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ORIGINAL RESEARCH

Identification crisis: a fauna-wide estimate of biodiversity expertise shows massive decline in a Central European country

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Abstract
Expertise in biodiversity research (taxonomy, faunistics, conservation with taxonomic background) appears to decline worldwide. While the "taxonomic impediment" is discussed extensively in the literature, much fewer papers focus on the identification crisis, i.e., the decreasing number of experts who can identify species, and the decline of species-based biodiversity research. As a test case to explore the gravity of the identification crisis, we chose Hungary, a Central European country with a strong history of comprehensive taxonomic expertise and research output. We set out to answer two main questions. (1) What proportion of the Hungarian fauna could currently be identified by Hungarian experts, and what factors determine which groups are covered; and (2) what are the trends of biodiversity research in Hungary, and what are the underlying reasons for these trends? We show that Hungary lacks active biodiversity experts for almost half of the nearly 36,000 animal species recorded in the country, and more than a quarter of the fauna have only one or two active experts available. We also show that faunistic research experienced a golden era between ca. 1990 and 2010. Since then, however, there has been a strong decline, with the number of active experts and published papers decreased to a level like that of the 1970s. Multiple factors are identified causing this trend, such as increased pressure to publish in high impact journals and increasing administrative duties of professional scientists. The next generation of biodiversity experts needs to be fluent in modern techniques and publication strategies but also maintain robust morphology-based knowledge to be equipped for identification tasks of difficult taxa. Despite being disadvantaged by exclusive application of citation-based evaluation, we do need more positions and focused grants for biodiversity researchers to maintain the country's knowledge base and to avoid being increasingly dependent on—equally declining—foreign expertise.

Keywords Faunistics · Taxonomy · Hungary · Hungarian fauna · Zoology · Invertebrates

The two last authors, Zoltán Csabai and Arnold Móra have contributed equally to this work.

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Introduction

Knowing our species is important, expertise is vital

The number of known animal species is 1.42 million globally (Bánki et al. 2021), although the real number of eukaryotic species is estimated to be between 1.8 (Costello et al. 2012) and 8.7 million (Mora et al. 2011), while some estimates arrived at far higher numbers (Larsen et al. 2017).

Once described, correct identification of species is a fundamental requirement for most disciplines of biology, such as evolutionary biology, ecology, phylogenetics, and for more applied fields such as conservation biology, agrozoology, plant protection, and even medicine (Löbl et al. 2023). We are firmly convinced that advanced societies should maintain a sufficient number of researchers appreciating the nature surrounding them, which requires a significant number of experts skilled in animal identification. Without such structured society most people are not even aware of the amount of knowledge they lack and of the amount of biodiversity that they can lose.

Who knows these species?

Biodiversity experts—including taxonomists, faunists, naturalists, conservation experts, etc.—are individuals, professionals or amateurs, capable of correctly identifying species of one or multiple taxonomic groups. However, the necessary knowledge to do so can radically differ between taxa.

For example, identification of several "popular" animal groups such as vertebrates, butterflies, large beetles, shell-bearing molluscs and many spider groups, can be done after short training (at least in Central Europe), because helpful identification guides and websites are available, the vast majority of species have already been described, there are relatively few species, and key characters to distinguish them are clearly defined.

A second animal group, termed here as "moderately popular", contains several taxa, e.g., numerous families of small-bodied beetles, terrestrial slugs, moths, and most spiders, in which identification requires considerably longer training and experience but is still generally manageable with reasonable time investment. For example, in many cases the skill of dissecting genitalia is essential, as is the ongoing awareness of minor or major taxonomic/nomenclature changes, or even the ability of describing new species, which are relatively frequent in these groups. Still, the biodiversity experts dealing with those groups do not necessarily have to be taxonomists in the sense of Wheeler (2014), discovering taxonomic novelties, because most European species are known to science, and the species new to a country's fauna can be identified based on available literature (including online checklists and identification platforms).

A third group of animal taxa, such as mites, free-living and parasitic nematodes, most Diptera and parasitic Hymenoptera, are termed "unpopular" here. Their identification requires deeper taxonomic skills than the previous groups, because the number of species can be extremely high, and species new to science are not uncommon. The unpopularity of these groups is mainly caused by being taxonomically intractable, requiring homology assessment based on profound and extensive hard-earned morphological knowledge, deeper knowledge on the characters of the entire group, wide knowledge of the taxonomic literature, in some cases having a molecular facility available, etc. Without these

demanding prerequisites, a biodiversity expert would not be able to recognize species new to science or new to his or her own country's fauna.

At least in the "unpopular" groups, the taxonomic impediment (i.e., the decline of taxonomic expertise) noticeably impacts the number of biodiversity experts capable of identifying species of a given animal group. Moreover, domestic specimens of "unpopular" or "moderately popular" groups are often dealt with by researchers working taxonomically mainly on tropical or otherwise exotic material but serve as biodiversity experts for these groups in their home country.

It is widely known in biodiversity research that the role of amateurs is important. Being an amateur in this context means that biodiversity research is not part of their job requirements. For example, between the 1950s and 2010s, over 60% of new European species were described by non-professionals (Fontaine et al. 2012), although those included students and retired professionals. The activity of amateurs was more important in "popular" groups than in "unpopular" ones. Nevertheless, when examining trends of biodiversity research, we should not forget to take into consideration that amateurs are an important part of the actual pool of biodiversity experts.

While the taxonomic impediment is extensively discussed in the literature (e.g., Systematics Agenda 2000 1994; Engel et al. 2021; Löbl et al. 2023), few studies focus explicitly on, or even mention (e.g., Löbl 2014; Lyal and Miller 2020; Taszakowski and Depa 2022) the identification crisis, i.e., the decreasing number and diversity of biodiversity experts.

Taxonomic bias on multiple levels and the model country

Because some groups are much more difficult to identify than others, we expect a bias in the number of biodiversity experts across taxa with animal groups including more "popular" species having more experts than ones with smaller, less attractive species. Such taxonomic bias has been identified multiple times in other countries and globally (e.g., May 1988; Leather 2009; Hamer 2013) and in other branches of biology, well beyond taxonomy, such as in behavioural neuroscience (Mathuru et al. 2020), ethology (Rosenthal et al. 2017), conservation biology (Bajomi et al. 2010; Dixon et al. 2022), etc. Moreover, there increasingly are animal groups, which lack taxonomic experts in the country or even globally.

Furthermore, the number of biodiversity experts and the capability of identifying local/national faunas, which is a key to biodiversity studies (Secretariat of the Convention on Biological Diversity 2007), are different between countries (e.g., Whitmore et al. 2021). Nevertheless, countries with similar scientific history and economic backgrounds likely show comparable trends.

For these reasons, it is important to explore to what extent biodiversity experts of a country are able to identify the local fauna, and what the current trends are in light of modern project-based science funding, which is generally thought not to be compatible with the constraints of more exploratory and uncertain research (Hubert and Louvel 2012) and for sure not to be suitable to raise biodiversity experts.

A suitable model to explore these issues is Hungary, a Central European country with historically intensive biodiversity research. Zoological research started in Hungary at the beginning of the nineteenth century, and its intensity has increased until the 1980s (Csuzdi and Mahunka 2007). While never published as a policy, it was a well-known goal amongst Hungarian biodiversity researchers since the 1960s to have biodiversity experts for each taxonomic group in the country, as our interviews revealed (see below). Between 1983

and 2003 the number of Hungarian zoologists (including ecologists, physiologists, ethologists, etc.) has been above 400 (Bakonyi et al. 2007). The *Fauna Hungariae* series (see Supplementary File 5), which aimed to monograph each animal group of the Hungarian fauna, was published between 1953 and 1991 (one volume published in 2016) and is now largely online at https://www.izeltlabuak.hu/fauna-hungariae. With over 160 parts being published, covering about 60% of the Hungarian fauna (Matskási 1987), it is comparable in magnitude and quality to similar series of other European countries. Thus, the trends found in this country are probably similar to those of its neighbours.

What the present study has done

To get an overall picture about biodiversity expertise in Hungary, we pursued several lines of evidence to answer two main questions. (1) How much of the Hungarian fauna could currently be identified by Hungarian experts, and what factors determine these numbers, and (2) what are the trends of biodiversity research in Hungary, and what are the reasons behind these trends?

Considering the total number of species in the country, the total number of biodiversity experts capable of identifying them is currently clearly insufficient. The present trends predict that the situation will continue deteriorating in the future. We also show a strong decrease in number of biodiversity publications and of the active number of biodiversity experts since ca. 2010 indicating a strong decline in biodiversity research in Hungary.

Materials and methods

Specifying successive, derived questions and the logical order of our methods

For the question 'How much of the Hungarian fauna could currently be identified by Hungarian experts, and what factors determine these numbers?', (a) we counted the number of known species of the Hungarian fauna based on published evidence and to a lesser extent, based on expert opinion; (b) we counted the number of Hungarian experts capable of identifying each taxonomic group to show a current picture of national identification capability. To explore the background of the bias in the number of experts between groups, we aimed to understand which animal groups are interesting for the general public. The rationale behind this is to study whether laypeople could provide a source from which biodiversity experts may arise. For this, (c) we collected all posts (i.e., photos of animals to be identified) for 10 months that appeared on a nation-wide animal identification social media platform ("Állathatározó" = Animal identification group in Facebook). Furthermore, (d) we interviewed experts of "moderately popular" and "unpopular" groups about the reason why they chose the group they have been studying in order to enlighten the background behind study group selection in one's early career. Since several interviewed people mentioned that identification books were crucial for them when they started dealing with a taxon, (e) we estimated the proportion of Hungarian fauna that has ever been monographed (i.e., whether identification books being available or not). This latter dataset also indicates the portion of the Hungarian fauna that can potentially be identified using literature even if active experts of the given groups are not available.

For the question 'What are the trends of biodiversity research in Hungary, and what are the reasons behind?', (f) we compiled all available publications by Hungarian authors

from Hungarian journals containing locality data of invertebrates between 1970 and 2020 in order to explore trends of the intensity of biodiversity research. Because we found a severe decrease in number of publications and in number of active experts since ca. 2010, (g) we conducted a survey among the experts with decreased publication activity to understand their reasons, and finally, (h) using abstracts of a nation-wide competition for university students (OTDK: National Scientific Conference of Students' Associations, and OFKD: National Higher Educational Environmental Science Student Conference), we analysed whether the number of university students being engaged with a taxonomic group decreased between 1970 and 2020 or not.

Estimation of the number of known species of the Hungarian fauna

We assembled numbers of species for each taxonomic group based mostly on published evidence. When no such comprehensive study was available, we relied on expert opinion, as indicated in Supplementary File 2. For many groups the number of species was largely based on the *Fauna Hungariae* series, but in other groups with recent research activity, new, updated faunas and checklists were available.

Active biodiversity experts

While compiling our dataset on the number of biodiversity experts capable of identifying a taxonomic group, we soon realized that the level of knowledge is variable even within a single taxonomic group. For example, there are "real" experts, who work on a given group for years, follow the international taxonomic and faunistic literature, would certainly realize a species new to the Hungarian fauna, their identifications are trusted by colleagues, they publish/collect relatively regularly, and have seen the vast majority of the species of the country; and "marginal" experts, who are able to identify a fraction of species with the help of other, more experienced experts and the literature. In our compilation we only counted the former group.

In amphibious freshwater insect groups it is a common issue that one biodiversity expert is working on larvae and another one on the adults, who will necessarily have different sets of knowledge. In those cases, we did not distinguish between them and handled both kinds of experts as biodiversity experts capable of identifying species of this taxon.

Interest of laypeople in animal identification

It is important to consider the awareness of the general public of the animals they encounter, i.e., what kind of animals they find worth identifying, because interest of laypeople may influence the scientific orientation of future biodiversity experts. For this reason, we collected data from a Hungarian language Facebook page called "Állathatározó" (= Animal identification) during a 10-month period (16 July 2020–17 May 2021). Identification (up to species or genus level whenever possible), classification, name of the person who posted (in order to identify active and less active people for various analyses) and the date of posting were recorded. We note that the number of that Facebook group's members was 6,017 on the first day and reached 17,008 a year later. This exceptional increase probably was due to the COVID pandemic when people had much free time to post their animal photographs for identification.

How experts of "unpopular" or "moderately popular" groups started their careers?

We interviewed 42 Hungarian biodiversity experts with expertise on groups that are not among the most popular animal groups. These include true bugs, spiders, Diptera, Hymenoptera, smaller insect orders, various kinds of worms, and even "difficult to identify" beetles. We grouped the experts into two categories based on whether they decided to work on their group on their own account, or whether somebody else (usually an influential senior colleague) suggested or urged them to study a "difficult" group.

Estimation of the proportion of Hungarian fauna that has ever been monographed

We compiled a database of all nation-wide monographs (that contain sufficient information for identifying species of a given group). No such literature list was available beforehand. Therefore all authors, who cover a considerable part of Hungarian biodiversity experts, checked and added monographs to the list after careful consideration of the above criteria. As a second step, the number of species that were covered by each work was added, or in popular groups (e.g., butterflies) where several identification books covered similar number of taxa, we marked that all species reported from Hungary are covered by monographs.

A factor to consider was that the quality of identification books varies considerably. Moreover, for some groups, monographs were written 60 years ago, hence likely being out of date. Furthermore, in case of some groups (e.g., aphids, spiders) species are typically identified based on continuously updated foreign websites. Nevertheless, the sum of all species ever appeared in a monograph is a good estimate on how much of the Hungarian fauna is identifiable based on identification books.

Faunistic papers and monographs

To explore the literature and its temporal trends an extensive and comprehensive online search and data mining were undertaken for faunistic papers according to the following criteria. Those papers were taken into consideration that (1) contain faunistic records (see below) of invertebrates from the territory of Hungary; (2) published in a Hungarian journal (published in Hungary either in Hungarian or any other language) between 1970 and 2020; or (3) available on the World Wide Web, i.e., via search platforms, journal databases or individual homepages (see Supplementary File 6). Compilations and catalogues fit the criteria 2 and 3, as results of long-term faunistic works, and were added to the list too. In addition, monographs containing the results of studies on the fauna of certain territories (e.g., national parks) were also included, although these are not or only partly available electronically.

Vertebrate faunistic papers were not collected, because identification of vertebrates typically requires a different set of knowledge in the laboratory and the field, not easily comparable with those of experts of invertebrates. Also, vertebrate faunistic data collection largely moved to online platforms in the last decades (which would mask the trends), unlike data collection of invertebrates.

By default, faunistic records contain exact sampling sites and dates but, in this study, the following records were also taken into consideration: new occurrence data for larger but

well-defined areas (e.g., a certain mountain, lake), or new occurrence data without exact date but with well-defined time interval.

We treated papers dealing with aquatic and terrestrial invertebrates separately, because they require different methods and approaches, and different teams of specialists work on them (for aquatic and terrestrial groups see Supplementary File 6).

After the compilation of the list of papers, we extracted all the names of authors and calculated the total number of articles published by each author in the 50 years period from 1970 to 2020. Those who were the authors of at least three papers were considered biodiversity experts and represented approx. 30% of the authors. For each expert who published more than 3 articles, we defined the active period, i.e., the period between the first and the last paper, regardless of the number and length of gaps (i.e., the years when they did not publish). Among the experts publishing at least 5 papers between 1970 and 2020 (altogether 130 persons), we also counted the number of amateurs and professionals for their taxonomic and faunistic research has been part of their job at least at a given period of their life.

Survey among biodiversity experts with decreased publication activity

We made a table of all authors and the number of papers they published between 2006–2010, 2011–2015, and 2016–2020. Then, we selected authors who published fewer papers between 2016–2020 compared to 2006–2010 or 2011–2015, and those who published fewer papers between 2011 and 2015 than between 2006 and 2010. We united these three groups, and omitted those people from the list, who did not publish any papers before 2010, because they most probably started their career after the start of decline of faunistic papers. We also removed the deceased. As a result, we got a list of 161 people. We tried to find their contacts, and finally could successfully send our questionnaire to 123 people by contacting them via e-mail or social media.

In the questionnaire, the experts first had to choose between three statements: (1) "My work results in no, or less faunistic data than it has previously"; (2) "My work results in similar amount of faunistic data than it has previously, but I publish my data less extensively than before"; (3) "I do not feel that I have published less faunistic papers than before." The latter option was given to experts because even if we knew that the questionnaire was sent only to those people who published smaller number of papers than previously, the dataset reflected only the number, not the length and content of the faunistic papers. In other words, it is possible that somebody has published fewer papers but an equal or larger amount of faunistic records.

Experts choosing the first statement received seven questions, the ones choosing the second statements received eight, while the ones choosing the third statement, received nine questions. These questions about the reasons were formulated after initial discussion among the authors of this paper. Experts had to choose between numbers 0 (meaning that they did not want or could not answer) and 1–5 in which 1 meant that they did not agree with the statement, while 5 meant that they fully agreed. All three groups had the opportunity to answer a final question about possible additional factors regarding the decline of faunistic research. The list of questions and answers are compiled in Supplementary File 8.

For the data analysis, we merged the experts choosing the second and third statements. The results of the questionnaire surveys are illustrated in the form of bidirectional bar charts (Fig. 5).

Number of faunistics-related abstracts on students conferences

In Hungary, the OTDK (Országos Tudományos Diákköri Konferencia = National Scientific Conference of Students' Associations) has been organizing conferences for university students starting in 1970, and then from 1975 every other year. While between 1975 and 1999 all Natural Sciences (chemistry, physics, biology, mathematics, geology) were together, from 2001 to 2019 biology was handled separately. The abstracts of all presentations can be downloaded from the OTDK website (https://otdk.hu/konyvtar/rezumek). From 1988, another Student Conference was held in alternating years from the ones of OTDK. Its name was OKDK (Országos Környezettudományi Diákkonferencia = National Student Conference of Environmental Science) for the first four conferences (1988–1994), and OFKD (Országos Felsőoktatási Környezettudományi Diákkonferencia = National Higher Educational Environmental Science Student Conference) from 1996. We counted all abstracts that require identification skills of an invertebrate group (e.g., covering faunistic and ecological topics). As the target group of the two conference-series was the same, namely students in biology and environmental studies, data after 1994 of the OFKD were pooled for every 2 years (e.g., OFKD 1998 + OTDK 1999) so that they could be compared with the previous ones. In the first two OKDK conferences no abstract book was issued, while the third conference contained selected abstracts, i.e., not all works of the given year. Therefore, only abstracts starting from the 4th OKDK were considered. No OTDK abstract book was published in 1997.

We believe that counting the faunistics-related abstracts of each conference would provide us with the information whether the number of young biologists interested in taxonomy and species identification was decreasing or not.

MS O365 Excel and JASP 0.16.3 (JASP Team 2022) software packages were used for data editing, descriptive data analysis, and charting.

Results

Number of species

The estimated number of known species of the Hungarian fauna is 35,912. To determine this number, expert opinion and personal communications with experts were used in 28 out of the 375 taxonomic groups, but in most of those cases there is a reference for recorded species numbers (see Supplementary File 1 for sources used, and Supplementary File 2 for the list of groups and the number of species reported from Hungary).

Active biodiversity experts

Our survey revealed that at this point in time, the country lacks experts for species of an astonishing 42.5% (15,274) of the species known to occur in Hungary (Fig. 1). These groups mostly include tiny animals such as small "worms" (Platyhelminthes, Nematoda, etc.) and insect groups such as families of Diptera, Hymenoptera and Coleoptera containing tiny species, as well as several groups of mites. For a further 33.5% of animal species (12,040) there are only one or two experts. It is often the case that one or both of them left academia and work as amateurs, or are close to retirement or already retired, indicating that

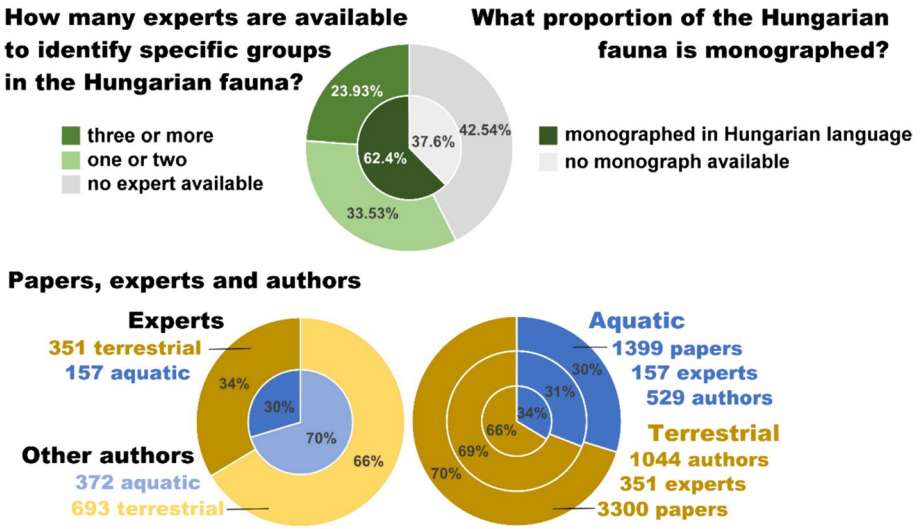

Fig. 1 Basic ratios used to determine the sharp decline in biodiversity studies, and to justify the realization of an identification crisis. Upper pie chart shows the ratios of the number of species in the Hungarian fauna according to availability of experts (outer ring) and monographs (inner ring). The lower pie charts demonstrate the share of experts (lower left) and faunistic papers (lower right) for terrestrial and aquatic realms

this fraction of nation-level identification knowledge will be lost in the next few decades. There are three or more experts for 8595 species of Hungarian animals, which is ca. 23.9% of the entire fauna. These mostly include large-bodied invertebrates, such as butterflies and large moths, large and colourful beetles, some aquatic insects (dragonflies, mayflies, caddisflies), spiders, and, of course, vertebrates. Supplementary File 2 contains the number of experts per groups.

Interest of laypeople in animal identification

During a 10 months period (between 16 July 2020 and 17 May 2021) we collected all (2671) posts (photos) of Hungary's main animal identification group on social media. These identification requests were posted by 1183 people. Of them, 32 posted at least 10 (10–54) images, 412 people posted 2–9 images, and the remaining 739 people posted a single image each.

A clear taxonomic bias is evident form these data. Out of the 2671 posts, 1050 contain images of vertebrates, and 1620 of invertebrates. The ten largest groups of posted animals were Lepidoptera (moths and butterflies: 336), beetles (321), mammals (321), birds (317), spiders (285), reptiles (234), molluscs (160), amphibians (143), Hymenoptera (123), Diptera (93) and true bugs (83). Although the extremely speciose Hymenoptera and Diptera received a relatively high attention, most posted species were large bodied wasps, hornets, ants, and crane- and hoverflies (all data are compiled in Supplementary File 3). "Unpopular" animal groups received less attention. For example, only 9 posts asked for identification of mites, while 4 posted images of Collembola, both groups being very speciose. Thus, there was a strong positive correlation between the animal groups having numerous biodiversity experts and the ones being interesting for laypeople.

How experts of "unpopular" or "moderately popular" groups started their careers?

Sixteen persons (38%) among the 42 interviewed experts of "unpopular" or "moderately popular" groups reported that they started their career on their own accord, whereas for the majority of them (26 persons: 62%) somebody else, typically a senior colleague or professor suggested working on an "unpopular" or "moderately popular" invertebrate group. All data are compiled in Supplementary File 4.

Estimation of the proportion of Hungarian fauna that has been monographed

Approximately 22,421 species were covered by identification books (see Fig. 1 and Supplementary File 5). This means that ca. 62% of the Hungarian fauna have appeared in monographic books, which is more than what currently active experts can identify.

Compilation of datasets: Faunistic papers and monographs, and their authors

During the studied period (1970–2020) 4343 papers published in 54 journals and in 7 monographic books (Supplementary File 6, and Fig. 1) were found, among which 1399 contained records for aquatic and 3300 for terrestrial invertebrate groups (in 356 papers data for both aquatic and terrestrial groups were published).

The number of the faunistic papers has changed quite dramatically from year to year during the 50-year-long study period. The average number of papers per year about terrestrial lifeforms was 64.7 while in the case of the aquatic taxa it was 27.4. Higher activity was observed in terrestrial taxa between 1981 and 2014, while the period between 1998 and 2011 was the most productive for aquatic studies. There has been a clear decrease in the number of articles between 2010 and 2020. This is particularly true for aquatic taxa. By 2019–2020 we have returned to the level seen in 1972, from 68 to 8 papers per year, but the number of articles about terrestrial life has also fallen by 50% between 2010 and 2020 (Fig. 2).

Based on the authors of the papers, the number of experts identified for the entire study period is 351 on the terrestrial part, while lower (157) for aquatic organisms. "Terrestrial" experts were active for a slightly longer period than "aquatic" ones: an average of 17.5 vs 15.7 years, while the median activity is 15 vs 12 years. The longest activity covers the entire 50-year period (2 experts) at the terrestrial side, while it was 48 years (one expert) for the aquatic part (Fig. 1). The average number of experts available per year was much higher (121.1) for terrestrial groups than for aquatic taxa (53.7). The highest numbers of available and publishing experts were between 2000 and 2010 for both the aquatic and the terrestrial groups, followed by a sharp decline to the level last seen in 1972 (60 people): from 101 to 18 (18%) and from 165 to 44 (27%) people, in aquatic and terrestrial groups, respectively (Fig. 3).

Our analysis also revealed that a rather small fraction of the actively publishing biodiversity experts are amateurs (for terrestrial groups: from 130 authors with at least 5 papers, only 20 [15%] were amateurs, see Supplementary file 7, a similar number as in Spain [Bello et al. 1992], 13%).

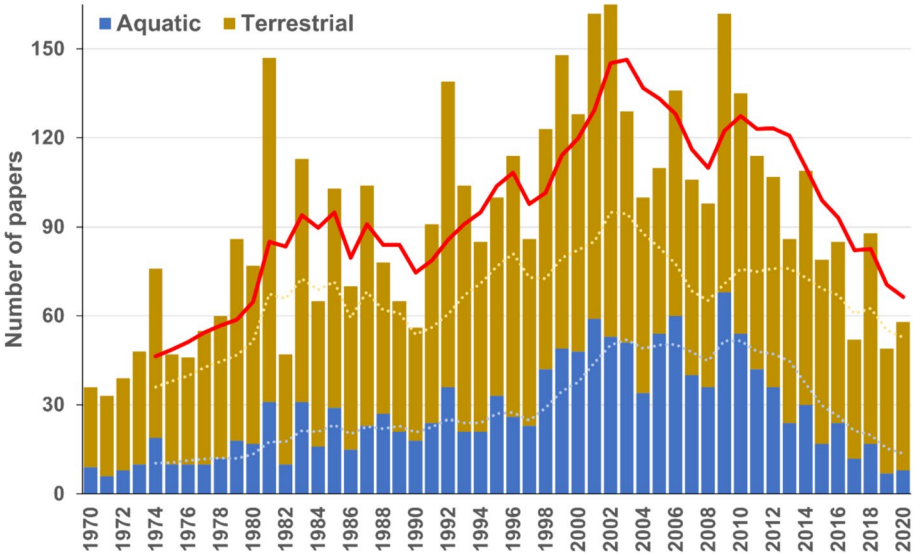

Fig. 2 The numbers of invertebrate faunistic papers published between 1970 and 2020 showed an increasing trend until 2000, then after 10 years of stagnation suddenly fell to the level of the 1970s and 1980s in just a few years. The red solid trend line is a 5-year moving average calculated from the number of articles published each year regardless of whether they are about aquatic or terrestrial invertebrates. The light brown and light blue dotted trends lines are the same for papers about terrestrial and aquatic invertebrates, respectively

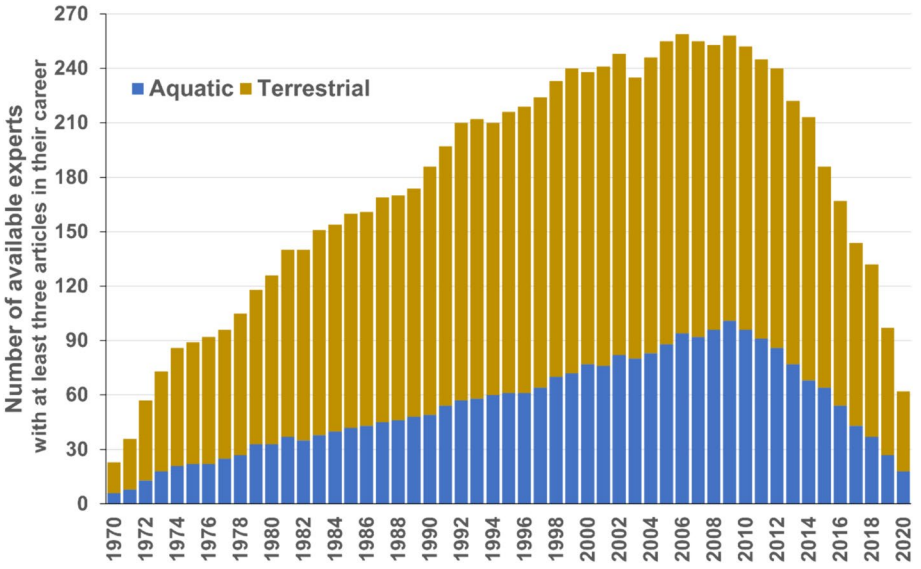

Fig. 3 Numbers of actively publishing (=author of three or more papers in the reviewed period) biodiversity experts of invertebrate animal groups between 1970 and 2020, similarly to the number of papers, showed a massive decline in the last 10 years. The rising and falling trends are clearly visible without any smoothing

Survey among biodiversity experts with decreased publication activity

Out of the 123 people we contacted, 61 (49.6%) returned the questionnaire. Thirty-two people chose the first statement ("my work results in no, or less faunistic data than it has previously"), 23 chose the second statement ("my work result in similar amount of faunistic papers than it has previously, but I publish my data less extensively than before)", and six chose the third statement ("I do not feel that I have published less faunistic papers than before)". All questions and answers are compiled in Supplementary File 8.

Among the people producing less faunistic data (first statement), the most important reasons were other duties, lack of support from their employer, and publication pressure. Among the people producing similar amount of faunistic data as before, but publishing a similar or smaller number of papers than before (second and third statements), the main reason for their decreased publication activity (or in 5 cases their claim why others publish less) was other duties, the pressure to publish in high-ranked journals, the large amount of data remaining in unpublished reports, and the lack of support from the employer (Fig. 4).

Experts mentioned the following additional factors in the last, narrative question:

(1) From the 1960s, there were large projects focusing on the fauna of certain geographic areas of Hungary, such as the Bakony Mountains (ca. 20 monographs, the first being Tapfer 1966, and the last Tóth 2015), Bátorliget (Mahunka 1991a, 1991b), and the national parks (Hortobágy NP: Mahunka 1981, 1983; Kiskunság NP: Mahunka 1986,

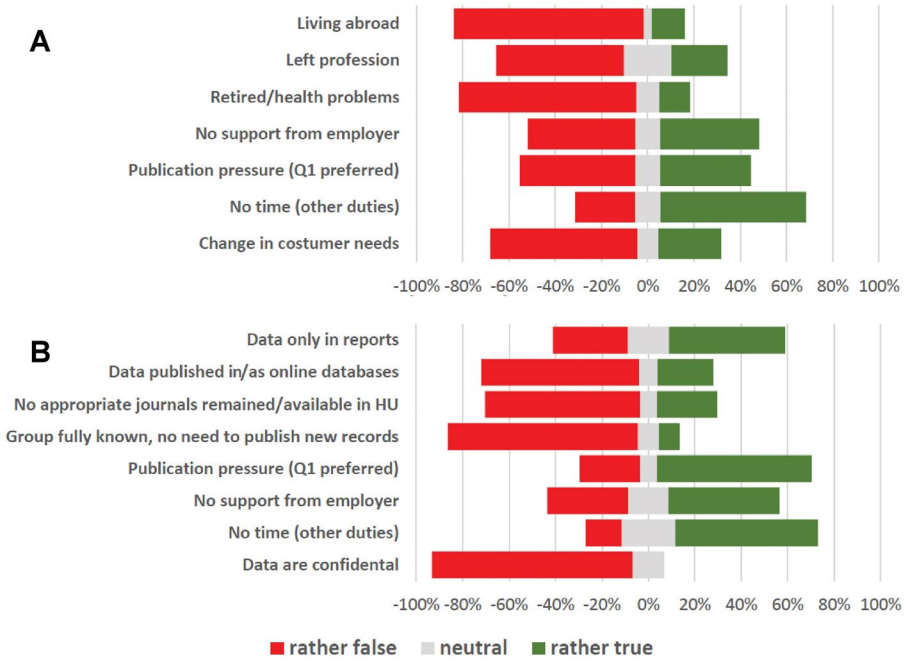

Fig. 4 **A** The reasons to produce less faunistic data based on the questionnaire responses of biodiversity experts who felt that they have recently produced and published less data ($N=30$). **B** The reasons to publish less faunistic data based on the questionnaire responses of biodiversity experts who felt that they have recently produced the same but published less ($N=23$) or the same ($N=5$) amount of data

1987; Aggtelek NP: Mahunka 1999; Bükk NP: Mahunka 1993, 1996; Fertő-Hanság NP: Mahunka 2002), resulting in a wealth of faunistic papers and data. These faunistic and floristic research programs were largely coordinated by enthusiastic colleagues, who were also in leading positions, hence able to organise such projects. Since there are no biodiversity experts in such position at this point in time, large-scale survey projects presently lack coordination.

(2) The societal prestige of biodiversity experts is low (at least this is what they feel and experience themselves), which has a negative effect on the number of young, up-and-coming biodiversity experts.

(3) Collecting protected species and storing them in private collections is illegal, and the number of protected species has increased in the last 2–3 decades (i.e., 709 plant and animal species have been given protected status since 2000: https://termeszetvedelem.hu/kereso/vedett-fajok/). The fear of punishment for illegal activity, and the bureaucracy and cost of obtaining collecting permits discourages both established and upcoming biodiversity experts from collecting animals and publishing faunistic data.

(4) One expert mentioned that he/she is a biology teacher, who has done biodiversity surveys previously, but has stopped in the last years mostly because of the increasing bureaucracy and workload in the school they are working at, which leaves no time for collecting and publishing.

Number of faunistics-related abstracts at students conferences

The number of student abstracts requiring identification skills of an invertebrate group varied between five and ten between 1975 and 1993, and in 1995 it abruptly increased above 20. This number has been above 20 until 2011 (except for 2001, when it was 14), when a sudden decrease took place, and the number dropped to the level of the 1970s (Fig. 5, raw data are compiled in Supplementary File 9).

Discussion

Taxonomy is the discipline that describes, categorises, and names organisms. Faunistics (regional biodiversity research) provides occurrence records and reveals distribution of species based on correct identification. The inseparability of these two disciplines is illustrated by the European Red List of Insect Taxonomists (Hochkirch et al. 2022), which provided the outcome of a survey of 1,527 self-declared taxonomists. Among them, 72.5% work both on taxonomy and faunistics, 14.4% do only faunistics, while the remaining 13.1% do only taxonomic research. These disciplines are crucial for countless areas of environmental science, such as ecology, evolutionary and conservation biology as well as applied sciences (e.g., environmental protection, water and landscape management, agriculture including pest management, ecotourism). Awareness of biodiversity is an important component of a well-educated society that cares about the future of its natural environment. The numerous posts and active people on social media platforms of animal identification groups indicate that the general public is interested in the animals they encounter and have an interest in knowing more about them. However, supraindividual biology often experiences lack and/or decrease biodiversity expertise in many animal groups and geographic areas, and is increasingly incapable of satisfying the thirst for knowledge of the general public (Löbl 2014).

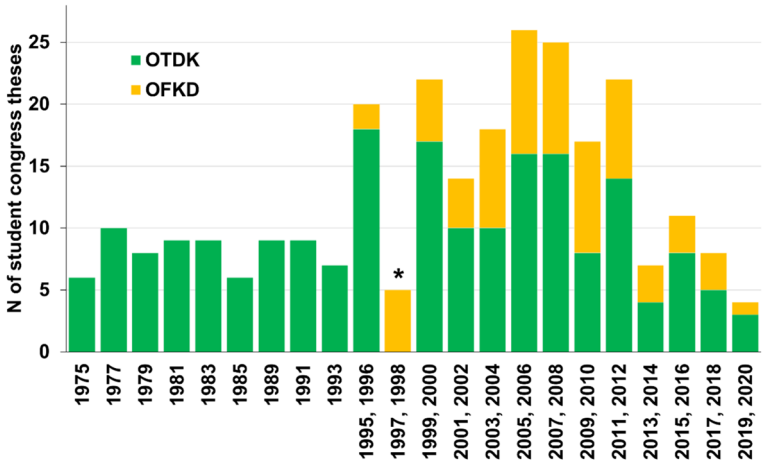

Fig. 5 The number of studies requiring identification skills of an invertebrate group presented at student conferences between 1975 and 2019, based on the book of abstracts. OTDK: National scientific student conference, OFKD: National Higher Education Environmental Science Student Conference, *The book of abstracts for the OTDK of 1997 was probably never published, thus we could not present specific data for that year, but it is supposed to be similar to the previous and the following year

One of the main reasons for this is the waning presence of taxonomy and identification skills in higher education in biology in most countries (Weilbacher 1993; Greene 2005; Löbl et al. 2023), partly due to the ever-increasing body of knowledge and partly because it became displaced by molecular biology, genetics, and computer analyses. Taxonomy suffers from lack of funding and loss of positions on a global scale, termed and extensively discussed as "taxonomic impediment" (Systematics Agenda 2000 1994; Wheeler et al. 2004; de Carvalho et al. 2005, 2014; Engel et al. 2021; Löbl et al. 2023). The discussion of the "identification crisis" (i.e., the decrease of number and diversity of people capable of identifying animals), which is a similar problem rooted in the decline of biodiversity research and expertise, stays mostly in the hallways of universities, natural history museums, plant protection and conservation institutions, and is far less documented than the taxonomic impediment. Rare examples (e.g., Löbl 2014; Taszakowski and Depa 2022) are mostly opinion papers without support of hard evidence. A rare in-depth assessment on the United States federal government's capacity to accurately report non-native organisms found that "substantial improvement" is needed (Lyal and Miller 2020). To provide a starting point to understand the current situation and the trends related to the ability of animal identification we choose Hungary, a Central European Country with an outstanding past in taxonomic expertise and intensive biodiversity research. We asked two main questions: How diverse is the pool of biodiversity experts, i.e., to what extent the local experts can identify the local fauna, and what are the trends in the number of publications and the number of actively publishing biodiversity experts in the last few decades.

Diversity of biodiversity experts

A compilation of all biodiversity experts in Hungary showed that the country lacks active biodiversity experts for almost half of its fauna. On top of this, for more than a

quarter there are only 1 or 2 active experts available, and furthermore, there is a sufficient number of experts for only less than a quarter of the fauna. It is often the case that among the one or two active experts of a taxon, one or both are already retired, or may leave academia any time, leaving an irreplaceable vacuum in the knowledge of the country's fauna. Moreover, we document a strong taxonomic bias favouring mostly vertebrates and partly some popular invertebrate taxa.

What shapes the diversity of biodiversity experts

The ability of correctly identifying species largely depends on the characteristics of the animal group. Learning to identify "popular" groups such as butterflies and "unpopular" ones, such as free-living nematodes, requires radically different levels of energy and time investment. Also, the amount of helpful literature and the number of expert colleagues to learn from are likely much lower for "unpopular" groups.

In Hungary, most biodiversity experts, and the vast majority of experts of "unpopular groups" are professionals (regarding the role of amateur biodiversity experts, see under "Trends in biodiversity research"). Nevertheless, only a small percentage of professionals become experts in "unpopular" animal groups. To illuminate what factors determine the animal group a professional biodiversity expert will be specialized in, we interviewed experts of "unpopular" groups. While a few of them choose the "unpopular" groups of their own accord, majority of them started working on their group following the suggestions of an influential professor or colleague at the university where they had graduated or in the museum or research institute where they had been working, a dwindling group of senior taxonomic mentors. These interviews also revealed that at least between the 1960s and the 1990s the general view was that every taxonomic group should have its expert in the country, but one expert per group was sufficient.

An illuminating example is that of Klára Dózsa-Farkas, who, as a student, was interested in frogs. During the first year at university, she started visiting Olivér Dely, the curator of herpetology at the Hungarian Natural History Museum. After about a year she spent learning about frogs, Dely told her that one frog-specialist is enough for the country, so it was time to look for another group to study. Dely suggested Prof. Andrássy, the expert of nematodes, as her supervisor. The thesis of Dózsa-Farkas, supervised by Prof. Andrássy, was the study of animals living in the water pipe system of major Hungarian cities. Since it was mostly nematodes that were found in the analysed water, she became relatively familiar with nematodes and learned to identify them. After she defended her thesis, she was soon granted a position as an assistant professor, while Andrássy suggested her to work on another group, the Enchytraeidae, because one nematode-specialist was sufficient in Hungary. Thus, Dózsa-Farkas started working on Enchytraeidae, in which group her 50-year work resulted in the description of 34 species from Hungary new to science (Dózsa-Farkas 2020).

Lastly, before students choose a taxon to study, they first have to be interested in nature as strongly as to choose to study biology. Being interested in living organisms often was triggered by their parents, spending sufficient time in the nature during leisure activities, having natural surroundings at their parents' home, etc., which nowadays are often not met (Frobel and Schlumprecht 2016).

Identification books

Although to a lesser degree than the suggestions of an influential professor, available identification books or monographs can also play an important role in rising a young enthusiast's attention for a given animal group, mentioned by a few of the interviewed biodiversity experts. Even if over 60% of the Hungarian fauna has appeared in monographic works, most of them were published before 1990, are outdated, and not eye-catchy. Even the ones published recently are not available in bookstores but can only be purchased from the publisher or sometimes a copy turns up in antiquarian book shops. The availability of most Fauna Hungariae volumes online will partly mitigate this issue.

How was it in the past and how will it be in the future?

While we now clearly see the current situation of the diversity of Hungarian biodiversity expertise, we lack sufficient information to estimate similar percentages in the past in order to determine trends of the last decades. However, our data suggest that the diversity of biodiversity experts was higher, at least between the 1990s and 2010s than today, and that it will continue to decrease in the future. It is generally true that biodiversity discovery (and the ability of species-level identification) in several of the megadiverse families rests almost exclusively on the shoulders of very few specialists, as demonstrated for marine Gastropoda by Bouchet et al. (2016) and for Diptera by Whitmore et al. (2021). For example, the recently deceased László Papp (1946–2021) reported ca. 2000 dipteran species new to the fauna of Hungary (Soltész and Peregovits 2021). With his death, we lost the expertise to identify thousands of dipteran species. Also, with the sudden passing of Ottó Merkl (1957–2021) Hungary lost its nation-wide knowledge in dozens of beetle families. The expertise of István Andrássy (1927–2012), who published a handbook of three volumes and 1622 pages on the Hungarian free-living nematodes (see Dózsa-Farkas et al. 2012), and that of the extremely actively publishing acarologist Sándor Mahunka (1937–2012) also was not perpetuated by successors. This list can go on and on.

Current, project-based, impact factor-seeking research and publication strategies (discussed below) do not support careers in which an individual must spend years learning a difficult, speciose, hard-to-identify group before the first papers (usually in a low impact factor journal) can be published (Coleman and Radulovici 2000). Instead, high impact publications are required within a very short time after starting PhD studies, or a project. As a result, the taxonomists and biodiversity experts in the Hungarian higher education have almost disappeared, and were replaced by experts in other disciplines, such as evolutionary biology and behavioural ecology. Similarly, the Hungarian Natural History Museum, which has been the national "cathedral" for biodiversity research for 200 years, has been considerably weakened in its role. Furthermore, the Hungarian Academy of Sciences used to have three zootaxonomist professors as regular members in the last few decades. After their deaths, nobody with such expertise succeeded them, resulting in a decrease of support and lobbying power for animal taxonomy and biodiversity research. As a result, there are no highly influential professors in the field anymore, and the chance that a young biologist student interested in birds will be directed towards an "unpopular" group has decreased to nearly zero. This will inevitably lead to further narrowing of biodiversity expertise in the future as bias towards showy taxa,

such as mammals and birds, is widespread in organismic science. The late Simon Leather called it "taxonomic chauvinism" (Leather 2009) or "vertebratism" (Leather 2013).

Annual Bioblitz events have been organized by the Hungarian Biodiversity Research Society since 2006. These events have been inspired by the event in Walden Pond (Massachusetts, USA), where in 1998, over a hundred experts gathered to collect and identify macroscopic organisms, and finally reached a reported number twice higher than the previously estimated one (Wilson 2002). During the Hungarian events usually 55–65 experts collect and identify plants, animals and fungi, and the outcome is a list of ca. 2000–2500 species, of which ca. 80–85% are animals. It has been always difficult or impossible to find experts for some taxa such as Diptera and Acari. Furthermore, some of the older members of the always participating leading experts deceased or cannot join anymore due to health problems. In the same time, there have always been around 20 young biodiversity experts at the beginning of their careers (mostly students), although their fluctuation is generally high, as many leave academia or continue their careers abroad.

How is the situation in other countries?

According to a recent report on European taxonomic capacities (Hochkirch et al. 2022), Hungary is within the upper third in the list of European countries on the Red List Index of insect taxonomists, indicating a still good taxonomic capacity. The 12th position of Hungary is preceded by Czechia, Germany, Russia, United Kingdom, Italy, France, Spain, Austria, Slovakia, Switzerland and Denmark, and followed by countries such as Finland, Ukraine, Poland, Belgium, Croatia and Bulgaria. The population sizes, GDP, scientific history, and richness of the fauna show great variabilities across countries. With this paper, we provide a detailed overview of Hungary's identification capacities and hope similar data will be made available in future for other countries for comparison.

Trends in biodiversity research

Why do the number of papers and publishing experts decrease?

We show, based on an analysis of all invertebrate faunistic papers between 1970 and 2020, that faunistic research experienced a golden era between ca. 1995 and 2010 in both aquatic and terrestrial invertebrates in Hungary. In the last decade, however, we notice a strong decline, and the number of papers and active experts went down to the level of the 1970s. What factors cause these negative trends?

Changes in science and scientometrics

In the academic world research proposals are won and permanent positions offered based on past publication activity. Instead of the number of publications, rather their quality matters, which erroneously is determined exclusively by means of citation counts and their derivatives (impact factor, SCImago Journal Rankings, H-index, see Krell 2000, 2002). Papers reporting only faunistic data and written in traditional extensive format are very rarely or not at all accepted by journals with an impact factor, which is still widely considered to be one of the main measures for publication "quality" (Krell 2000, 2002), while in fact, it only indicates the short-term attention a paper attracts (Krell 2012). As a result, in

the publication rush, researchers otherwise capable of performing faunistic research, tend to abandon it. Even if faunistic data are produced as a by-product of ecological research, they are less often published to avoid wasting time on "useless" papers. Moreover, publishing "raw" biodiversity data is neither demanded nor encouraged by procurers (National Parks, other conservation organizations), which contributes to valuable data remaining in unpublished research reports and field notes.

This was different 30 to 50 years ago, when the number of publications was an important measure of one's publication activity, especially in Central and Eastern European countries. This old practice was criticized also, as in many cases it encouraged unjustified increases of the number of articles. It was not really fair that a paper of local interest published in a local journal was put on a level with a widely applied research result published in an international journal, but this kind of performance evaluation was more favourable to publications with purely faunistic content than the current system.

The publication pressure also manifests itself in the changes of expectations from employers. As mentioned by several colleagues in the questionnaire, employers (leaders in universities and research institutes) often are not supportive to employees publishing low-impact biodiversity papers.

Changes in administrative pressure

Overwhelming administrative duties were part of the reasons for less time for publishing taxonomy and faunistics (e.g., Niemczyk and Rónay 2022). It is difficult to objectively judge whether those tasks were fewer a few decades ago, but according to the survey, they were. This problem may specifically affect Hungary (and most likely other Central and Eastern European countries). There, partly due to underfunding and staff shortages as well as due to the permanence of previous inappropriate practices, management and scientific duties are not clearly separated. Institutes and departments do not have a separate leader (and even staff) for the management of operative and technical issues, in many cases a significant part if not all such tasks fall onto the researchers, cutting down their time and, more importantly, their energy for research.

Museums, National Parks

Natural history museums used to be the strongholds of taxonomic research, partly because of their collections that serve as an essential research infrastructure, and partly because they traditionally were among the largest employers of taxonomic researchers. We observe a global shift in the focus of natural history museums towards outreach (exhibitions, shows, parties, informal education, etc.), with fewer positions being available for collection-based researchers (Andreone et al. 2014; Naggs 2022).

Before and shortly after the democratic transition in Hungary (1990), becoming a curator in one of Hungarian museums either in the capital Budapest or in one of the smaller towns was a highly sought-after, intellectual position, which provided sufficient income for the basic expenditures of a family. During those times, museums provided a considerable share of biodiversity publications, and employed ca. 15% of zoologists (Bakonyi et al. 2007). Their impact was probably even higher. The situation changed around the 2000s, when the salaries in those institutes were not adjusted for inflation, thus, became relatively low. Even if some of those museums would provide available positions for enthusiastic

young biodiversity experts, young people after finishing university would be unable to start an independent life on the salaries provided.

Furthermore, the situation of the Hungarian Natural History Museum (HNHM) is aggravated by the sense of existential insecurity that has been created among its staff in relation to the museum's envisaged move to the countryside. Currently, this plan has been apparently ceased for financial reasons. This also seems to be not unique. In 2031, parts of the collection of the Natural History Museum in London will be moved to the Thames Valley Science Park in Reading (about an hour away from the current location) (Smith 2024) after a much more remote location was seriously considered for some time (Naggs 2022). Similar plans have been made public for the Muséum National d'Histoire Naturelle (Paris) with Dijon, over 300 km away, as destination (Anonymous 2023). Moving collections of natural history museums from their original place into remote areas that are often not ideal for biodiversity research, is also a sign of interpreting collections as storage places, and not as active resources for biodiversity research.

Similar trends can be seen in the case of national parks and other institutions of nature conservation, showing a decrease of biodiversity research, partly due to a decrease in the actual surveying and data collection activities by their own staff, partly because of decreasing in funding for external scientists for biodiversity studies.

Changes in the quality of education

The decline in the recognition and popularity of science can be observed all over the world (Krapp and Prenzel 2011; Anderhag et al. 2016; Steidtmann et al. 2023) and can be seen in the field of education as well. In Hungary the number of natural science classes is decreasing, already in elementary school. The number of people continuing their studies in this direction in higher education is also decreasing; moreover, the lack of educational reform and the deterioration of quality during the last 20 years at universities is clearly visible. After secondary school, the best students continue their studies abroad (Ginnerskov-Dahlberg 2021). The amount of taught material at Hungarian universities is constantly decreasing and is not replaced by the transfer of modern knowledge or the acquisition of skills and the provision of competences, but rather by addressing basic deficiencies of lower-level schooling. In addition, the underfunding of the education system, the lack of students' motivation, the low number of teachers and their very high workload also do not help in high quality talent management and in finding and training students who may be receptive to becoming biodiversity researchers (Frobel and Schlumprecht 2016). The Bologna system (Zahavi and Friedman 2020), which has been applied in Hungary since 2006, also did not help in raising a future generation of taxonomists and biodiversity experts. It was more likely for a student to be engaged in an animal group in the previous system, in which they have to write a single thesis during the 5 years period of their biology studies. Instead, under the Bologna system, they have to finish a bachelor thesis in three, and a master thesis in another 2 years.

Less and changing biodiversity projects

As mentioned above, the world and science are transforming. It is currently very hard to get funding for pure biodiversity research without "added values". Large-scale projects of the past, such as the inventories in Bátorliget or the Bakony Mountains, are no longer feasible. In a non-judgmental manner, people and decision-makers do not see and understand

the direct benefit of biodiversity research delivering pure data, if it is not translated to, for example, "ecosystem services" or "assessment categories: good vs bad", i.e., to a more tangible benefit for society. Nowadays, even influential professors are unable to get bigger grants for pure biodiversity research while new generation scientists cannot become influential professors if they only do faunistics without these added values. But if added values and new methods are in the focus, the publication and availability of basic biodiversity records fade to the background or get lost (see above).

Faunistic research used to be requested and paid for by National Parks since the 1970s and 1980s, which were content with receiving long species lists of their fauna. Since Hungary joined the European Union, the 'classic' faunistic research has been largely replaced by monitoring of selected groups of species, mostly those flagged as "Natura 2000" species. This resulted in limited efforts being allocated in finding as many species as possible in the field. Even if faunistic data were produced as a by-product, they were often not published because of the low reputation of faunistic papers.

Lack of a new generation

The number of faunistics-related abstracts on student conferences shows trends similar to the overall picture: increase between ca. 1970 and 2010, and strong decrease since then. The reasons for this decrease have to do with the lack of positions and/or the poor salaries of the available positions for such biodiversity experts in museums and universities, and the decreasing number of faunistics and/or taxonomy-oriented supervisors in universities. A lower number of experts in the new generation can easily lead to a negative spiral, resulting in an even more strongly decreasing number of active biodiversity experts over time.

Amateur biodiversity experts

Posts collected from an animal identification social media group revealed that the general public is interested in knowing what animals live around them. Some laypeople can become biodiversity experts capable of identifying species of animal groups, and thus, can contribute to biodiversity research. It is often believed that the decreasing funding of biodiversity research (understood in a wider sense, but mostly referring to taxonomy) is compensated by the high number of amateur taxonomists and biodiversity experts (Fontaine et al. 2012). However, this is a misconception. In that study, retired taxonomists and students were also considered amateurs. This was not and could not be an approach to follow in our present study, because when looking at five decades of biodiversity publications, it is impossible to decide which author was amateur or retired when they were authoring a given publication. Instead, we treated every expert "professional" if they had ever been a professional during their career. Using this method, we found that the proportion of actively publishing amateur biodiversity experts is small compared to professional ones (20 out of 130: ca. 15%). This proportion is similar to the European average of "volunteers" (18.3%, see Hochkirch et al. 2022: Fig. 11 therein). It appears that nowadays, at least in Hungary, once somebody is interested in an animal group early in their career, they will eventually graduate in biology and will find a job where they can use their knowledge in animal identification, or give up.

Our survey on laypeople's posts on a social media group revealed that they were mostly interested in animal groups that are well covered by experts, and only very few posts target species that nobody can identify in the country. As already shown by Fontaine et al.

(2012), amateurs typically study popular, usually large bodied animal groups. Why is it so? Amateurs, who collect, observe, take photos and identify animals for fun, do this activity for their own interest. They need direct experience of success in a reasonable time. For example, identification of large beetles or butterflies is possible with some books available in popular bookstores or e-commerce platforms, and the species-specific traits are clearly visible with a naked eye or a magnifying glass. Probably few amateurs would invest in expensive microscopes or would do time-consuming dissections to identify tiny and hard-to distinguish mites or miniature flies.

Summing up, we neither can expect that amateur biodiversity experts would fill the existing gaps in biodiversity expertise, nor can we hope that the amateurs will compensate for the future loss of professional experts in taxonomy and faunistics. Nevertheless, the 15–20% of amateurs among biodiversity experts, although small, are in no way negligible. Those experts deserve support from professionals to contribute to the knowledge of the fauna as much as possible.

What can we do to mitigate the problem?

The number and diversity of active biodiversity experts is decreasing, and we can predict that this trend will continue in the future. Therefore and because of the other reasons discussed above, the amount of available up-to-date biodiversity information is also decreasing. To revert or at least reduce these negative trends, we would need to change how we plan, perform and publish biodiversity research, and how we raise the next generation of biodiversity experts. On the other hand, besides bottom-up changes through education, top-down solutions are also necessary, such as ensuring permanent positions and long-term funding for taxonomy and faunistics (Löbl et al. 2023).

Raising biodiversity experts with the ability of correctly identifying species and understanding molecular methods

Classic faunistics, which only produces locality data and faunal lists for geographic areas without any additional information, with limited availability, published in regional museum journals, is not what we would like to bring back. Instead, in the training of the young generation of biologists modern techniques must play a significant role, in addition to classic taxonomic knowledge.

The ability of correct identification would ensure avoiding false faunistic data and littering GenBank/BOLD with incorrectly assigned species names due to inadequate identification (e.g., Groenenberg et al. 2011; Radulovici et al. 2021; Csabai et al. 2023). At the same time, the knowledge of molecular techniques could provide an additional set of information to the occurrence data. It can ignite taxonomic and systematic studies (e.g., Rowson et al. 2014) and help revealing the natural history of species (Sun et al. 2016; Csapó et al. 2020; Löbl et al. 2023). Based on the principles of the increasingly important approach of "integrative taxonomy" (Dayrat 2005; Pante, et al. 2015), "integrative faunistics" can be promoted as an approach that does not only produce occurrence data, but, for example, builds barcode reference libraries and helps to make the barcode coverage as complete as possible. Currently, the barcode databases are not yet fully covering the fauna even in Europe (Weigand et al. 2019; Richling and Proschwitz 2021; Csabai et al. 2023), and there are difficulties arising from the application of the single marker approach and from barcode sharing in some groups (Darschnik et al. 2019; Rewicz et al. 2021; Prieto et al. 2021;

Dincă et al. 2021; Geiger et al. 2021). Increasing the coverage of the barcode reference databases and fixing errors can only be done successfully with the substantial involvement of competent biodiversity experts with classic morpho-taxonomic knowledge. Therefore, future generations should understand these challenges and must fill the gaps accordingly.

Data analysis and publication strategy

It is necessary to show to early career researchers, ideally during their early training, how biodiversity research can be placed at the centre of a scientific career, so that it represents scientific performance that can be measured even according to current expectations by publications of smaller or larger biodiversity datasets, fauna inventories, checklists, and meta-analysis of biodiversity data in international journals. These journals, even the ones with impact factors and high rankings, increasingly offer the opportunity to present faunistic results in the form of concise data papers that shed light on the structure and main characteristics of the data with some basic analyses in addition to the metadata of the dataset. An increasing number of journals allow extensive electronic supplements containing raw data. Such supplements are an acceptable alternative when the publisher archives them together with the main paper. A very important common feature of the world of data papers is the mandatory open data policy, the free use of data published in global or local online databases, biodiversity platforms (e.g., GBIF, BOLD, iNaturalist), and data repositories (e.g., Dryad, Zenodo, Figshare).

The new generation of biodiversity experts, in addition to compiling, managing, and publishing their own data, must master preparing and publishing meta-analysis-like local or even global analyses for a specific area, habitat or group of organisms, thereby increasing the international visibility of their work. We believe that this will give positive feedback on their work, as a kind of self-stimulating process.

Filling gaps in fauna-wide knowledge

To stop the decrease of number and diversity of biodiversity experts, the next generation's attention must be directed towards "unpopular groups", since we can only manage, understand, protect, and use what we know. Most biodiversity experts start being interested in a given group of animals (mostly large bodied, "beautiful" ones), and eventually become experts, while this is rarely the case for groups of tiny or unattractive organisms, which thus remain without experts.

The role of higher education would be to introduce under-researched taxonomic groups to biology students. The attitude of the youth has changed, in that they would like to achieve results quickly, with the smallest possible work investment. Most of them are not at all willing to start a scientific work that begins with 2–5 years of studying difficult-to-identify taxa. However, if we show them the methods and possibilities outlined above at an early stage, then some of them, by the time they finish their university education, may already have the basic knowledge needed to identify a specific group of under-explored organisms. This might be a suitable strategy, using a combination of classic and new methods that will be able to produce visible outputs at the international level within a reasonable timeframe. For "unpopular" groups, there is an increased potential to discover new species, solve taxonomic problems, write monographs, contribute to identifiability of species, which is already a higher level output than a pure list of scientific names.

Classic taxonomic knowledge is sought after

We recognize that using molecular techniques and data analyses are not the only ways for the new generation towards academic career. There will always be students with interest in morphology. While they should also understand the principles of molecular techniques and quantitative data, robust morphology-based faunistic knowledge of a given animal group can be expanded towards taxonomy, and could lead to a bright scientific career, especially if is associated with cooperation with ecologists and molecular phylogeneticists.

Since learning the taxonomy and identification of a speciose group is so time-consuming, scientometric methods used in other supraindividual biological disciplines should not work the same way: there should be less rigorous quantity control, at least in the early career of biodiversity experts. We do not consider publication pressure a negative factor, since publications are important outcomes of research and the main tools to share the acquired information. Instead, the publication pressure should be more taxonomy-oriented, and should not drive experts away from taxonomic revisions towards research topics that can be published in journals with 'high impact'.

Role of amateur scientists

The presence of citizen scientists (individuals capable of being involved in citizen science projects led by professionals) and amateur scientists (scientists, who work independently out of their own interest and without payment) is probably stronger in welfare states, i.e., it increases with the wealth of citizens. However, as shown above, as wealth grows in Hungary or any given country, the hope that amateur scientists replace missing professional biodiversity experts is only realistic in "popular" animal groups. Biodiversity experts in "unpopular" groups will not come from unpaid amateurs. Biodiversity expertise (i.e., the ability of identifying species) in those taxonomic groups goes hand in hand with the discovery of new species and revising genera, i.e., taxonomy in a strict sense. Therefore, at least for the "unpopular" groups, the solution is the same as outlined for taxonomic impediments: we need more funds and more jobs. However, while in "unpopular" groups amateur scientists would have a smaller role, their importance can be considerable for "popular" groups. Lifting up laypeople to become amateur scientists would require increasing public awareness, by NGOs, natural history museums, universities, national parks, and even online platforms. Nevertheless, we are not naive; a healthy amateur scientist community can only stand on the shoulder of professionals, and if natural history museums and university departments lack biodiversity experts, amateur scientist will have nobody to seek support from.

Radical changes are needed in biodiversity research management

While bottom-up approaches, such as educating the next generation to become modern biodiversity experts with knowledge in modern techniques, and supporting amateur scientists is important, this may not be enough. Top-down solutions are also necessary, because even if we raise a few skilled young biodiversity experts, they may not find open positions and even if they do, their publication records may not be competitive enough to successfully run for the limited resources and win against hypotheses-driven researchers. In order not to lose the biodiversity knowledge in future generations, changes are necessary on the level of

governmental and science politics. There are several good examples to allocate funds specifically for exploring the biodiversity of a country, such as the National Institute of Biological Resources in South Korea (https://www.nibr.go.kr/cmn/sym/mnu/mpm/511050000/enHtmlMenuView.do#), or the Swedish (https://www.artdatabanken.se/en/det-har-gor-vi/svenska-artprojektet/) and the Norwegian Taxonomy Initiative (https://www.biodiversity.no/Pages/135523/The_Norwegian_Taxonomy_Initiative).

By using exclusively citation-based metrics, it is almost impossible for biodiversity experts to achieve the same marks as those conducting hypothesis-based research due to the peculiarities of the scientific field and the established publication practices (Krell 2000, 2002). Therefore, while it is understandable that picking one discipline and handling it independently from the others would sound controversial, we should work towards informing decision-makers in science policy that alternative ways of science evaluation are necessary for fairly assessing biodiversity research. For example, number of occurrence records published can be a better additional metric to evaluate a biodiversity expert's performance, rather than the number of citations and H-index alone. But this should also be handled with care and on a case-by-case basis, because, for example, identifying land snails is always quicker than that of tiny insects that require careful preparation. Writing identification books, which is one of the most important tasks for biodiversity experts and taxonomists (see below), will not result in the increase of impact factor metrics-based evaluation, but it should definitely be appreciated considering the huge time commitment and future benefit. Methods comparing within subject categories (Q1–Q4 rankings, for example SCImago Journal Ranking or Clarivate Journal Category Rankings based on Science Citation Index Expanded (SCIE) and based on Journal Citation Indicator (JCI)), may improve the situation a little, but since 'Biodiversity science' is not an independent subject category, the recognition of more local, data-providing, biodiversity-revealing research also encounters difficulties based on these evaluation systems. Ensuring positions that are open only for biodiversity research is a must, and cannot be filled solely on grounds of citation-based performance. As we outlined above, this does not mean that a biodiversity expert only has to identify animals and publish less inspiring pure species lists. The positions for biodiversity experts have to be filled with people, who are able to transfer their knowledge in international publications and ideally, making it freely available in online datasets. Furthermore, they should be good communicators to the general public. Only these top-down changes, together with the change of thinking, publication strategy and educating the next generation of biodiversity experts, would provide the necessary knowledge to maintain identification capabilities for a country's fauna in the long term (Engel et al. 2021).

Sources for writing identification books

One way to facilitate animal identification for the future is to build quasi-complete DNA barcode reference libraries; the other is to translate the existing biodiversity knowledge into identification books (sensu lato, including online identification platforms as well). As several experts we interviewed mentioned, their interest to become an expert of a taxonomic group started with an identification book. The *Fauna Hungariae* series, published between 1953 and 1991, was an excellent project, but it has unfortunately ceased. A similar, more modern project is the AidGap series of the Field Studies Council in the UK (see, e.g., Bee et al. 2022), which resulted in the publication of dozens of well-illustrated identification books about the fauna and flora of the British Islands. Initiating similar projects to write

scientifically sophisticated identification books should be a priority in Hungary as well as in other countries.

Stimulate publication of unpublished faunistic data

As shown above, a considerable amount of faunistic data remains in unpublished and inaccessible research reports and notes. Funding and outlets should be provided to encourage authors to publish their data, preferably in a format that is more modern than a list of scientific names in a museum journal. Research (e.g., Horizon) and conservation (e.g., LIFE) projects, both programs of the EU, generate a wealth of biotic data. To make their data available to the public (e.g., through GBIF), the publication of data in online databases should be one of the conditions for funding.

How can taxonomic bias be lessened?

Interests of the society determines the allocation of resources to research on, and conservation of, the various taxonomic groups and public opinion (Wilson et al. 2007). For example, in the USA, birds, mammals and fish have a more positive social image amongst the general public than reptiles, amphibians, invertebrates or micro-organisms (Czech et al. 1998). Increased science communication targeting children and young people can be a solution to change this and help to recruit more young biologists interested in invertebrate taxa and change the attitudes of the society in this direction. Social media, influencer videos and public-school education are the most efficient tools to reach these generations. Scientific journal editors, peer reviewers and decision makers in the field of science and conservation also have opportunities to lessen taxonomic bias.

Concluding Remarks

While biodiversity knowledge has been declining in Hungary and elsewhere, where it had been traditionally strong, we still have the expertise to build a new generation of biodiversity experts. Taking advantage of this declining expertise and combining it with modern methods could raise young biodiversity experts to maintain the national capacities to deal with the ongoing biodiversity crisis and to avoid a complete extinction of knowledge of the fauna and flora we share the country and the planet with. Political will and modest financial resources would go a long way to avoid irreversible damage to the national biodiversity expertise.

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online questionnaire; Péter Kóbor complied the database of identification books. Zoltán Csabai analysed the data. All Hungarian authors contributed in collecting data of animal groups (number of species and experts). Barna Páll-Gergely, Zoltán Csabai and Frank-Thorsten Krell wrote the manuscript. All authors read and approved the final manuscript.

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Declarations

Competing interests The authors declare no competing interests.

References

Anderhag P, Wickman P-O, Bergkvist K, Jakobson B, Hamza KM, Säljö R (2016) Why do secondary school students lose their interest in science? Or does it never emerge? A possible and overlooked explanation. Sci Edu 100:791–813. https://doi.org/10.1002/sce.21231

Andreone F, Bartolozzi L, Boano G, Boero F, Bologna MA, Bon M, Bressi N, Capula M, Casale A, Casiraghi M, Chiozzi G, Delfino M, Doria G, Durante A, Ferrari M, Gippoliti S, Lanzinger M, Latella L, Maio N, Marangoni C, Mazzotti S, Minelli A, Muscio G, Nicolosi P, Pievani T, Razzetti E, Sabella G, Valle M, Vomero V, Zilli A (2014) Italian natural history museums on the verge of collapse? ZooKeys 456:139–146. https://doi.org/10.3897/zookeys.456.8862

Anonymous (2023) Save the collection of the Paris National Museum of Natural History. https://www.researchgate.net/post/Can_you_help_to_save_the_collections_of_the_Museum_National_dHistoire_Naturelle_in_Paris

Bajomi B, Pullin AS, Stewart GB, Takács-Sánta A (2010) Bias and dispersal in the animal reintroduction literature. Oryx 44:358–365. https://doi.org/10.1017/S0030605310000281

Bakonyi G, Korsós Z, Samu F (2007) A hazai zoológiai intézmények—egy felmérés tanulságai [Hungarian zoological institutes—lessons of a survey]. Magy Tud 168:1407–1413

Bánki O, Roskov Y, Vandepitte L, DeWalt RE, Remsen D, Schalk P, Orrell T, Keping M, Miller J, Aalbu R, Adlard R, Adriaenssens E, Aedo C, Aescht E, Akkari N, Alonso-Zarazaga MA, Alvarez B, Alvarez F, Anderson G et al (2021) Catalogue of life checklist (version 2021–10–18). Catalogue of Life, Leiden. https://doi.org/10.48580/d4t2

Bee L, Oxford GS, Smith H (2022) The evolution of field guides to British spiders. Arachnology 19:158–165. https://doi.org/10.13156/arac.2022.19.sp1.158

Bello E, Becerra JM, Valdecasas G-A (1992) Counting on taxonomy. Nature 357:531. https://doi.org/10.1038/357531b0

Bouchet P, Bary S, Héros V, Marani G (2016) How many species of molluscs are there in the world's oceans, and who is going to describe them? Mém Mus Nation Hist Nat 208:9–24

Coleman CO, Radulovici AE (2000) Challenges for the future of taxonomy: talents, databases and knowledge growth. Megataxa 1(1):28–34. https://doi.org/10.11646/megataxa.1.1.5

Costello MJ, Wilson S, Houlding B (2012) Predicting global species richness using rates of species description and estimates of taxonomic effort. Syst Biol 61:871–883. https://doi.org/10.1093/sysbio/syr080

Costello MJ, May RM, Stork NE (2013) Can we name earth's species before they go extinct? Science 339:413–416. https://doi.org/10.1126/science.1230318

Csabai Z, Čiamporová-Zaťovičová Z, Boda P, Čiampor F Jr (2023) 50%, not great, not terrible—Pan-European gap-analysis shows the real status of the DNA barcode reference libraries in two aquatic invertebrate groups and points the way ahead. Sci Total Environ 863:160922. https://doi.org/10.1016/j.scitotenv.2022.160922

Csapó H, Krzywoźniak P, Grabowski M, Wattier R, Bącela-Spychalska K, Mamos T, Jelić M, Rewicz T (2020) Successful post-glacial colonization of Europe by single lineage of freshwater amphipod from its Pannonian Plio-Pleistocene diversification hotspot. Sci Rep 10:18695. https://doi.org/10.1038/s41598-020-75568-7

Csuzdi C, Mahunka S (2007) A magyar zootaxonómia rövid története [Short history of zootaxonomy in Hungary]. Magy Tud 168(11):1381–1386

Czech B, Kausman PR, Borkhataria R (1998) Social construction, political power, and the allocation of benefits to endangered species. Conserv Biol 12:1103–1112

Darschnik S, Leese F, Weiss M, Weigand H (2019) When barcoding fails: development of diagnostic nuclear markers for the sibling caddisfly species *Sericostoma personatum* (Spence in Kirby & Spence, 1826) and *Sericostoma flavicorne* Schneider, 1845. ZooKeys 782:57–68. https://doi.org/10.3897/zookeys.872.34278

Dayrat B (2005) Towards integrative taxonomy. Biol J Linn Soc 85:407–415. https://doi.org/10.1111/j.1095-8312.2005.00503.x

de Carvalho MR, Bockmann FA, Amorim DS, de Vivo M, de Toledo-Piza M, Menezes NA, de Figueiredo JL, Castro RM, Gill AC, McEachran JD, Compagno LJ, Schelly RC, Britz R, Lundberg JG, Vari RP, Nelson G (2005) Revisiting the taxonomic impediment. Science 307:353. https://doi.org/10.1126/science.307.5708.353b

de Carvalho MR, Ebach MC, Williams DM, Nihei SS, Rodriguez MT, Grant T, Silveira LF, Zaher H, Gill AC, Schelly RC, Sparks JS, Bockmann FA, Séret B, Ho H-C, Grande L, Rieppel O, Dubois A, Ohler A, Faivovich J, Assis LCS, Wheeler QD, Goldstein PZ, de Almeida EAB, Valdecasas AG, Nelson G (2014) Does counting species count as taxonomy? On misrepresenting systematics, yet again. Cladistics 30:322–329. https://doi.org/10.1111/cla.12045

Dincă V, Dapporto L, Somervuo P, Vodă R, Cuvelier S, Gascoigne-Pees M, Huemer P, Mutanen M, Hebert PDM, Vila R (2021) High resolution DNA barcode library for European butterflies reveals continental patterns of mitochondrial genetic diversity. Commun Biol 4:315. https://doi.org/10.1038/s42003-021-01834-7

Dixon HJ, Elmarsafy M, Hannan N, Gao V, Wright C, Khan L, Gray DK (2022) The effects of roadways on lakes and ponds: a systematic review and assessment of knowledge gaps. Environ Rev 30:501–523. https://doi.org/10.1139/er-2022-0022

Dózsa-Farkas K, Csuzdi C, Berczik A (2012) In memoriam Prof. István Andrássy (1927–2012). Opusc Zool Budapest 43(2):109–120

Dózsa-Farkas K (2020) Enchytraeids of Hungary (Annelida: Clitellata, Enchytraeidae). Pedozoologica Hungarica No. 7. Department of Systematic Zoology and Ecology of Eötvös Loránd University, Budapest

Engel MS, Ceríaco LMP, Daniel GM, Dellapé PM, Löbl I, Marinov M, Reis RE, Young MT, Dubois A, Agarwal I, Lehmann AP, Alvarado M, Alvarez N, Andreone F, AraujoVieira K, Ascher JS, Baêta D, Baldo D, Bandeira SA, Barden P, Barrasso DA, Bendifallah L, Bockmann FA, Böhme W, Borkent A, Brandão CRF, Busack SD, Bybee SM, Channing A, Chatzimanolis S, Christenhusz MJM, Crisci JV, D'Elía G, Da Costa LM, Davis SR, de Lucena CAS, Deuve T, Fernandes Elizalde S, Faivovich J, Farooq H, Ferguson AW, Gippoliti S, Gonçalves FMP, Gonzalez VH, Greenbaum E, Hinojosa-Díaz IA, Ineich I, Jiang J, Kahono S, Kury AB, Lucinda PHF, Lynch JD, Malécot V, Marques MP, Marris JWM, Mckellar RC, Mendes LF, Nihei SS, Nishikawa K, Ohler A, Orrico VGD, Ota H, Paiva J, Parrinha D, Pauwels OSG, Pereyra MO, Pestana LB, Pinheiro PDP, Prendini L, Prokop J, Rasmussen C, Rödel MO, Rodrigues MT, Rodríguez SM, Salatnaya H, Sampaio Í, Sánchez-García A, Shebl MA, Santos BS, Solórzano-Kraemer MM, Sousa ACA, Stoev P, Teta P, Trape JF, Dos Santos CVD, Vasudevan K, Vink CJ, Vogel G, Wagner P, Wappler T, Ware JL, Wedmann S, Zacharie CK (2021) The taxonomic impediment: a shortage of taxonomists, not the lack of technical approaches. Zool J Linn Soc 193:381–387. https://doi.org/10.1093/zoolinnean/zlab072

Fontaine B, van Achterberg K, Alonso-Zarazaga MA, Araujo R, Asche M, Aspöck H, Aspöck U, Audisio P, Aukema B, Bailly N, Balsamo M, Bank RA, Belfiore C, Bogdanowicz W, Boxshall G, Burckhardt D, Chylarecki P, Deharveng L, Dubois A, Enghoff H, Fochetti R, Fontaine C, Gargominy O, Gomez Lopez MS, Goujet D, Harvey MS, Heller K-G, van Helsdingen P, Hoch H, De Jong Y, Karsholt P, Los W, Magowski W, Massard JA, McInnes SJ, Mendes LF, Mey E, Michelsen V, Minelli A, Nieto Nafría JM, van Nieukerken EJ, Pape T, De Prins W, Ramos M, Ricci C, Roselaar C, Rota E, Segers H, Timm

T, van Tol J, Bouchet P (2012) New species in the Old World: Europe as a frontier in biodiversity exploration, a test bed for 21st century taxonomy. PLoS ONE 7(5):e36881. https://doi.org/10.1371/journal.pone.0036881
Frobel K, Schlumprecht H (2016) Erosion der Artenkenner. Natursch Landschaftpl 48:105–113
Geiger M, Koblmüller S, Assandri G, Chovanec A, Ekrem T, Fischer I, Galimberti A, Grabowski M, Haring E, Hausmann A, Hendrich L, Koch S, Mamos T, Rothe U, Rulik B, Rewicz T, Sittenthaler M, Stur E, Tończyk G, Zangl L, Moriniere J (2021) Coverage and quality of DNA barcode references for Central and Northern European Odonata. PeerJ 9:e11192. https://doi.org/10.7717/peerj.11192
Ginnerskov-Dahlberg M (2021) Student migration from Eastern to Western Europe. Routledge, London. https://doi.org/10.4324/9781003056287
Greene HW (2005) Organisms in nature as a central focus for biology. Tr Ecol Evol 20:23–27. https://doi.org/10.1016/j.tree.2004.11.005
Groenenberg DSJ, Neubert E, Gittenberger E (2011) Reappraisal of the '"Molecular phylogeny of Western Palaearctic Helicidae s.l. (Gastropoda: Stylommatophora)"': when poor science meets GenBank. Mol Phyl Evol 61:914–923. https://doi.org/10.1016/j.ympev.2011.08.024
Hamer M (2013) A national strategy for zoological taxonomy (2013–2020). South African National Biodiversity Institute, Pretoria. https://www.sanbi.org/documents/a-national-strategy-for-zoological-taxonomy-2013-2020/
Hári K, Fail J, Streito J-C, Fetykó KG, Szita É, Haltrich A, Vikár D, Radácsi P, Vétek G (2021) First record of *Aleuroclava aucubae* (Hemiptera Aleyrodidae) in Hungary, with a checklist of whiteflies occurring in the country. Redia 104:3–7. https://doi.org/10.19263/REDIA-104.21.01
Hochkirch A, Casino A, Penev L, Allen D, Tilley L, Georgiev T, Gospodinov K, Barov B (2022) European red list of insect taxonomists. Publication Office of the European Union, Luxembourg
Hubert M, Louvel S (2012) Project-based funding: what are the effects on the work of researchers? Mouvements 71:13–24
JASP Team (2022) JASP (Version 0.16.3) [Computer software]
Krapp A, Prenzel M (2011) Research on interest in science: theories, methods, and findings. Int J Sci Edu 33:27–50. https://doi.org/10.1080/09500693.2010.51864
Krell F-T (2000) Impact factors aren't relevant to taxonomy. Nature 405:507–508. https://doi.org/10.1038/35014664
Krell F-T (2002) Why impact factors don't work for taxonomy. Nature 415:957–957. https://doi.org/10.1038/415957a
Krell F-T (2012) The Journal Impact Factor as a performance indicator. Europ Sci Edit 38:3–6
Larsen BB, Miller EC, Rhodes MK, Wiens JJ (2017) Inordinate fondness multiplied and redistributed: the number of species on earth and the new pie of life. Q Rev Biol 92:230–265. https://doi.org/10.1086/693564
Leather SR (2009) Taxonomic chauvinism threatens the future of entomology. Biologist 56:10–13
Leather SR (2013) Institutional vertebratism hampers insect conservation generally; not just saproxylic beetle conservation. Anim Conserv 16:379–380. https://doi.org/10.1111/acv.12068
Löbl I (2014) Overestimation of molecular and modelling methods and underestimation of traditional taxonomy leads to real problems in assessing and handling of the world's biodiversity. Zootaxa 3768(4):497–500. https://doi.org/10.11646/zootaxa.3768.4.7
Löbl I, Klausnitzer B, Hartmann M, Krell F-T (2023) The silent extinction of species and taxonomists—an appeal to science policymakers and legislators. Diversity 15:1053. https://doi.org/10.3390/d15101053
Lyal CHC, Miller SE (2020) Capacity of United States federal government and its partners to rapidly and accurately report the identity (taxonomy) of non-native organisms intercepted in early detection programs. Biol Inv 22:101–127. https://doi.org/10.1007/s10530-019-02147-x
Mahunka S (ed) (1986) The fauna of the Kiskunság National Park, vol I. Akadémia Kiadó, Budapest
Mahunka S (ed) (1987) The fauna of the Kiskunság National Park, vol II. Akadémia Kiadó, Budapest
Mahunka S (ed) (1991a) The Bátorliget Nature Reserves—after forty years, vol 1. Magyar Természettudományi Múzeum, Budapest
Mahunka S (ed) (1991b) The Bátorliget Nature Reserves—after forty years, vol 2. Magyar Természettudományi Múzeum, Budapest
Mahunka S (ed) (1993) The fauna of the Bükk National Park, vol I. Magyar Természettudományi Múzeum, Budapest
Mahunka S (ed) (1996) The fauna of the Bükk National Park, vol II. Magyar Természettudományi Múzeum, Budapest
Mahunka S (ed) (1999) The fauna of the Aggtelek National Park, vol I. Magyar Természettudományi Múzeum, Budapest

Mahunka S (ed) (2002) The fauna of the Fertő-Hanság National Park, vol I. Magyar Természettudományi Múzeum, Budapest
Mahunka S (ed.) (1981–1983) The fauna of the Hortobágy National Park. Vol I–II. Akadémiai Kiadó, Budapest
Mathuru AS, Libersat F, Vyas A, Tesea S (2020) Why behavioral neuroscience still needs diversity? A curious case of a persistent need. Neurosci Biobehav Rev 116:130–141. https://doi.org/10.1016/j.neubiorev.2020.06.021
Matskási I (1987) In memoriam Dr. Zoltán Kaszab (1915–1986). Ann Hist-Nat Mus Natn Hung 79:5–36
May RM (1988) How many species are there on Earth? Science 241:1441–1449
Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B (2011) How many species are there on Earth and in the ocean? PLoS Biol 9:e1001127. https://doi.org/10.1371/journal.pbio.1001127
Naggs F (2022) The tragedy of the Natural History Museum. London. Megataxa 7(1):85–112. https://doi.org/10.11646/megataxa.7.1.2
Niemczyk EK, Rónay Z (2022) Roles, requirements and autonomy of academic researchers. High Edu Q 77:327–341. https://doi.org/10.1111/hequ.12403
Pante E, Schoelinck C, Puillandre N (2015) From integrative taxonomy to species description: one step beyond. Syst Biol 64(1):152–160. https://doi.org/10.1093/sysbio/syu083
Prieto C, Faynel C, Robbins R, Hausmann A (2021) Congruence between morphology-based species and Barcode Index Numbers (BINs) in Neotropical Eumaeini (Lycaenidae). PeerJ 9:e11843. https://doi.org/10.7717/peerj.11843
Radulovici AE, Vieira PE, Duarte S, Teixeira MAL, Borges LMS, Deagle B, Majaneva S, Redmond N, Schultz JA, Costa FO (2021) Revision and annotation of DNA barcode records for marine invertebrates: report of the 8th iBOL conference hackathon. Metabarcoding Metagenomics 5:e67862. https://doi.org/10.3897/mbmg.5.67862
Rewicz T, Móra A, Tonczyk G, Szymczak A, Grabowski M, Calleja EJ, Pernecker B, Csabai Z (2021) First records raise questions: DNA barcoding of Odonata in the middle of the Mediterranean. Genome 64(3):196–206. https://doi.org/10.1139/gen-2019-0226
Richling I, von Proschwitz T (2021) Identification problems of travelling snail species—new exotic introductions to tropical greenhouses in Gothenburg, Sweden (Gastropoda: Achatinellidae, Strobilopsidae, Helicarionidae). PeerJ 9:e11185. https://doi.org/10.7717/peerj.11185
Rosenthal MF, Gertler M, Hamilton AD, Prasad S, Andrade MCB (2017) Taxonomic bias in animal behaviour publications. Anim Behav 127:83–89. https://doi.org/10.1016/j.anbehav.2017.02.017
Rowson B, Anderson R, Turner JA, Symondson WOC (2014) The slugs of Britain and Ireland: undetected and undescribed species increase a well-studied, economically important fauna by more than 20%. PLoS ONE 9(4):e91907. https://doi.org/10.1371/journal.pone.0091907
SCImago, (n.d.). SJR—SCImago Journal & Country Rank [Portal]. http://www.scimagojr.com. Accessed 11 Jan 2023
Secretariat of the Convention on Biological Diversity (2007) Guide to the Global Taxonomy Initiative. Secretariat of the Convention on Biological Diversity, Montreal
Smith V (2024) Transforming the science and impact of natural history. Systematics Association 11th International Biennial Conference, 19th–21st June 2024, University of Reading, UK, pp. 66–67
Soltész Z, Peregovits L (2021) In Memoriam Papp László. Állattani Közlemények 106(1–2):159–163. https://doi.org/10.20331/AllKoz.2021.101.1-2.7
Steidtmann L, Kleickmann T, Steffensky M (2023) Declining interest in science in lower secondary school classes: Quasi-experimental and longitudinal evidence on the role of teaching and teaching quality. J Res Sci Teach 60(1):164–195. https://doi.org/10.1002/tea.21794
Sun S, Li Q, Kong L, Yu H, Zheng X, Yu R, Dai L, Sun Y, Chen J, Liu J, Ni L, Feng Y, Yu Z, Zou S, Lin J (2016) DNA barcoding reveal patterns of species diversity among northwestern Pacific molluscs. Sci Rep 6:33367. https://doi.org/10.1038/srep33367
Systematics Agenda 2000 (1994) Systematics Agenda 2000: Charting the Biosphere. A Global Initiative to Discover, Describe and Classify the World's Species. Technical Report. Systematics Agenda 2000, without location
Tapfer D (1966) A Keleti-Bakony madárvilága. Die Vogelwelt aus dem Ost-Bakony Gebirge. A Bakony Természettudományi Kutatásának Eredményei 3:1–77
Taszakowski A, Depa Ł (2022) The rapid decrease of biodiversity studies in well-researched areas—the case of Poland. Ann Upper Siles Mus Bytom Entom 31:1–5. https://doi.org/10.5281/zenodo.6472309
Tóth S (2015) A Bakony-vidék és a Balaton-medence herpetofaunája (Amphibia—Reptilia). A Bakony Természettudományi Kutatásának Eredményei 34:1–236

Weigand H, Beermann AJ, Čiampor F, Costa FO, Csabai Z, Duarte S, Geiger MF, Grabowski M, Rimet F, Rulik B, Strand M, Szucsich N, Weigand AM, Willassen E, Wyler SA, Bouchez A, Borja A, Čiamporová-Zaťovičová Z, Ferreira S, Dijkstra KD, Eisendle U, Freyhof J, Gadawski P, Graf W, Haegerbaeumer A, van der Hoorn BB, Japoshvili B, Keresztes L, Keskin E, Leese F, Macher JN, Mamos T, Paz G, Pešić V, Pfannkuchen DM, Pfannkuchen MA, Price BW, Rinkevich B, Teixeira MAL, Várbíró G, Ekrem T (2019) DNA barcode reference libraries for the monitoring of aquatic biota in Europe: Gap-analysis and recommendations for future work. Sci Total Env 678:499–524. https://doi.org/10.1016/j.scitotenv.2019.04.247

Weilbacher M (1993) The renaissance of the naturalist. J Env Edu 25(1):4–7. https://doi.org/10.1080/00958964.1993.9941937

Wheeler QD (2004) Taxonomic triage and the poverty of phylogeny. Phil Trans R Soc Lond B, Biol Sci 359:571–583. https://doi.org/10.1098/rstb.2003.1452

Wheeler Q (2014) Are reports of the death of taxonomy an exaggeration? New Phyt 201:370–371. https://doi.org/10.1111/nph.12612

Wheeler QD, Raven PH, Wilson EO (2004) Taxonomy: impediment or expedient? Science 303:285. https://doi.org/10.1126/science.303.5656.285

Whitmore D, Gaimari SD, Nihei SS, Evenhuis NL, Kurina O, Borkent CJ, Sinclair BJ, O'Hara JE, Zhang Z-Q, Moulton JK, Ribeiro GC, Bickel DJ, Giłka W, Andersen T, Rossaro B, Whittington AE, Lamas CJE, Heller K, Kehlmaier C, Courtney GW, Kerr PH, Blagoderov V (2021) Twenty years of Dipterology through the pages of Zootaxa. Zootaxa 4979(1):166–189. https://doi.org/10.11646/zootaxa.4979.1.17

Wilson EO (2002) The future of life. Vintage, New York

Wilson JRU, Proches S, Braschler B, Dixon ES, Richardson DM (2007) The (bio)diversity of science reflects the interests of society. Front Ecol Environ 5:409–414

Zahavi H, Friedman Y (2020) The Bologna process: an international higher education regime. The Bologna process and its global strategy. Routledge, pp 22–38

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