A Red List Index (RLI) was calculated for each country using the approach of Butchart et al. (2007). For this, a score of 1.0 was assigned to insect orders with Adequate Capacity and a score of 0 to insect orders with Eroded Capacity (see Annex for details).

Detailed information about the structure of the insect taxonomic community was collected through a self-assessment survey capturing the profiles of 1,527 European insect taxonomists. This survey provided an overview of key parameters - gender, age, employment status, discipline, seniority level, country of residence, taxon of interest, research method, experience, number of described species and genera, teaching and mentoring of young collaborators. Though highly significant, the self-assessment survey results should be interpreted with caution, as not all recognized taxonomists participated in it. Therefore, the current assessment does not represent the complete list of taxonomists in Europe, but a sample, in which certain variations are possible. Certain biases became apparent when comparing the number of taxonomists per country with the outcome of the Red List assessment (e.g. only 27 Czech taxonomists registered in the survey while the country had the best Red List Index in the Red List assessment based on the actual output of recent taxonomic publications).

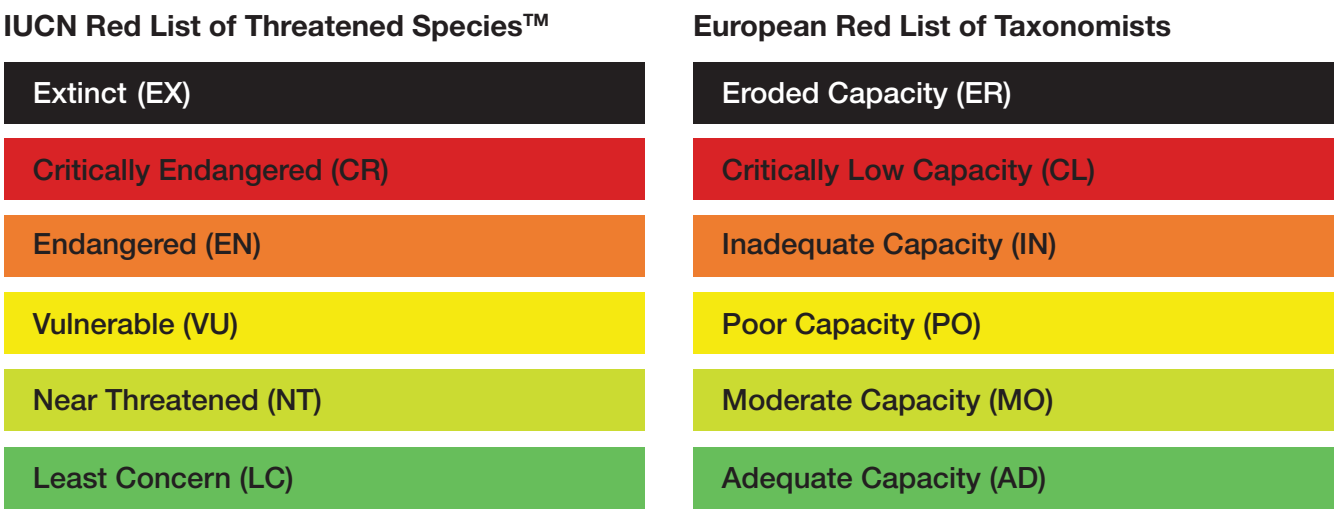


Fig. 1: Equivalences of the Red List categories used in the IUCN Red Lists of Threatened Species™ and the Red List of Taxonomists. The abbreviations, in the brackets, are used throughout the text.

[7] https://cloud.pensoft.net/s/mGpyQYUPQOMPs8C

The names of taxonomic experts were extracted from the scientific literature and from the institutional databases of CETAF and IUCN to pre-populate a database of entomologists who potentially meet the working criteria for taxonomists. This resulted in 2,345 provisional name records. An online self-registration portal was developed to complement, verify and update the initial information through a GDPR-compliant self-declaration process. An outreach campaign was launched to promote the project and the self-registration portal across the extensive networks of the project partners. Between 1 May and 30 November 2021, the portal registered 1,527 self-declared insect taxonomists from 44 European countries, of which 1,196 were from the EU27. The collected data includes the name, gender, age, country of residence and activity, institutional affiliation, ORCID profile (if available), the taxonomic group(s) of interest, and the research outputs available.

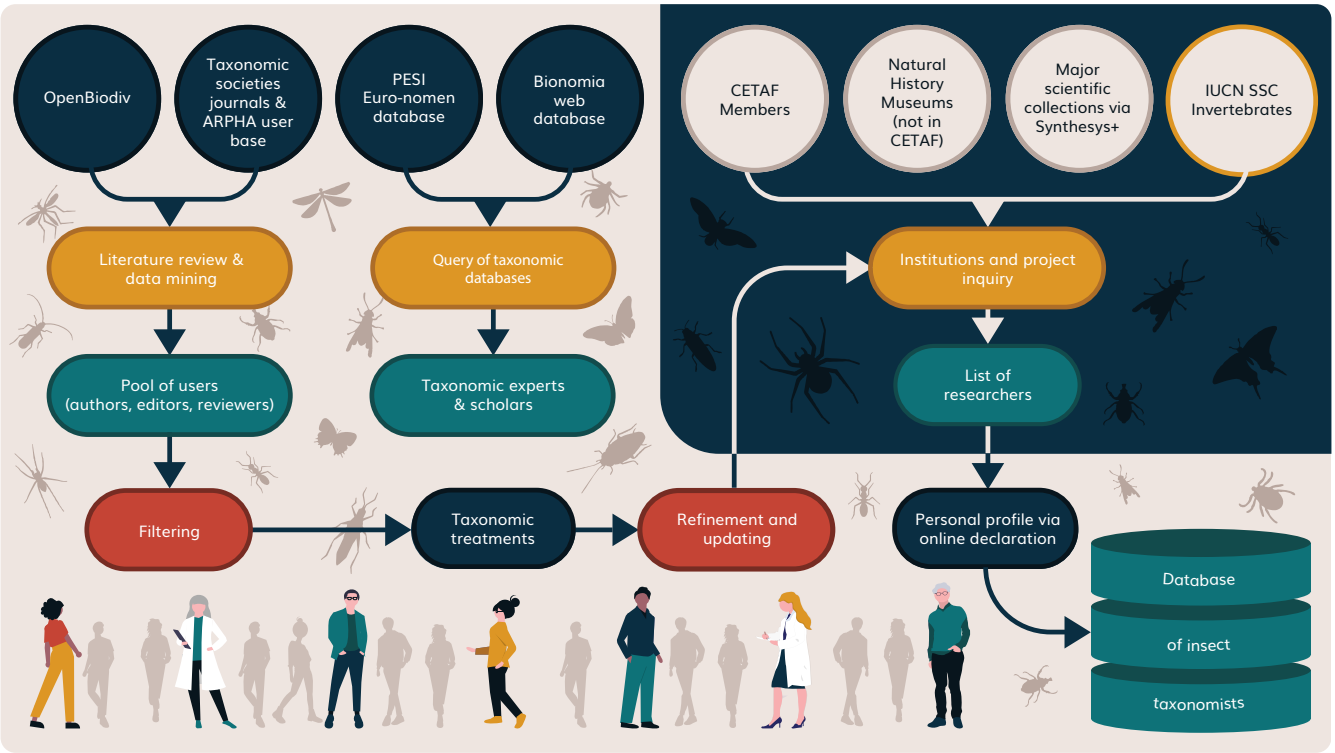


Fig. 2: Process of preliminary identification of taxonomists through literature review and data mining, query of taxonomic databases and institutional inquiry. The final step of self-declaration also aimed to verify the extracted data.

4 Results

4.1 European Red List of Insect Taxonomists

4.1.1 Threat status of taxonomists by insect order in Europe

Overall, taxonomic capacity is threatened (the threatened Categories are Eroded Capacity (ER), Critically Low Capacity (CL), and Inadequate Capacity (IN)) or eroded for 41.4% and 34.5% of the insect orders at the European and the EU levels, respectively (Fig. 3). In Europe, taxonomic capacity is Critically Low for one insect order (Embioptera), Inadequate for four orders and Poor for seven orders. The results for the EU are similar, but the taxonomic capacity for Embioptera is Eroded and two insect orders have Moderate rather than Poor Capacity (Table 1).

Table 1 provides an overview of the Red List assessment for the taxonomic capacity for all insect orders in Europe and the EU. Taxonomic capacity is particularly low for Embioptera (Footspinners or webspinners) and was assessed as Critically Low for Europe and as Eroded for the EU). During the last decade, only one taxonomic publication for this insect order is listed on Web of Science (Hollier 2013) and not a single publication covers taxonomic descriptions of new species or genera or identification keys. However, it should be noted that Embioptera is a species-poor insect order (441 species listed in Catalogue of Life) and only 13 species have been recorded from Europe. Taxa with Inadequate Capacity include Cockroaches (Blattodea), Lice (Psocodea) and Thrips (Thysanoptera).

4.1.2 Threat status by country

The variation in the number of insect orders covered by taxonomists among countries substantially varies (Fig. 4). The highest Red List Index was found for Czechia, in which Adequate Capacity was found for 24 insect orders, while it was Eroded for five orders (Zygentoma, Embioptera, Phasmida, Grylloblattodea, Mecoptera). Germany had the second highest RLI, covering nearly all insect orders (except for Embioptera), but with a Critically Low Capacity for Hemiptera and Psocodea, Inadequate Capacity for Coleoptera, Diptera and Siphonaptera, and Poor Capacity for Thysanoptera, Hymenoptera and Lepidoptera. The lowest RLI was found for countries with a low GDP, such as Albania (RLI: 0.014) covering only a single order (Diptera) with Inadequate Capacity, Azerbaijan (RLI: 0.021) covering two orders (Hymenoptera: IN, Lepidoptera: CL), or Belarus (RLI: 0.062), covering four orders (Hemiptera: IN, Coleoptera: PO, Lepidoptera: IN, Diptera: IN). Figure 5 provides a spatial overview of the taxonomic capacity in European countries based on the Red List Index.

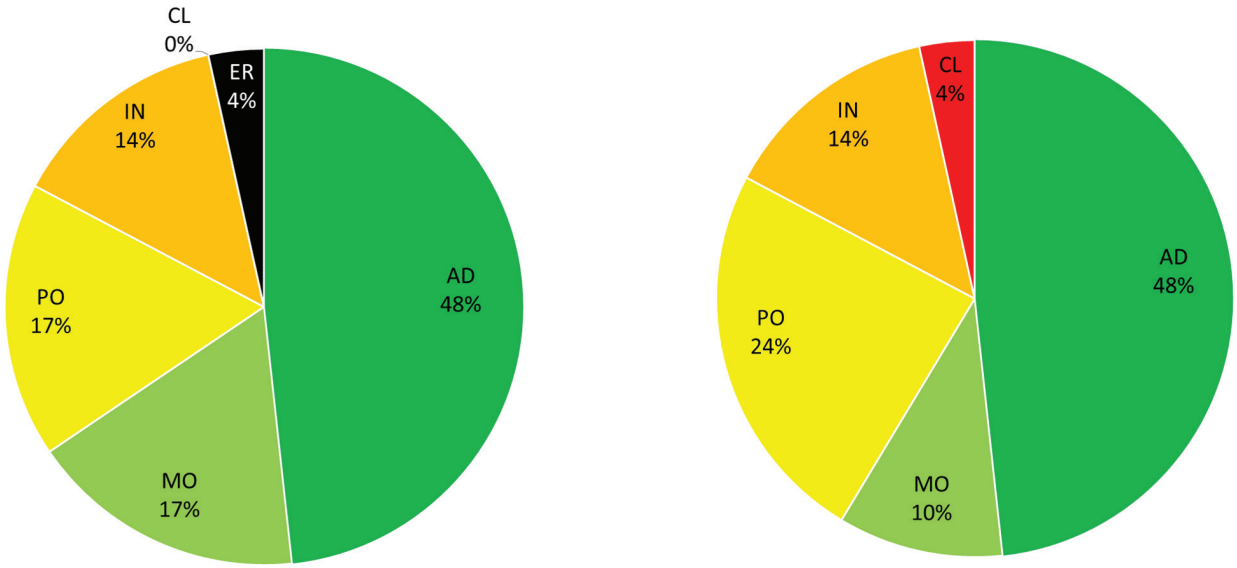


Fig. 3: Overview of the Red List of taxonomist expertise by insect order for Europe (left) and the EU (right); Red List categories are: ER: Eroded Capacity, CL: Critically Low Capacity, IN: Inadequate Capacity, PO: Poor Capacity; MO: Moderate Capacity and AD: Adequate Capacity.

Table 1: Red List assessments for taxonomic capacity by insect order for Europe and the EU.

Order	Common Name	Europe	EU
Archaeognatha	Bristletails	AD	AD
Zygentoma	Silverfishes / Firebrats	AD	AD
Ephemeroptera	Mayflies	AD	AD
Odonata	Dragonflies / Damselflies	AD	AD
Plecoptera	Stoneflies	AD	AD
Embioptera	Footspinners	CL	ER
Zoraptera	Angel Insects	AD	AD
Dermaptera	Earwigs	PO	PO
Mantodea	Mantises	MO	AD
Blattodea	Cockroaches	IN	IN
Isoptera	Termites	AD	AD
Phasmida	Stick Insects	PO	MO
Grylloblattodea	Ice Crawlers	IN	IN
Mantophasmatodea	Gladiators	AD	AD
Orthoptera	Grasshoppers / Crickets	PO	MO
Psocodea	Lice	IN	IN
Thysanoptera	Thrips	IN	IN
Hemiptera	True Bugs	PO	PO
Megaloptera	Alderflies / Dobsonflies	AD	AD
Raphidioptera	Snakeflies	AD	AD
Neuroptera	Net-winged Insects	AD	MO
Coleoptera	Beetles	PO	PO
Strepsiptera	Stylopses	AD	AD
Hymenoptera	Bees / Wasps / Ants	MO	MO
Trichoptera	Caddisflies	MO	MO
Lepidoptera	Butterflies / Moths	PO	PO
Mecoptera	Scorpionflies	AD	AD
Diptera	Flies / Mosquitoes	PO	PO
Siphonaptera	Fleas	AD	AD

When analysing national Red List categories by insect order (Fig. 6.1 for all European countries and Fig. 6.2 for the EU), it was evident that smaller insect orders in particular had lower country coverage. The four largest insect orders (Coleoptera, Diptera, Lepidoptera, Hymenoptera) were all covered by >80% of all countries (in the case of Coleoptera and Lepidoptera even by >90%), but Adequate Capacity was only attained in 26% (Coleoptera) to 58% (Hymenoptera) of all countries. Substantial variation was also found among some smaller insect orders. For example, Adequate Capacity for Ephemeroptera (4,187 species) was found in 65% of all European countries, while for Blattodea (4,898 species) Adequate Capacity existed only in 17% of the countries.

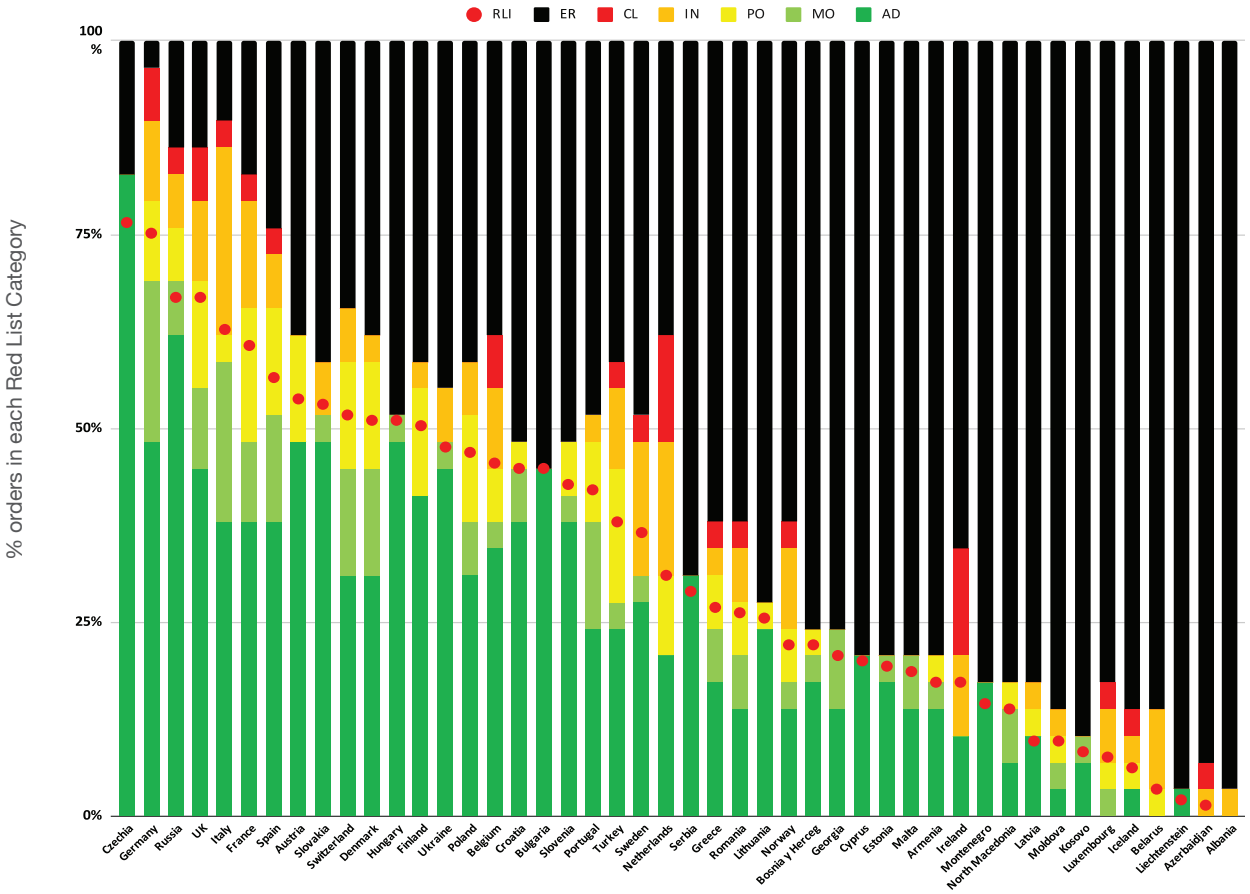


Fig. 4: Red List categories for all insect orders by European country, sorted by Red List Index (red dotted line).

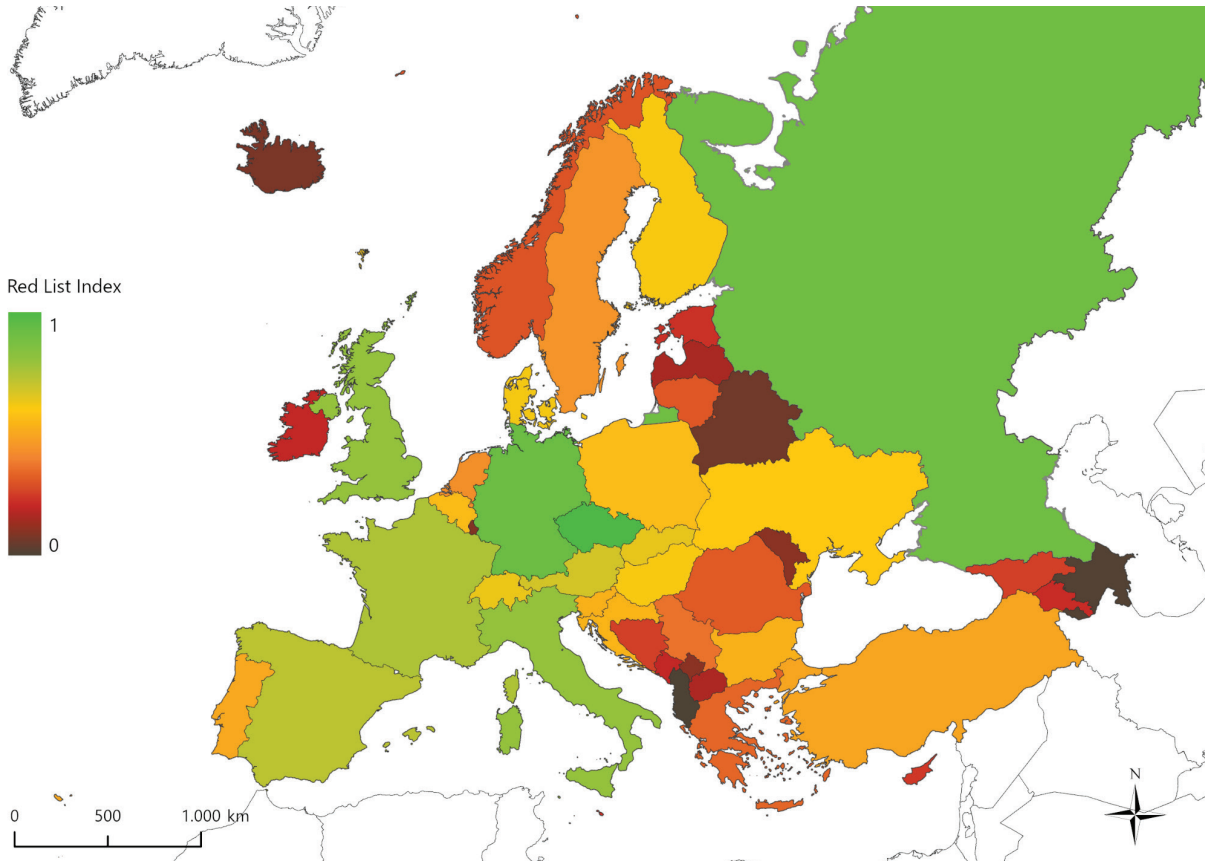


Fig. 5: Overview of the taxonomic capacity in European countries based upon the Red List Index (colour gradient corresponds to the Red List Index value between 0 and 1, where “0” means Eroded Capacity (ER) and “1” means Adequate Capacity (AD)).

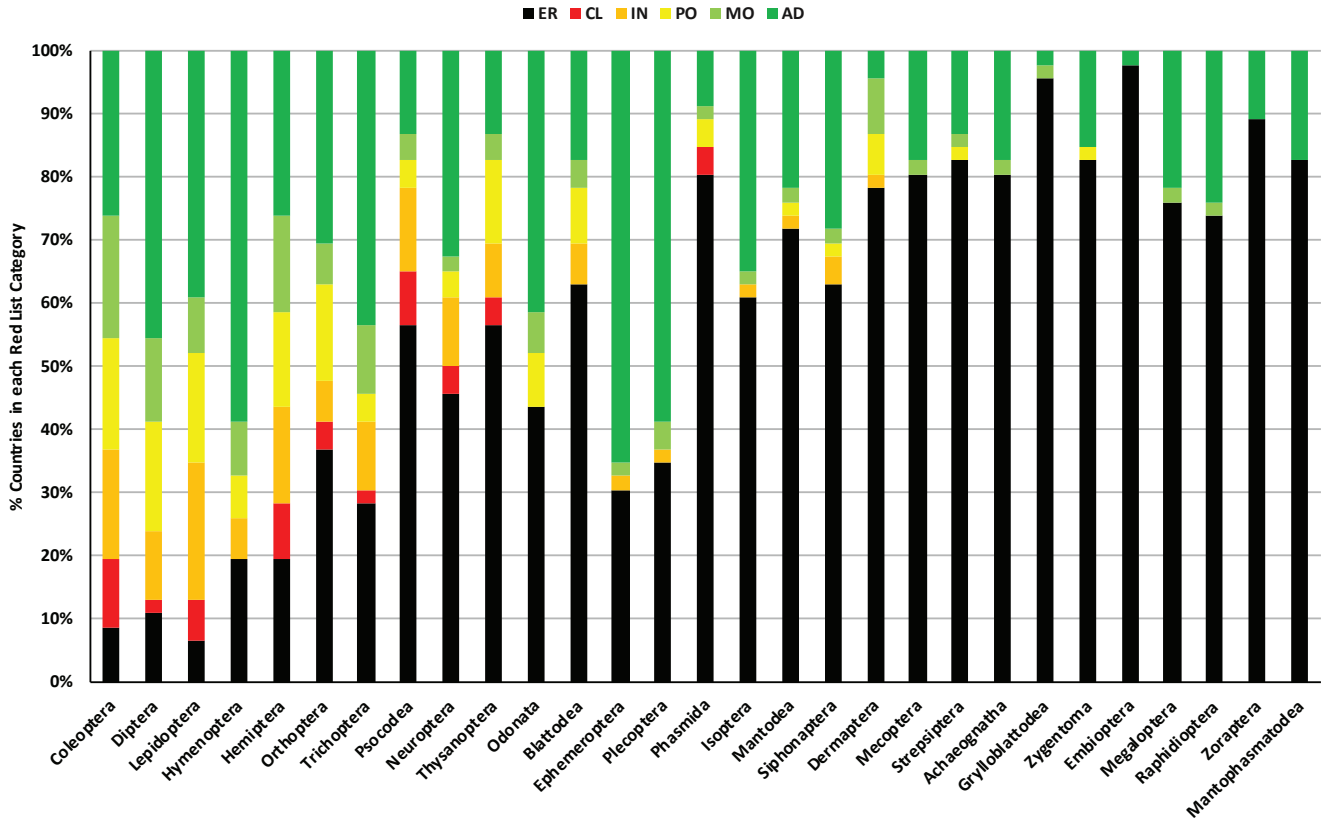


Fig. 6.1: Red List categories for all European countries by insect order, sorted by decreasing species number.

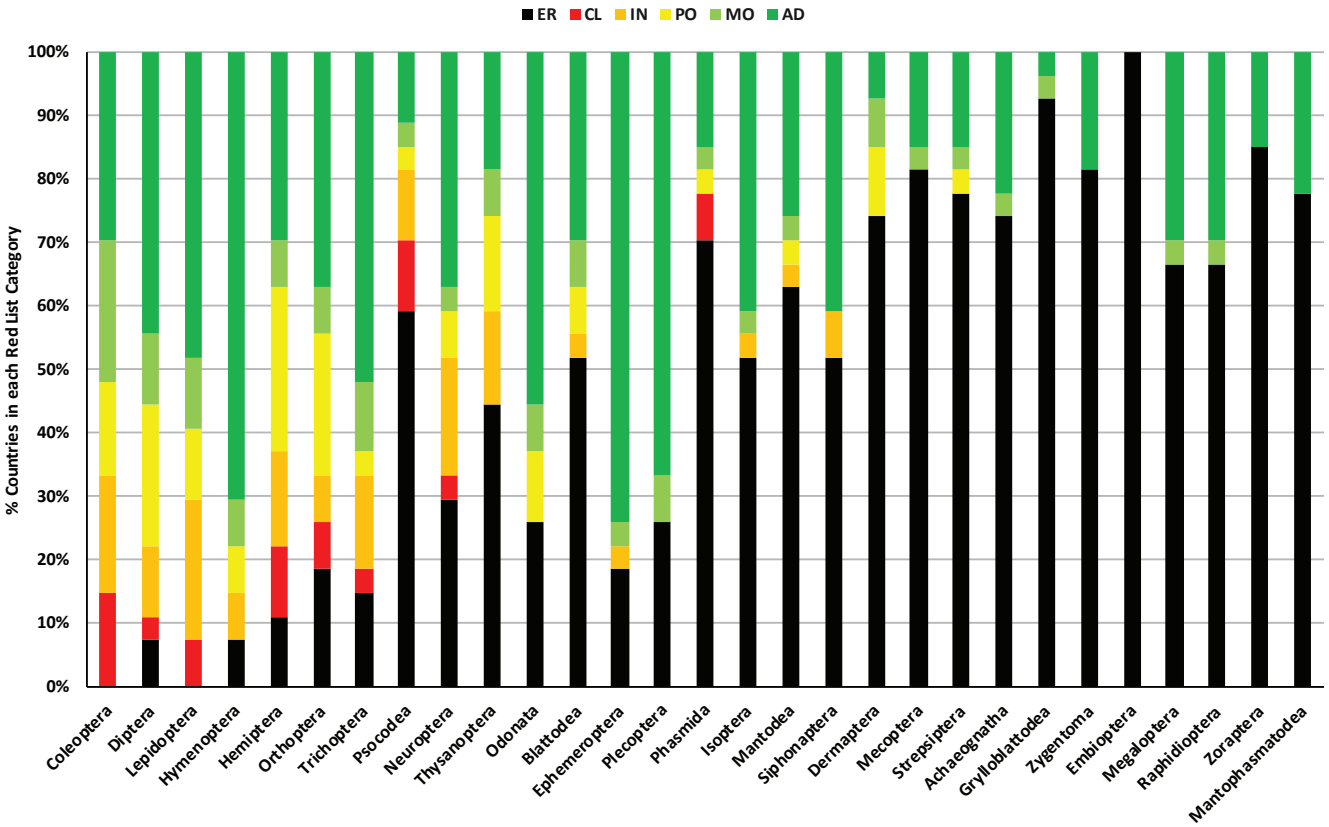


Figure 6.2: Red List categories for EU countries by insect order, sorted by decreasing species number.

4.1.3 Gap analysis for EU countries

To prepare EU countries for tackling the ongoing biodiversity crisis and to enable them to develop suitable insect monitoring schemes and conservation action plans, it will be important to close the obvious gaps in capacity on insect taxonomy at EU level as well as at national level. Therefore, a priority list has been developed based on the Red List analysis and the survey results.

Taxonomic capacity can mainly be built at a country level by securing continuity of taxonomic research in museums, institutes, universities or similar structures; by developing suitable conditions where experts either are lacking or disappearing and by creating permanent jobs for taxonomists while reducing competition with other disciplines (see Section 4.3.2 below). The European Union could provide funding mechanisms or resource allocations to support countries in developing capacity in insect taxonomy or reaching more favourable levels of taxonomic capacity. Obviously, it is not necessary that all countries (particularly the smaller ones) cover all insect orders, but at least the most species-rich taxa, which also contain numerous pollinators, need to be covered. Our Red List analysis at the national scale helps to identify major gaps in coverage. At the EU level, the following insect orders need special attention (sorted by species number):

Coleoptera (PO) Adequate coverage is only present in eight EU countries. Capacity building is particularly required in Greece and Romania, which have a Critically Low Capacity but a high species richness. At the EU level, taxonomic capacity is Inadequate or even Critically Low for many pollinating Coleoptera families, such as Curculionidae, Chrysomelidae, Scarabaeidae, Cerambycidae, Elateridae and Cantharidae. It is thus strategically advisable to prioritise funding for taxonomic research on these species-rich families, particularly in countries with low capacity for Coleoptera taxonomy.

Diptera (PO) Twelve EU countries have Adequate Capacity for Diptera taxonomy. Eroded Capacity has been identified for Cyprus and Luxembourg. Even though these countries are small and, therefore, unlikely to build capacity for all insect taxa in the short term, the five most species-rich insect orders (including Diptera) should be covered. Diptera contains numerous important pollinators and is, therefore, a vital insect order to cover. A Critically Low Capacity has been revealed for Ireland. However, it needs to be considered that not all taxonomic publications are listed on Web of Science. Hoverflies (Syrphidae) are, for example, part of the All-Ireland Pollinator Plan[8] and good identification literature for hoverflies is available for Irish hoverflies. The need for alpha taxonomists is stronger in southern European countries, such as Italy and Romania (which have Inadequate Capacity). There is some obvious variation in taxonomic capacity among Dipteran families. While the Syrphidae and Calliphoridae have Adequate Capacity on the European and EU scale, the capacity for Bombyliidae, Tabanidae, Lauxaniidae and Mydidae is Critically Low and for the Blephariceridae even Eroded. Targeted funding mechanisms for such Diptera families can help to close these gaps.

Lepidoptera (PO) Even though butterflies are extremely popular among citizens and also in science, the taxonomic capacity for this species-rich insect order is Poor. This is mainly due to the high species numbers of moths and Microlepidoptera, many of which are nocturnal. In the EU, taxonomic capacity for Lepidoptera is Critically Low in Ireland and Luxembourg. Even in large countries, taxonomic capacity on Lepidoptera is Inadequate in France and Italy and Poor in Germany and Spain. On the family level, taxonomic capacity is Critically Low for Crambidae, Arctiidae, Oecophoridae, Notodontidae and Cosmopterigidae. The largest Lepidopteran families (Noctuidae and Geometridae) both have Inadequate Capacity in Europe.

Hymenoptera (MO) While the taxonomic capacity for Hymenoptera at the European and EU levels is Moderate, this may be influenced by incomplete species lists in the major global databases, such as Catalogue of Life. Within the EU, taxonomic capacity for Hymenoptera is Eroded in Luxembourg and Latvia, Inadequate in Ireland and Slovakia and Poor in Germany and Croatia. Notably, there is considerable variation between Hymenopteran lower taxonomic groups. While taxonomic capacity is Adequate for Formicidae and Vespidae, it is Critically Low for the Eumenidae and Inadequate for Pompilidae and Ichneumonidae.

[8] https://pollinators.ie

Hemiptera (PO) Only eight EU countries have adequate coverage of this species-rich insect order. Taxonomic capacity is Eroded in Latvia, Estonia and Malta. Even countries with high GDP have a Critically Low Capacity (Germany, Sweden), Inadequate Capacity (Italy, Netherlands) or Poor Capacity (France, Spain). The Hemiptera family Anthocoridae is known to contain pollinators (Wardhaugh 2015), but for this family, capacity is Adequate at the EU scale.

Orthoptera (MO) Taxonomic capacity is Adequate in ten EU countries, but Eroded in Ireland, Greece, Lithuania, Latvia and Cyprus. Among the larger European countries, taxonomic capacity is Critically Low in Belgium and the Netherlands, Poor in Spain and Austria and Moderate in Italy. However, this may also be influenced by the good identification literature available in these countries. Orthoptera contains some pollinating groups, in Europe particularly the Tettigoniidae may be relevant, for which a Moderate Capacity has been identified at the EU level.

Trichoptera (PO) In the EU, taxonomic capacity is Adequate in 14 countries, but Eroded in Estonia, Cyprus, Latvia and Malta. Among the larger EU countries, it is Critically Low in the Netherlands, Inadequate in Italy, Poland, Belgium and Ireland and Moderate in Germany and France.

Psocodea (IN) Taxonomic capacity for Psocodea is overall Inadequate in the EU. Nearly all European countries need to build or increase taxonomic capacity for this insect order. Adequate Capacity is only present in Czechia, Croatia, Hungary, Slovenia and Malta. Funding mechanisms for taxonomic research on Psocodea are, therefore, required at the EU level.

Thysanoptera (IN) The role of thrips as pollinators is probably understudied and the taxonomic capacity on this insect order is Inadequate at the EU level with Eroded Capacity in twelve countries. Adequate Capacity is only present in five countries (Bulgaria, Czechia, Croatia, Hungary, Slovakia). Increased efforts to build taxonomic capacity for this insect order are therefore required at the EU level.

Blattodea (IN) Adequate Capacity for Blattodea exists in only eight EU countries and even some larger countries (Spain, Poland, Sweden, Ireland) have Eroded Capacity for this insect order. Some Blattodea (Ectobiidae) are known to be pollinators (Wardhaugh 2015) and, therefore, require increased attention in the mainstreaming of ecosystem services.

Dermaptera (PO): Dermaptera taxonomy has Adequate Capacity only in two EU countries (Germany and Czechia). As a smaller insect order, taxonomic coverage is not required in all countries, but it is even Eroded in some larger ones (Sweden, Belgium, Austria, Ireland) and Poor in France, Italy and the Netherlands.

Embioptera (ER) The Embioptera are the only insect order with Eroded Capacity in the EU. As this insect order is very small (447 species described so far), and only fifteen species are recorded in Europe, it would not be necessary to build taxonomic capacity for it in all EU countries. However, given the important role European taxonomists play in building taxonomic capacity in developing countries at least a minimum coverage is advisable. Particularly the countries with high GDP and the existence of large research museums (Germany, France, Italy, Spain and Netherlands) should increase their efforts to build taxonomic capacity for Embioptera.

4.2 Main characteristics of the European taxonomic community

The self-assessment survey resulted in 1,527 identified taxonomists in Europe and 1,196 in the EU. The following sections describe the main characteristics of the European taxonomic community based on the analysis of the survey results. Further details can be found in the Annex to this report.

4.2.1 Geographical distribution

As per their country of residence, a total of 491 registered taxonomists (32% of the total) are concentrated in three countries, Germany (180), Spain (169) and Italy (142), followed by Russia (77), Poland (64) and the United Kingdom (53). Altogether, they represent nearly half of the registered taxonomic experts in Europe (Fig. 7).

4.2.2 Gender

Male taxonomists in Europe are by far predominant with a representation of 81% vs. 19% of taxonomists identifying as female. The gender balance for the EU is similar with an even lower percentage of women of 18 % vs. 82% men (Fig. 8).

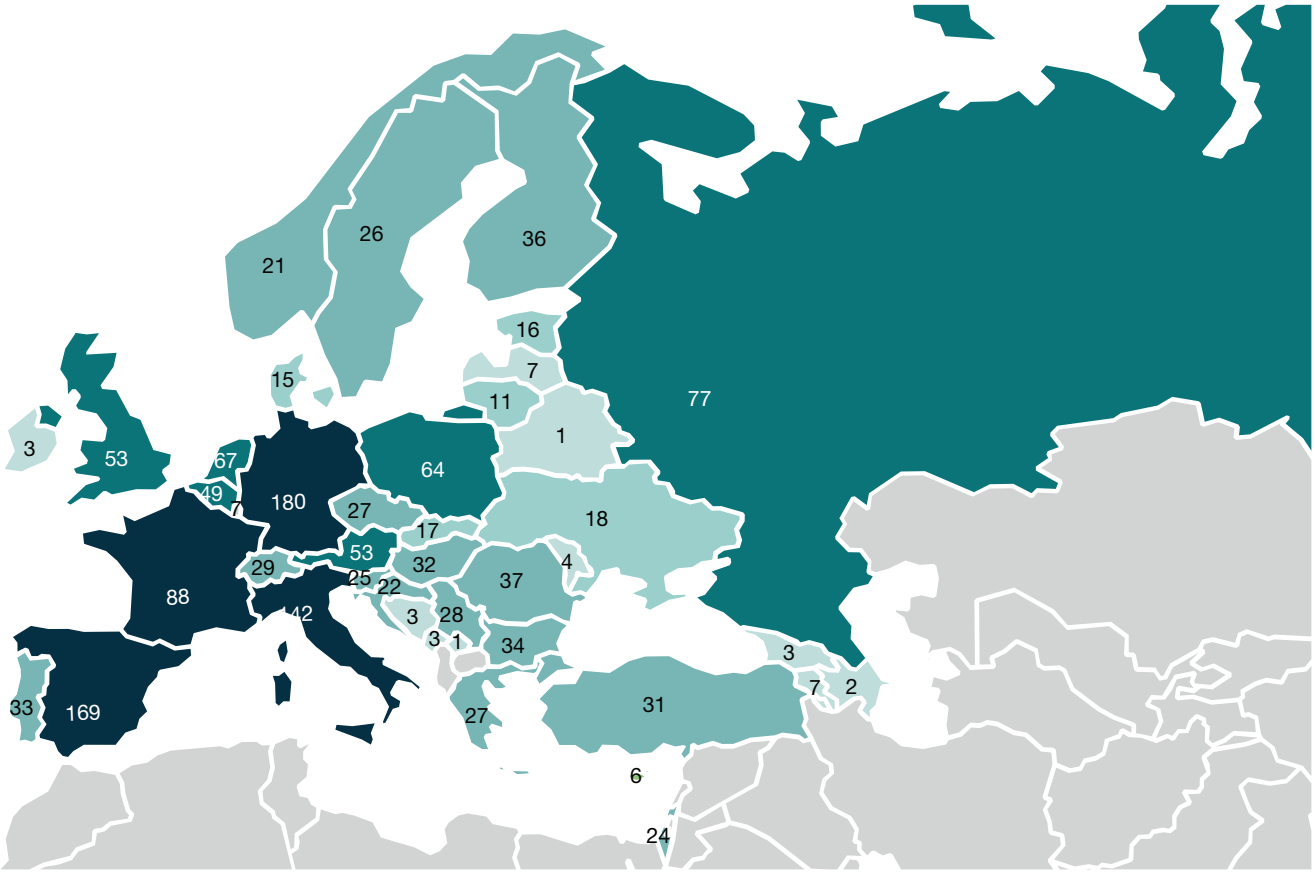


Fig. 7: Geographic distribution of surveyed taxonomists (numbers show the number of respondents to the survey, who self-declared themselves as "taxonomists").

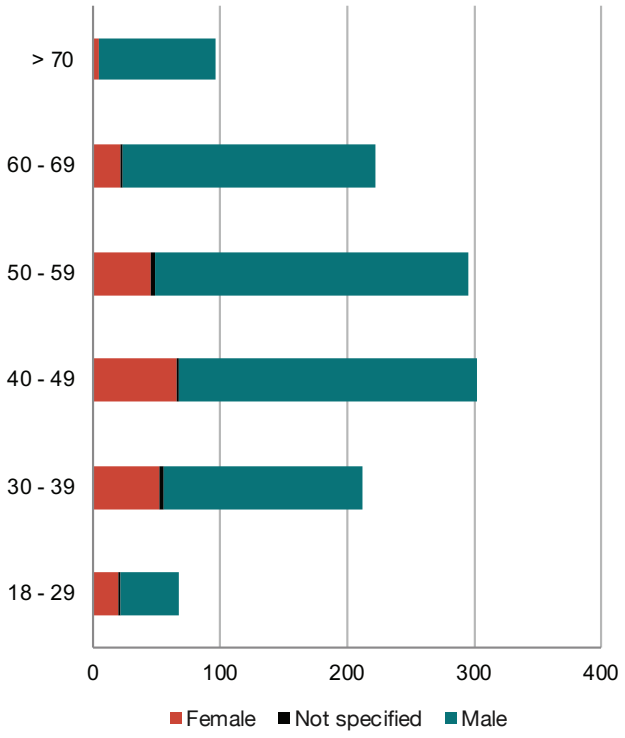


Fig. 8: Gender and age distribution of European taxonomists.

4.2.3 Age

Half of the taxonomists are within the 40 to 59 age group, 19% in the 60 to 69 group and 8% 70 or older. The least number, just 6%, are early career researchers. This age structure corresponds to the fact that young graduates must advance in their level of qualification and publication record before they become taxonomists, as confirmed by the data on education and qualification.

4.2.4 Professional experience

More than half of the respondents have been active for more than 20 years, nearly 30% for 30 or more years, while in the other extreme, young taxonomists (with less than 5 years of experience) count for less than 9% (Fig. 9). Fewer than 25% of respondents are in the early career stage, with less than 10 years of experience as taxonomists. This may be explained by the fact that taxonomic skills are developed after years of study and experience. This is confirmed by the data on education level.

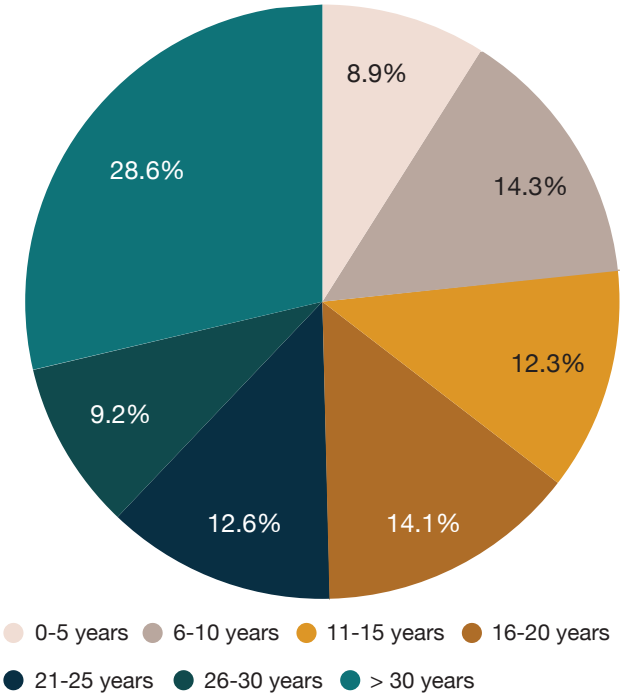


Fig. 9: Number of years of professional experience.

4.2.5 Qualification

Classified by the highest level of qualification obtained, the respondents are overall (91%) university graduates, a large majority of whom hold doctoral or postdoctoral degrees (60%) (Fig. 10).

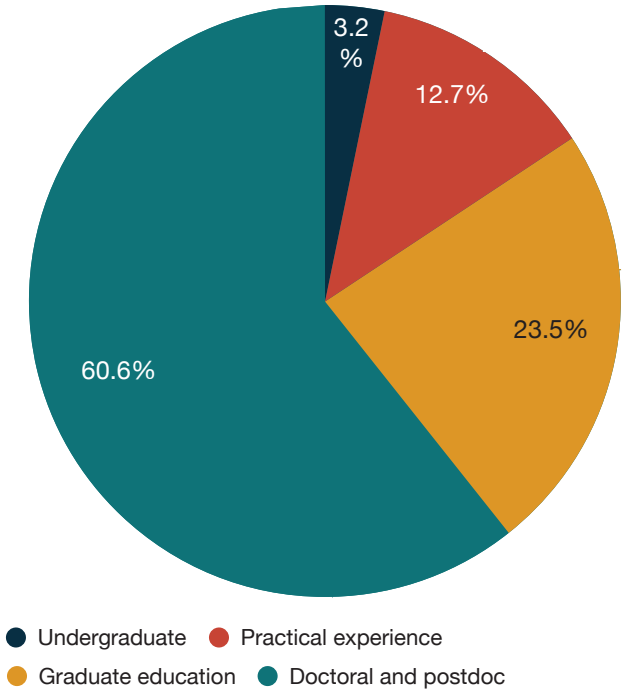


Fig. 10: Level of qualification of European taxonomists.

4.2.6 Employment status

More than half of the respondents were permanently employed as researchers in research institutions (Fig.11) but it does not mean they are necessarily employed as taxonomists. In addition, more than one in four taxonomists are actively contributing to taxonomy on a non-dedicated basis, either as volunteers (18%) or as retired taxonomists (9%). Even fully employed experts may have other job descriptions, leaving them with little time for taxonomic research, as researchers are rarely employed for taxonomic research only.

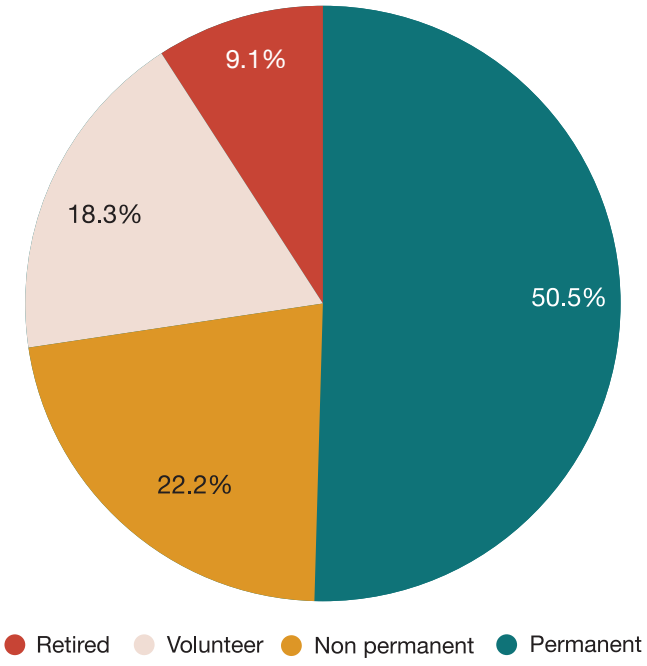


Fig. 11: Employment status of European taxonomists.

4.2.7 Research focus

Another aspect of the survey looked into the research focus of taxonomists, in terms of taxonomic discipline, taxon of primary interest, and research method.

Discipline: almost three out of four taxonomists are dedicated to both taxonomy and faunistics[9], while 14% are only in faunistics and the remaining 13% only work in taxonomy (Fig. 12).

Taxon of interest: The five largest insect orders capture most of the interest (74%) of taxonomists: Coleoptera

[9] Taxonomy deals predominantly with the evolutionary classification of taxons while faunistics – with their geographical distribution and occurrence on a given territory.

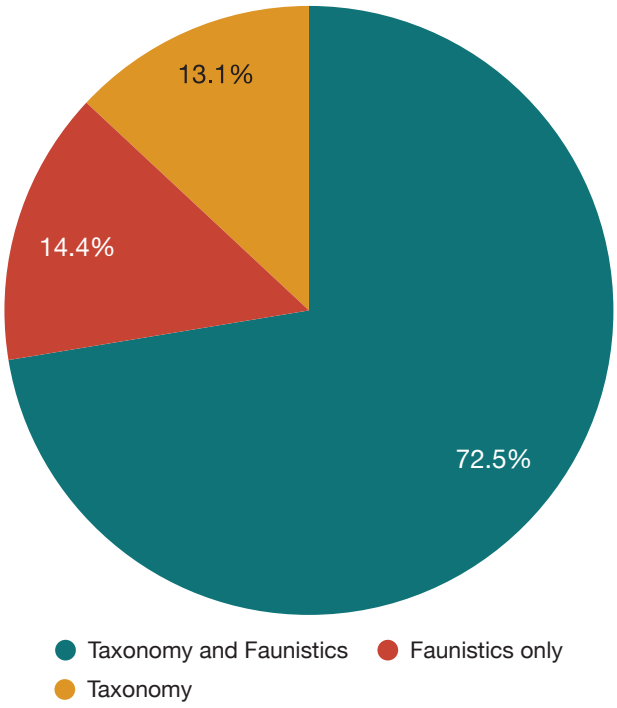


Fig. 12: Primary research discipline of taxonomists in the EU.

(24%) Lepidoptera (13%), Hymenoptera (16%), Diptera (13%), Hemiptera (8%). This, however, does not guarantee sufficient capacity for these orders as the number of species within them is proportionately larger than the number of taxonomists investigating them (see Red List gap analysis) (Fig. 13).

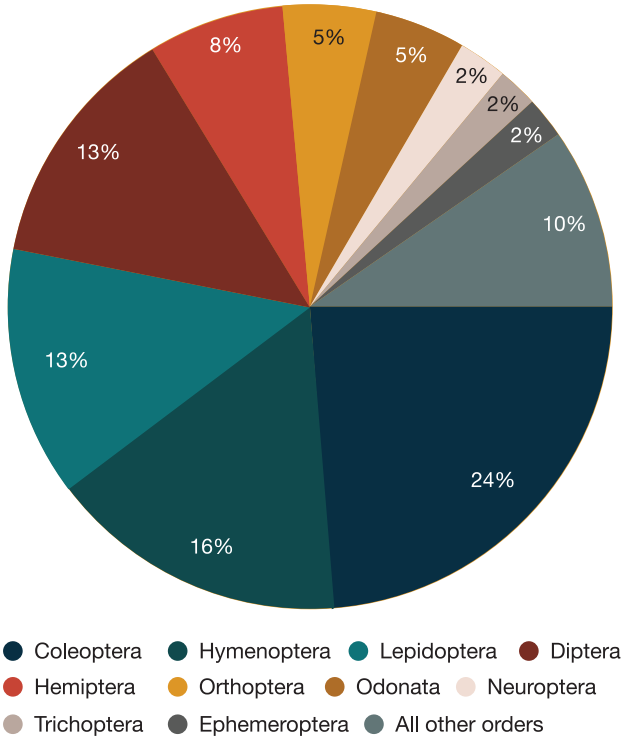


Fig. 13: Primary focal taxonomic group of European insect taxonomists.

Research method: a total of 56% of taxonomists are focused on traditional taxonomy, using morphological methods at the core of their research. Molecular analysis is also extensively utilised with a 22% share and integrative approaches that apply both methods being the third most important method, used by 17% of taxonomists. (Fig. 14). With respect to age, there seems to be a clear increase in interest in integrative and especially molecular research methods among younger generations of taxonomists (Fig. 15).

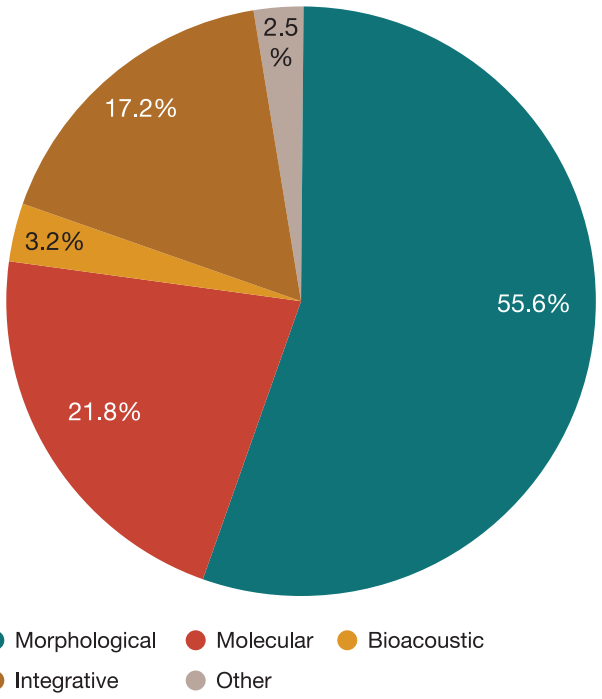


Fig. 14: Primary research method pursued by European taxonomists.

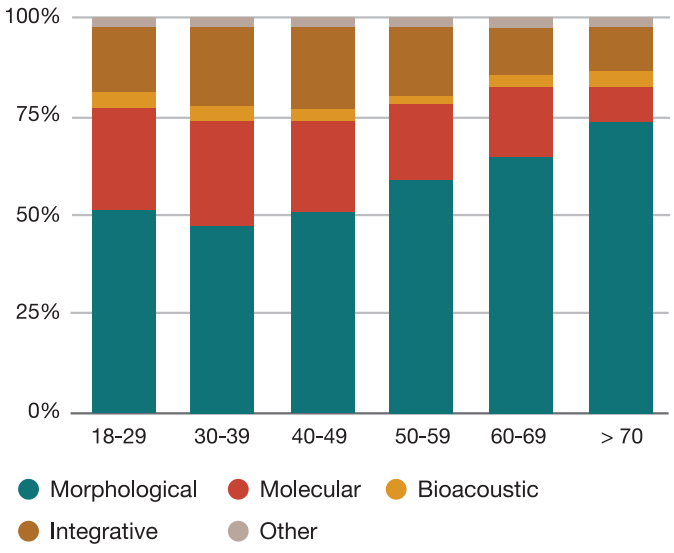


Fig. 15: Primary research method by age group.

4.2.8 Teaching and networking

More than 61% of taxonomists teach and therefore ensure transfer of knowledge through formal education. The same percentage applies to taxonomists who are members of academic societies, which implies strong networking with peers and collaborators.

4.3 Better understanding the European taxonomic community

The results of the Red List assessment, the taxonomic survey and the expert consultations were used to analyse the current status of taxonomic expertise on insects in the EU, and the underlying reasons behind its erosion.

4.3.1 Interest in taxa studies/capacity per insect orders

The four largest insect orders were also the most studied orders from the survey (Coleoptera, Hymenoptera, Lepidoptera and Diptera), but due to their extremely high species numbers these orders do not reach the Adequate levels of expertise capacity in the Red List, rather they are assessed as Poor Capacity (PO) or Moderate Capacity (MO). However, species richness alone does not purely explain taxonomic capacity. Some orders with relatively low species richness are also assessed as Critically Low or Eroded, such as Embioptera. In some cases, this might be explained by the distribution of taxa, like Grylloblattodea or Embioptera, which do not occur in Europe or have only a few species here. Other aspects that may determine the level of taxonomist capacity are body size and colouration. Insect orders with large and colourful species (e.g. dragonflies, butterflies) have better taxonomic capacity than groups with small and less colourful species (like Psocodea or Thysanoptera). Other factors that may explain the level of taxonomic capacity for an insect order may be their use as ecological and bioindicators. For instance, Ephemeroptera and Plecoptera, which have an Adequate Capacity assessment, are both indicators of freshwater quality. Both insect orders have a fairly high number of registered experts (50 Ephemeroptera experts, 35 of which have permanent positions, 39 Plecoptera experts, 22 with permanent positions). Thus, the use of mayflies and stoneflies in freshwater monitoring schemes may have created a higher demand for mayfly and stonefly taxonomists as well as taxonomic training (25 of the Ephemeroptera experts and 18 Plecoptera experts provide training). The new initiative to develop a European pollinator-monitoring scheme might thus increase the number of taxonomic positions for Lepidoptera, Diptera and Hymenoptera as well. However, it should not be forgotten that commonly neglected pollinator taxa (some beetle families, moths, non-syrphid flies, wasps, thrips, flower bugs, bush crickets) may require special attention, as the proposed European pollinator monitoring scheme is set to focus on wild bees, hoverflies and butterflies in the short term (Potts et al. 2020).

4.3.2 Capacity at country level

A country's taxonomic capacity is strongly correlated to GDP, although there are some exceptions. For example, Czechia and Poland have a very good capacity compared to some other countries that have a higher GDP such as the Netherlands. The reason for this might be found in research traditions, but also in a lower level of scientific transformation. Several large research museums in western European countries have changed their research focus towards more "modern" disciplines and former taxonomic researchers were replaced by modellers, phylogeneticists etc. In the Netherlands, all former entomological collections have been transferred to Naturalis in Leiden, with a significant loss of taxonomic poistions overall. The number of taxonomists within a country does not always mean adequate taxonomic capacity (in terms of insect orders covered). Countries with higher Red List Index scores also had a higher number of institutions (natural history museums, national academies of sciences, research institutes) where taxonomy was practised, compared to those with low Red List scores, even though the number of institutions may be linked to GDP. The main reason for taxonomic erosion in countries discussed during the workshop is a lack of funding towards taxonomy. Even Germany, the country with the highest GDP in Europe, experiences significant taxonomic erosion for some insect orders. Lack of funding appears to be a key factor explaining the erosion of taxonomic capacity. Taxonomic publications receive lower citation rates by their very nature. As long as citation indices are used in funding decisions for which taxonomists apply and compete with scientists from other disciplines, research institutes will continue to replace taxonomists with experts in other fields (e.g. evolutionary biologists, ecologists etc.). In addition, taxonomic journals are traditionally ranked low in Web of Science and Scopus and this makes authors look for other thematic journals and thus change the focus of their research.

Entomologist doing field work. Photo: Gabriela/stockadobe.com

The erosion of taxonomic capacity by country appears to be less severe for insect taxa that are necessary for freshwater monitoring (Plecoptera, Ephemeroptera) than for other insect taxa. Pollinators show a highly variable Red List pattern. While taxonomic capacity is Adequate for some butterfly families (e.g. Nymphalidae, Pieridae, Papilionidae), it is Critically Low for longhorn beetles (Cerambycidae), bee flies (Bombyliidae) or potter wasps (Eumenidae). EU countries with Eroded Capacity for Hymenoptera include Latvia and Luxembourg, and for Diptera Cyprus and Luxembourg. Taxonomic Capacity is Critically Low for Coleoptera in Greece, Ireland, Netherlands and Romania, for Diptera in Ireland, and for Lepidoptera in Ireland and Luxembourg.

4.3.3 Ageing

The self-assessment survey indicates that there is a strong age bias in taxonomic expertise towards the older age groups, with the age group 40 - 49 being the most represented, followed by 50 - 59; 60 - 69. The fact that the age group 18 - 29 is the lowest represented suggests that the taxonomist population is ageing, with insufficient supplementation of young early career taxonomists. The bias may be even stronger when considering that older persons may be less likely to take part in online surveys (Wagner et al. 2018). One possible reason for a low proportion of young taxonomists could be due to limited opportunities for professional training, which was shared during the expert workshop, and the fact that not all professional taxonomists provide training. At the same time, a significant number of taxonomists are employed in museums and opportunities for interaction with university students is probably not optimal. This reasoning is further supported by the outputs of the workshop where there was an expressed need for more outreach towards young people in regards to providing hands-on experience of how species are identified (i.e. the different techniques used) (see further information in the Annex). Another possible reason highlighted by the workshop was the lack of permanent jobs in taxonomic research. Most jobs in museums now focus either on the exhibition part or on putatively more

"modern" types of research. Other reasons for such an age bias, as indicated by the community in the workshop, are the low engagement of new generations and old-fashioned perceptions of the discipline. Moreover, younger scientists more often use molecular methods or integrative taxonomy compared to older taxonomists, who tend to focus on morphological methods.

4.3.4. Gender balance

There is a clear gender bias among European taxonomists across the major parameters, for instance, age, taxa of interest, country and professional status/seniority. In terms of gender bias across age groups, it is least extreme for the youngest age group (18 - 29). However, this could be an artefact of the low number of taxonomists in this age group. Also, the low gender bias in Greece, Cyprus and Ukraine may be an artefact of the low number of taxonomists represented in these countries. For some taxa (e.g. Orthoptera), a stronger gender bias is observed compared to others. Ephemeroptera has the weakest gender bias, this being perhaps a consequence of their use as bioindicators. With regard to gender bias and seniority it could be inferred, although cautiously, that seniority progress is slower or less for women compared to men as there is a higher proportion of women in the 'middle aged' groups (40 - 49 and 50 - 59) in junior researcher positions, fewer men in the same age classes hold junior positions. This is also supported by the survey data, in that women appear to have significantly less experience, and men appear to have more practical experience at a younger age compared to women. It is difficult to pinpoint gender bias for each country. Based on the discussions in the expert workshop, it can be inferred that the gender bias is most likely the result of general social equality issues and the traditional views of what taxonomists are (i.e. "middle-aged men"), and the fact that taxonomic activities (which involves collecting and insects) are considered men hobbies (Belk and Warendorf 1994). Another reason could be the lack of visibility of women taxonomists and taxonomists from diverse backgrounds (from all genders, social backgrounds, ethnicity, etc). This is indicated by the taxonomic communities' expressed need for more outreach toward society. From these results, gender bias is very likely caused by multiple factors, including lower opportunities for women to be exposed to taxonomic research and gain an interest, limited career opportunities as well as discrimination of women in hiring decisions. Making the playing field fair for all genders will be crucial to address these shortcomings and close the gap.

4.3.5 Parataxonomy and citizen science

The general increase in citizen science projects in recent years is evident in entomology. For example, twenty different projects are listed on the EU citizen science platform[10] under the category Insects and Pollinators. Parataxonomists can be seen as 'biological diversity technicians' (Duelli 1997) who are not necessarily fully-fledged experts in the taxonomy field. However, if they are skilled enough to separate specimens in 'morphospecies' by eye (Guerra-Garcia et al. 2008) their involvement has the potential to greatly increase the efficiency of monitoring and research on insects. This preliminary work greatly facilitates data collection for studies at a larger scale and in regional monitoring networks, including citizen science networks.

The involvement of taxonomists in citizen science projects and networks is beneficial in two main ways. Firstly, it increases the capacity for insect observation, recording and species identification; and permanent and constant quantitative monitoring (e.g. via photos, geo-coordinates and other types of metadata). Secondly, it exposes citizens to the skills of taxonomic identification, which increases their own knowledge and appreciation for insect taxonomy and thus many of them join the ranks of parataxonomists. Furthermore, citizen science projects rely on and involve a large number of experts, including taxonomists, to verify the incoming records. Recent studies (Richter et al. 2021) among citizen scientists in several countries revealed the primary motivations for members of the public to participate in citizen science projects are intrinsic, such as "to have fun" and to "do something (good) for nature" and extrinsic, such as "contribute to science", "contribute to nature conservation and "learning". The study showed that participants welcome training on insect identification.

[10] https://eu-citizen.science

5 Recommendations

In order to address the significant deficit in insect taxonomic expertise within the EU and across Europe as a whole, and ensure the long-term sustainability of taxonomic capacity in Europe, this chapter presents three sets of recommendations – on strategic, science and societal engagement. They are implicitly linked and mutually supportive, thus, they should not be taken in isolation, but implemented holistically.

Strategic recommendations (STR) - providing the framework to foster taxonomy

A. **Funding requirements and allocation:** to provide targeted and long-term funding specifically directed at sustaining and increasing taxonomic capacity across Europe.

B. **Policy development:** to integrate the essential role of taxonomists into policy formulation and implementation at the EU and national level.

Science recommendations (SCI) - reinforcing the far-reaching impact of taxonomy

A. **Knowledge:** to ensure the continuous overview of the available taxonomic capacity including periodically reassessing the European Red List of Insect Taxonomists and expanding the approach to other species groups.

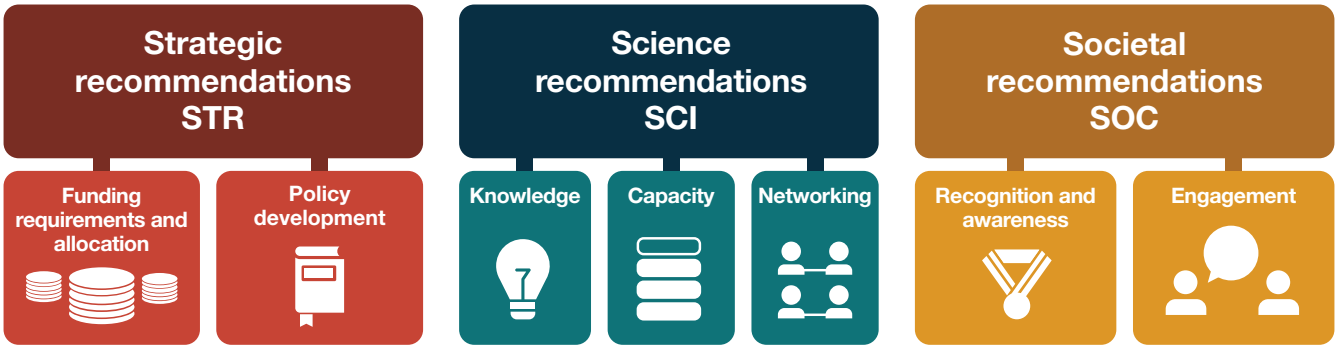
B. **Capacity:** to increase taxonomic capacity through dedicated knowledge exchange, education, training and development opportunities for professional taxonomists.

C. **Networking:** to promote networking among taxonomists, including by maximising the use of modern technologies in research, publishing, and knowledge exchange.

Societal recommendations (SOC) - engaging society in taxonomy

A. **Recognition and awareness:** to increase the understanding and acknowledgement of the importance of taxonomic expertise by using effective means of public communication.

B. **Engagement:** to actively engage citizen science initiatives in insect taxonomic research in order to maximise the synergies and in supporting efficient research and cost-effective monitoring of biodiversity.



5.1 Strategic recommendations (STR)

Providing frameworks to foster taxonomy

A. Funding allocation – adequate resources in terms of quantity and availability, in the long run, is a pivotal component of a sustainable framework for taxonomy. Funds are necessary to achieve:

- Stability in the way funding for taxonomy is provided
- Balanced taxonomic expertise distribution
- Centralised information on taxonomic expertise
- New generations' vocational dedication
- Secured taxonomic positions
- Improved evaluation criteria for professional careers

RECOMMENDATION STR-A1

Develop targeted and sustainable funding mechanisms to support taxonomy

The European Commission should *secure stable funding for insect taxonomy* as an essential element of basic research, and the fundamental building block of applied research and innovation. This should facilitate the consolidation and improvement of taxonomic expertise across Europe. To that end, the work programmes and calls under the Horizon Europe and subsequent EU Framework Programmes for Research and Innovation should include taxonomic capacity-building objectives that could maintain permanent professional positions in taxonomy.

Example: Launch a regular targeted Horizon Europe **calls to study important insect groups** for which taxonomic capacity is Inadequate or Critically Low at the EU level (e.g. Coleoptera, Hymenoptera), with a special emphasis on taxa with an important role in ecosystems, provision of ecosystem services and human health.

RECOMMENDATION STR-A2

Invest in projects that aim at closing the gaps in taxonomic capacity at national levels

EU countries should provide *investment in projects, programmes and institutional development measures* that support the targeted development of taxonomic capacity to cover the existing gaps in taxa, geographical areas, countries and/or vulnerable ecosystems.

Example: Creation of a natural history museum or entomological research institute, a taxonomic facility, in Romania (high species richness but Critically Low Capacity).

RECOMMENDATION STR-A3

Support the use of a central European information hub on taxonomic expertise

The EU (EC/EEA) **should allocate funds to support the creation and maintenance** of an overarching *portal or platform that provides updated and targeted information on the available taxonomic expertise* across Europe. This would

provide a centralised roster of taxonomic expertise in the EU and thus facilitate the efficient allocation and mobilisation of experts in relevant knowledge centres.

Example: expansion of the existing database under the Red List of Taxonomists, to be connected to the CETAF Registry of Collections, Research and Expertise and further linked to the Knowledge Centre for Biodiversity. The EEA could also play a role in setting up and running such portal/platform, e.g. through the European Topic Centre (ETC) on Biodiversity and Ecosystems 2023-2026

RECOMMENDATION STR-A4

Stimulate research careers in taxonomy, through relevant established educational and research-funded programs (with improved support for women)

The European Commission should *include specific references to taxonomy in the Marie Skłodowska-Curie and ERASMUS programmes with dedicated courses.* Additional financial support should be provided for women to aid the conciliation between family and work life (e.g. child-care expenses). This may help reduce gender bias in taxonomic expertise.

Example: to **launch specific funding calls for the insect taxonomy**, differentiated from other fields, such as ecology or phylogenetics, to reduce transdisciplinary competition, with criteria to encourage women participation.

RECOMMENDATION STR-A5

Ensure long-term funding for senior and junior positions in taxonomy

EU countries should initiate specific funded employment programmes that both maintain existing positions of taxonomists in research organisations and facilitate a smooth transition from older to younger generations to ensure continuity.

Example: collaborate with social and professional programmes and agencies to **launch merit programmes or long-term paid internships** to ensure effective transfer of knowledge and continuity.

B. Policy development – new policy initiatives to encourage linkages to and integrate taxonomic knowledge into wider biodiversity-related initiatives and contribute to building the capacity of the taxonomic community. Such policies will result in:

- Creating and sustaining long-term professional positions for taxonomy experts
- Taxonomy knowledge-transfer programmes for biomonitoring and conservation
- Professional career support for taxonomists

RECOMMENDATION STR-B1

Diversify the evaluation criteria for career development for taxonomists

The academic institutions should ensure that the rating requirements for professional achievements should include criteria other than impact factors of journals and the number of citations. These criteria should be elaborated by a dedicated task force from academia, museums and collections and competent authorities.

Example: Criteria for career excellence could include participation in citizen science projects, contributions to capacity building and exchange initiatives, development of taxonomic keys and field guides and others.

RECOMMENDATION STR-B2

Boost innovation and new jobs, by fostering collaboration between the scientific community and the private sector

The European Commission (DG Employment, Social Affairs and Inclusion, DG Research and Innovation, and DG Environment) should promote the collaboration between industry and science that will result in innovation pathways and *jobs in fundamental and applied disciplines outside public research organisations.* This could be included in future calls targeting the private sector with relevant co-funding requirements.

Example: The foreseen **CETAF European Agency of Taxonomy** could constitute a stakeholders' forum to leverage existing initiatives and multiply the impact to promote the social economy at large.

RECOMMENDATION STR-B3

Link biodiversity monitoring needs (e.g. under the Habitats Directive or the European Pollinator Monitoring Scheme, the proposed EU Nature Restoration Law or the process to review the implementation of the Biodiversity Strategy) with the available taxonomic expertise at national and EU levels

Based on the results of the present study, the European Commission should encourage EU countries to support the development of specific tools to improve the taxonomic expertise linkage to the needs of monitoring biodiversity on the spot, in order to achieve a multidisciplinary understanding of biodiversity and natural resources preservation.

Example: linkages with the **CETAF Registry of Collections, Research and Expertise** to easily detect needs and gaps, and with the **IUCN Red List of Threatened Species**, and the SSC regional expert network, in order to have a comprehensive perspective.

5.2 Scientific recommendations (SCI)

Reinforcing the far-reaching impact of taxonomy

A. **Knowledge** – This European Red List of Taxonomists marks the baseline and identifies key priorities to boost taxonomic knowledge and expertise through:

- Self-registering process for taxonomic knowledge/expertise
- Expanding the Red List of Taxonomists
- Taxonomic expertise availability as transversal action overtime
- Wide dissemination campaigns to reach out to different users

RECOMMENDATION SCI-A1

Maintain up-to-date, harmonised and unified information about the status and evolution of taxonomic expertise in Europe

The European Commission (via funded calls and guiding policies), EU countries, and academic institutions should support and ensure the maintenance of adequate repositories of the taxonomic expertise in Europe. In particular, to make them certain to provide accurate, reliable and sustained information on the European taxonomic capacity at different levels, regions and times. Such tools would overcome the lack of up-to-date comprehensive information which impedes the understanding and effective tackling of the taxonomic capacity gaps, detection of trends and implementation of corrective actions.

Example: Ensure continuous management of a *portal/platform that provides updated and targeted information on the available taxonomic expertise* across Europe based on **existing networks** (such as CETAF and SSC), in combination with the implementation of **self-registering tools** (such as the one developed for RLT). The **expansion of the existing database** under the RLT project should be connected to the CETAF Registry of Collections, Research and Expertise and linked to the Biodiversity Knowledge Centre when this becomes operational.

RECOMMENDATION SCI-A2

Expand the European Red List of Insect Taxonomists to cover other relevant taxonomic groups

The European Commission should provide funds to organisations (such as CETAF and IUCN) to expand the current study to facilitate *access to a comprehensive overview of taxonomic expertise across multiple* taxonomic groups (e.g. plants, fungi, invertebrate groups other than Insects) matched with other determining factors of biodiversity, such as species checklists, species richness by country and species distribution.

Example: Open calls for **further research** with a view to ensure that the current database on insect taxonomists becomes comprehensive, well used and kept up-to-date.

RECOMMENDATION SCI-A3

Continue the European Red List of Taxonomists as a transversal action

The European Commission should recognize the importance of having permanent registries of taxonomic capacity and therefore, provide funds to first, *ensure monitoring of the taxonomic capacity over time*, the information would need to be scalable and flexible, as to integrate trends, different levels of granularity and distribution. Secondly, the European Commission should support IUCN in linking the assessment of taxonomic capacity to the Red List assessment of species, as it involves, and depends upon, largely the same circle of experts.

Example: This initiative could continue under the Horizon Europe framework programme and be inserted as an action throughout the Biodiversa+ partnership, as **a transversal action**. Reassessments of European Red Lists of species could be expanded to cover also the available taxonomic capacity for the taxon in question. In any case, periodic reassessments of capacity are recommended at maximum of ten-year intervals.

RECOMMENDATION SCI-A4

Communicate **the significance of this assessment of taxonomic capacity to other scientific fields**

The involved organisations in the present study, including the European Commission, should commit to disseminating widely the results of this Red List of Insect Taxonomists throughout the scientific community and the general public. This communication effort would aim first, to raise awareness of the need to have taxonomic expertise in place, and also engage with new scientific communities to cover a variety of potential users that would provide complementing efforts to support addressing biodiversity loss from an ecosystem approach.

Example: The partners in this consortium and the European Commission undertake an **effective communication campaign** to disseminate the results of this endeavour using their networks and engaging their peers and partners, including the academic and research community, European and national authorities responsible for research and management of biodiversity, agriculture, forestry and marine resources, etc. When the EC communicates the mid-term review (expected 2024) of 2030 Biodiversity Strategy implementation recognizes the instrumental importance of the taxonomic expertise and highlights the threat stemming from its erosion.

RECOMMENDATION SCI-A5

Elevate the citation of taxonomic papers in scientific publications

To recognise the *value and impact of taxonomy at a multidisciplinary level*, publishers and scientific editors should insist on the correct citation of papers that identify taxa and describe new species across scientific disciplines, e.g. molecular biology, medicine, agriculture etc. To ensure the systematic application of this principle, standards should be developed and endorsed by the scientific community.

Example: A **protocol and best practice guide** on the correct tracing and citation of taxonomic papers to be developed and endorsed by the scientific community (through networks and associations such as CETAF) and promoted at European level and through academic networks.

B. Capacity – Build capacity through ensuring life-long and multidisciplinary training with aims to tackle key structural features of the taxonomic community, such as:

- Involvement of non-professionals in taxonomic work
- Mobilisation of expertise
- Linkages with Research Infrastructures and data aggregators
- Revised excellence criteria

RECOMMENDATION SCI-B1

Improve the collaboration of professional taxonomists with amateur naturalists

Specific programmes for citizen science should be developed by the European Commission with specific calls for concrete collaborations with citizen science initiatives and professional organisations, focusing on taxa that are: i) species-rich, ii) understudied, or iii) bear special relevance for environmental, economic and/or societal reasons.

Example: Develop an **education and capacity building (modular) programme provided by experts to amateurs**, that could produce a cascade effect to enlarge capacity in the field. The focus should be placed on relevant species in biodiversity hotspots and protected areas across Europe and involve professionals in those areas. This should be done strategically alongside the deployment and development of AI tools that help identify, describe and monitor species (such as identification guides, keys or automated image recognition systems).

RECOMMENDATION SCI-B2

Support capacity mobilisation and access programmes

Scientific organisations and societies should *organise and implement exchanges and "training the trainers" programmes* as well as more dedicated training sessions on specific topics of interest and need on the spot.

Example: facilitate the **exchange of experts** between countries with high taxonomic capacity and those with lower capacity or low GDP (with fewer resources but most likely higher biodiversity richness).

RECOMMENDATION SCI-B3

Establish linkages between taxonomic facilities and organisations (CETAF), research infrastructures (DiSSCo), aggregators (GBIF) and users (e.g. IUCN Red List)

Research infrastructure managers should support and provide mechanisms to allow production of FAIR data, facilitate open access to integral species data, and implement harmonised and standardised initiatives for data collection and management.

Example: **Such online platforms** should be supported to strengthen and expand engagement with taxonomic facilities (such as museums, botanic gardens and universities) where fundamental research is conducted and most of the taxonomic expertise is concentrated.

RECOMMENDATION SCI-B4

Foster the involvement of new generation researchers in taxonomy through formal education and collaboration with youth organisations

Universities should recognise and integrate the importance of taxonomy into their curricula. To that end, universities could *undertake a revision of excellence criteria, the introduction of indicators of research excellence leading towards biodiversity conservation impact* (e.g. studies connected to those groups of organisms where capacity is hindered or inadequate). Such measures could help prevent further erosion of taxonomic capacity that results from the ageing of taxonomic experts.

Example: A **blended high-level education programme** could be launched in partnership with youth environmental organisations (Global Youth Biodiversity Network, Youth and Environment Europe, Global Campaign for Education, etc.) and with university-based and museum experts strongly involved in its implementation.

C. Networking – To ensure mobilisation, exchange and acknowledgement of experts across borders of all kinds, including geographical, disciplinary, levels of expertise and seniority, the following should be prioritised:

- Efficient use of eLearning platforms
- Integrative taxonomy perspective
- Taxonomy across the entire data life cycle

RECOMMENDATION SCI-C1

Spread the use of and access to e-Learning platforms

To facilitate open access to material, *the European Commission should facilitate funding sources to existing learning platforms and organisations to provide up-to-date training courses*, and ensure that the existing taxonomic capacity is skilled and equipped with upgraded technological advances and innovations.

Example: Widen the scope and **outreach through e-learning mechanisms as DEST**, the Distributed European School of Taxonomy, supported by CETAF, allocating training in taxonomy and systematics with a flexible format to accommodate taxonomic needs and research careers.

RECOMMENDATION SCI-C2

Broaden the scope towards an integrative taxonomic approach

The European Commission should provide funds to foster collaboration between intermediary organisations to generate specific capacity-building programmes. Such programmes will help equip traditional taxonomists with *complementary approaches such as e.g. bioacoustics, genomic and DNA barcoding methods* with a view to support them in the transition *towards integrative taxonomy.* Specific support to the network of BioSCAN Europe would enable the acquisition of the necessary competencies, foster peer exchange, and promote networking and collaboration in specific transversal areas relevant to taxonomic knowledge.

Example: Involvement in initiatives such as the **EU-funded project Biodiversity Genomics of Europe (BGE)**, to accelerate the use of complementary methods for species recognition, identification and description.

RECOMMENDATION SCI-C3

Ensure that taxonomic expertise has access to and is integrated across the data life cycle

Taxonomists should interlink various types of biodiversity-related data (specimens, sequences, taxon names, literature etc.) when conducting their research in order to *complete the entire data life cycle*.

Example: Participation in projects such as **Biodiversity Community Integrated Knowledge Library (BiCIKL)** to facilitate gaining an overarching and systemic vision.

5.3 Societal recommendations (SOC)

Engaging society in taxonomy

A. Recognition and Awareness – better understanding, knowledge and recognition by the society are needed with regard to the value proposition of the taxonomic work. To this end, essential initiatives are:

- Events to connect taxonomists and the general public
- Focused campaigns to explain scientific outcomes
- Enhanced skills in science communication
- Rewarding opportunities for young researchers

RECOMMENDATION SOC-A1

Museums, botanic gardens and other taxonomic facilities should enhance their activities to communicate the importance of taxonomy expertise to underpin conservation and science

It is pivotal to *raise awareness across societal actors* of the value and impact of taxonomy and the work developed by taxonomists. This should in particular help to motivate young generations to join the scientific community in the medium and long term.

Example: Dedicate a **day at the museum for taxonomy**, as a pilot initiative of open doors giving access to collections and facilities to the general public, with experiences sharing and direct participation of researchers, e.g. via guided tours.

RECOMMENDATION SOC-A2

Public campaigns

Individual taxonomic facilities (natural sciences museums, botanic gardens, biodiversity centres) and their networks should ensure that the *awareness* about the importance of taxonomic work *reaches all layers of the public* as a vehicle to transmit in tackling societal challenges. These communication actions could be linked to initiatives such as the Global Coalition for Biodiversity launched by the European Commission or the international Alliance for Biodiversity Knowledge.

Example: Targeted campaigns disseminated through international working groups for communication (for example, the Biodiversity Flotilla[11]), with real case references, such as the number of described and undescribed species, rates of species disappearance, or in a more positive approach, contribution to biodiversity preservation with individual actions, etc.

[11] An ad-hoc group facilitating biodiversity communication under the roof of the CDB

RECOMMENDATION SOC-A3

Scientists should be better supported in communicating their research to the public

Scientists need *more support to effectively communicate the results of their taxonomic work* in order to gain the necessary recognition. The production of documentaries, podcasts, blogs and other media should more actively promote biodiversity topics and stress the important role of taxonomists in its study and conservation.

Example: Increase the communication skills of scientists with a specific **course for taxonomists on communicating science** (under the Distributed European School of Taxonomy of CETAF) to better communicate the scientific results, or establish partnerships between taxonomic facilities and professional communication agencies to promulgate science.

RECOMMENDATION SOC-A4

Recognise young taxonomists and their work

Biodiversity-related organisations in close collaboration and in full alignment with targets of the European Research Area should find and use attractive ways *to secure recognition to young generations of taxonomists,* and promote their taxonomic work.

Example: Funding and disseminating initiatives such as the **E-SCoRe Award that rewards excellence in taxonomic work** carried out by early-career investigators.

B. Engagement – From recognition to engagement, paths should be built to facilitate the active participation of citizens in generating and enhancing scientific outputs, in particular by:

- Producing bespoke communication materials
- Integrating citizen-science initiatives into formal taxonomic studies
- Highlighting contributions from women taxonomists

RECOMMENDATION SOC-B1

Produce communication materials

Partners to the present study should develop, with the support of the European Commission, different formats of presenting the results, with the aim of producing material in a language and format digestible by the general public who may then gain scientific literacy easily and thus, become better engaged with taxonomy. The European Commission could centralise this effort and largely distribute the outcomes in different conferences and events organised around biodiversity as well as through intensive use of social media.

Example: brochures, posters, guides, infographics and other material that explain the scope, value and impact of taxonomy for science and society that could be distributed throughout the network of museums and circulated through their press departments to connect with media, journalists and communicators.

RECOMMENDATION SOC-B2

Integrate citizen-science initiatives into the strategic framework of taxonomic facilities

The European Commission should support the engagement and involvement of societal actors in the co-creation of taxonomic knowledge by delivering specific funding lines for museums and entomological societies to connect with citizen science projects and other volunteering programmes to collaborate in the observation, description, classification and monitoring of species. Networks, organisations and associations (such as ECSA, CETAF and others such as Friends of Museums) could equally foster and promote this kind of collaborative initiative.

Examples: to produce simple guides and clear keys integrated into easy-to-use web-based tools and applications for tablets and smartphones. Such products will stimulate participation, attract young people and create at large a solid citizen base for taxonomy recognition. Bioblitz events are also useful to engage the public and can be combined with modern automated image recognition tools, such as those provided by *observation.org*.

RECOMMENDATION SOC-B3

Recognise and illustrate the contribution of women to taxonomy

The European Commission and academic institutions should launch targeted campaigns with a view to *closing the gender gap in the insect taxonomy field,* including in schools (primary and secondary) and universities. The education community (teachers and school/universities networks) should collaborate in communicating the achievements and contributions of women in taxonomy through relevant channels that reach the student population.

Example: A **calendar of women taxonomists,** with featured interviews.

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Annex

Detailed description of the data and methods used for this report is available at:
https://cloud.pensoft.net/s/mGpyQYUPQOMPs8C

The data used for this analysis, except personal data, is available on request from the European Commission.


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