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DYNAMICS OF COLLECTION ACCUMULATION: ESTIMATION OF RESEARCH EFFORTS ON THE EXAMPLE OF THE MAMMAL FAUNA OF THE CHERKASY REGION, UKRAINE

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Abstract

The article deals with the dynamics of the amassment of natural history collections on the example of one of the regions of Ukraine, the fauna of which is under constant attention of researchers. This region is the Middle Dnipro Region, namely the Cherkasy region (Cherkasy Oblast since 1954) in general and Kaniv Nature Reserve in particular, which are the sites of long-term monitoring studies of fauna and bases for conducting field research and field practices of students. The dynamics of collections development is considered on the example of the collections of the National Museum of Natural History of the National Academy of Sciences of Ukraine. The article shows the continuity of specimen income to the collections and, at the same time, significant changes in the dynamics of such income. Several indicators that can reflect the dynamics of research efforts are proposed. The decades (1900–1919, etc.) are chosen as time periods, and the variables are the total number of specimens per decade and the total number of families they represent. These indicators can be used to evaluate three dependent notions: in terms of fieldwork, the completeness of the captures (records); in terms of research history, the intensity of research; and in terms of museology, the abundance of collections. Among the indicators tested are the geometric mean (SQRT ($N_{fam} \times N_{sp}$)), the quadratic mean (SQRT [($N_{fam}^2 + N_{sp}^2$) / 2]) and the Simpson diversity index ($1 / \sum (p_i)^2$). The first two indicators are highly dependent on sample sizes and therefore vary widely; and for this reason, the author recommends using with Simpson's diversity index. It can be used to estimate the distribution of not only the number of specimens by family for each decade (essentially a comparison of family abundance), but also any other distributions, replacing families with genera or orders and changing the analysis periods depending on the amount of available data. The term 'research effort' can be used as a synonym for 'collecting effort', which can be found in the publications of English-speaking colleagues. The algorithm for assessing 'research effort' is an important tool in analysing the history of collections, levels of research on regions, and the history of research.

Cite as

Zagorodniuk, I. 2023. Dynamics of collection accumulation: estimation of research efforts on the example of the mammal fauna of the Cherkasy region, Ukraine. *Theriologia Ukrainica*, **26**: 167–175. [In English, with Ukrainian summary]

Динаміка наповнення колекцій: оцінка дослідницьких зусиль на прикладі теріофауни Черкащини (Україна)

Ігор Загороднюк

Резюме. Розглянуто тему динаміку наповнення природничий колекцій на прикладі одного з регіонів України, фауна якого перебуває під постійною увагою дослідників. Таким регіоном є Середнє Подніпров'я, а саме Черкащина в цілому (Черкаська обл. з 1954 р.) та Канівський природний заповідник, зокрема, які є полігонами багаторічних моніторингових досліджень фауни і базами для проведення теренових досліджень і польових практик студентів. Динаміку наповнення колекцій розглянуто на прикладі колекцій Національного науково-природничого музею НАН України. Показано неперервність надходжень зразків до колекцій і одночасно значні зміни динаміки таких надходжень. Запропоновано декілька показників, які можуть відображати динаміку дослідницьких зусиль. В якості часових термінів обрано десятиліття (1900–1919 і т.д.), а змінними обрано загальну кількість зразків за десятиліття і загальну кількість родин, які вони представляють. За зазначеними показниками можна оцінювати три взаємозалежні поняття: в термінах польової роботи — повноту обловів (обліків), в термінах історії досліджень — інтенсивність досліджень, в термінах музеології — рясноту зібрань. Серед тестованих показників — середнє геометричне (SQRT ($N_{fam} \times N_{sp}$)), середнє квадратичне (SQRT [($N_{fam}^2 + N_{sp}^2$) / 2]) та показник різноманіття за Сімпсоном ($1 / \sum (p_i)^2$). Перші два показники сильно залежні від обсягів вибірок і тому змінюються у великих межах; у зв'язку з цим автор рекомендує запинитися на показнику різноманіття за Сімпсоном. За ним можна оцінювати розподіл не тільки числа зразків за родинами для кожного десятиліття (по суті порівняння рясноти родин), але й будь-які інші розподіли, замінюючи родини на роди або ряди та змінюючи періоди аналізу залежно від обсягу доступних даних. У якості синоніма до поняття «дослідницькі зусилля» (research efforts) можна використати «колекторські зусилля» (collection efforts), що можна зустріти в публікаціях англомовних колег. Алгоритм оцінки дослідницьких зусиль є важливим інструментом у аналізі історії колекцій, рівнів вивченості регіонів та історії досліджень.

Ключові слова: накопичення колекцій, динаміка досліджень, дослідницькі зусилля, фауна України.

Introduction

Dedicated to the 100th anniversary of the Kaniv Nature Reserve [1]

Many studies of faunal diversity are based on natural history collections that reflect the composition of the fauna and allow for the verification of certain information, comparisons and reassessments. Such collections are continuously accumulated in various research centres, and they are a valuable source of data on previous states of the fauna and on the characteristics of certain species that can be studied using collection specimens.

Among the regions of constant attention of researchers of the mammal fauna is Cherkasy Oblast, one of the central regions of Ukraine (the oblast was established in 1954) and the centre of many theriological studies and conferences. All of this naturally results in the accumulation of collections that carry extremely valuable information about biotic diversity, dynamics of natural complexes, history of research, and also allow verification of any statements about the status of species, current and previous states of fauna and patterns of long-term changes in biota. The value of scientific collections is multifaceted and only grows over the years [Zagorodniuk *et al.* 2014].

Such collections are accumulated in various centres: as scientific collections in museums, nature reserves and academic institutions, as comparative and reference collections in various applied institutions (sanitary-epidemiological and plant protection stations, etc.), as didactic materials at university departments that organise field training and research at the respective biological stations. One of the largest is the theriological collection at the National Museum of Natural History, NAS of Ukraine [Zagorodniuk 2022b]. In fact, this paper is devoted to its analysis.

[1] The materials of this article were presented in October 2023 at the respective anniversary conference.

General overview of the region, collections, and collectors

Features of the region

Materials from the Cherkasy region have repeatedly become one of the most remarkable in the study of the mammalian fauna of Ukraine. Among them, it is necessary to mention the description of one of the last records of the wolverine in Ukraine [Kessler 1880], the first record of the grey dwarf hamster on the Right Bank of the Dnipro [Charleman 1915], and the only reliable record of the garden dormouse in Ukraine [Hirenko & Litvinenko 1971]. For the first time in Ukraine, populations of such species as dormice, pine voles and bank voles have been studied in detail in this very region [Mezhzherin & Mykhalevych 1983]. Two powerful theriological research schools were formed in Cherkasy Oblast, the school of Serhii Samarskyi [Gavrilyuk *et al.* 2022] and the school of Vitaliy Mezhzherin [Myakushko & Semenyuk 2022]. Several theriological meetings were held here, including a game studies conference (Kaniv 1977), the first conference of the Ukrainian Theriological Society (Cherkasy 1984) [Zagorodniuk 2022a], and two Theriological Schools-Seminars (Kaniv Reserve 1995, 2008), the first of which essentially launched the regular theriological meetings in Ukraine [Zagorodniuk 1999].

The Kaniv Nature Reserve is one of the most famous centres of natural history in Ukraine, a cradle for many well-known researchers, scientific schools, conference series, and professional natural history publications. Among the variety of its tasks, functions and informal statuses, it is important to note the following five: 1) biostation, 2) field practices, 3) research base, 4) conferences, and 5) publications. Long-term population studies of small mammals were launched here [Myakushko 2021], and hundreds of future zoologists, including the author, carried out their first field studies here. In Cherkasy Oblast, including the Kaniv Nature Reserve and Cherkasy University, many theriological dissertations have been prepared (H. Horbenko, K. Solohor, A. Volokh, N. Ruzhilenko, S. Myakushko, A. Bilushenko, and others).

Features of the collections

The author has studied the mammal collection of the National Museum of Natural History of the National Academy of Sciences of Ukraine (NMNH). The values of this collection are: 1) its large volume; 2) its repeated inventory and descriptions, including the logs of receipts, an electronic database, and published catalogues; 3) analytical articles about specimens, expeditions, collectors, and researchers. The total volume of the collection, according to the electronic database (completed in 2016 in MS Access), is 20 503 specimens.

Collection specimens and their series, which are attributed in the database as ‘Cherkasy Oblast’ (including materials from the Kaniv Reserve), were analysed. The total number of such specimens is 182, with the extreme dates of 1911–2010, including 147 specimens deposited in the Department of Zoology of the NMNH and 35 specimens in the comparative collection of the Department of Palaeontology of the NMNH. The sources of the samples are extremely different; the majority of them are materials of expeditions, i.e. targeted collections. In the course of working on the materials for this article, the author made a significant number of corrections to the names of locations, collectors’ names, and material identifications, including due to changes in toponymy, administrative division, and taxonomy.

Collectors

Among the collectors who made a significant contribution to the formation of theriological collections with materials from Cherkasy Oblast (collectors of 5 or more specimens), it is important to mention eight researchers, including P. Kryzhov (36 specimens), S. Bezrodnyi (24), I. Pidoplichko (20), B. Popov (17), etc. Also, with smaller series (1–4 specimens), the collectors of theriological collections were such well-known zoologists as (in chronological order): Oleksandr Brauner (w/year), Eugene Zvirozomb-Zubovsky (1911, 1926), Leonid Portenko (1922), Serhii Ivanov (1925), Oleksandr Kryshtal (1925), Andrian Doloshko (1929–1930), Mykola Sharleman (1930–1931), Semen Lubkin (1931), Oleh Yatsenia (1964), Kateryna Solohor (1969–1970), and Liudmyla

Shevchenko (1971–1988). The earliest collections with the designation 'Kaniv Reserve' or 'Kaniv' date to the following years: 1930–1931 (M. Charlemagne, 3 specimens), 1931 (S. Lubkin, 1 specimen), 1936 (O. Brauner, 1 specimen), 1940 (B. Popov, 16 specimen).

Some of them also had special publications about the region's fauna, such as 'On the activity of the polecats in the Kaniv district' [Podoplichka 1930b], 'Game fauna in the Humanshchyna' [Doloshko 1931], and 'Sketch of the fauna of small animals in the vicinity of the city of Korsun' [Kryshtal 1932]. The data on Cherkasy Oblast are included in larger reviews, both old and more recent, including those authored by the mentioned collectors, such as 'Harmful Rodents of Forest-Steppe Zone of Right Bank Ukraine...' [Pidoplichka 1930a], 'Geographical distribution of harmful rodents of the Ukrainian SSR' [Kryzhov 1936], 'Distribution of dormice (Rodentia, Gliridae) in Ukraine' [Bezrodnyi 1991], two issues of the 'Fauna of Ukraine' 1956 and 1968, with descriptions of the orders of bats, insectivorans, and mustelids [Abelentsev *et al.* 1956; Abelentsev 1968].

General dataset

The specifics of the collections is that their constant accumulation over the years levels out the initially non-random nature of the collections, which is associated with different tasks of researchers and different areas of research requiring selective collection of material. Due to the large volume of collections and the summation of data from different researchers and from different periods, the collections are approaching the status of large non-selective samples that reflect the state of natural complexes[2]. The collections suffered some losses, in particular during WW2 and as a result of uncontrolled transfer of materials for processing. For example, shrews are missing from the collection for no reason (see Table 2).

Table 1. Key specimen collectors (≥ 5 specimens) and data on the number of specimens and collection dates

Таблиця 1. Ключові колектори зразків (≥ 5 екз.) та дані про кількість зразків і дати зборів

Researcher	Specimens	Years of collection	Status in the museum
Ivan Pidoplichko	20	1926, 1927, 1929, 1930, 1936	museum employee
Oleksiy Mygulin	5	1927, 1929, до 1936	visiting specialist
Petro Kryzhov	36	1936	museum employee
Borys Popov	17	1940	museum employee
Ivan Sokur	8	1965	museum employee
Vasyl Abelentsev	9	1965, 1985	museum employee
Anatoliy Volokh	6	1974–1975	graduate student
Serhiy Bezrodnyi	24	1988–1989	museum employee
Total	125	1926–1989	

Fig. 1. Old mammal specimens from Cherkasy Oblast: (*a*) bank vole (*Myodes glareolus*), 19.09.1931, leg. M. Charleman, NMNH-z No. 2004; (*b*) forest dormouse (*Dryomys nitedula*), 6.07.1940, leg. B. Popov, NMNH-z No. 646.

Рис. 1. Давні зразки ссавців з Черкащини: (*a*) нориця лісова (*Myodes glareolus*), 19.09.1931, leg. М. Шарлемань, ННПМ-z № 2004; (*b*) соня лісова (*Dryomys nitedula*), 6.07.1940, leg. Б. Попов, ННПМ-z № 646.

[2] Moreover, it is thanks to large collections that important information about rare species is also accumulated.

Nevertheless, the collections accumulated to date contain important data on the composition and dynamics of the regional fauna and the intensity of its research [Zagorodniuk 2017]. The data on the distribution of collection specimens by families and decades are summarised in Table 2. The family level of generalisation is determined by the general sample size and corresponds to the main eco-morphological types of mammals. Obviously, with an increase of general samples (e.g. when expanding the study to other collections or in case of enlargement of the analysed region), the taxonomic level can be lowered to genera or species.

In general, in the collections from Cherkasy Oblast, the class Mammalia is represented by 12 families, the proportions of which are very different, with a clear dominance of five of them—Arvicolidae, Gliridae, Muridae, Sciuridae, and Vespertilionidae (82% in total). Some families are represented by a clearly lower than expected proportion (based on the common methods of recording and catching practiced at different times, as noted above for the family Soricidae).

Dynamics and results by periods

The motives for selecting specimens to collect and their deposition in a scientific collection are very different, as are the values of the specimens and the levels of concern for their 'fate' (preservation). In particular, early researchers probably paid attention to wild (non-synanthropic) fauna and rarely seen species. Nevertheless, there are periods of greater and lesser activity of collectors. This can be seen when analysing the data by year (in our case, by decade), as shown in Table 2. Moreover, an increase in the volume of samples naturally leads to an increase in the number of identified taxa (Fig. 2), which is generally expected, since the increase in the volume of research increases the likelihood of obtaining samples of rarer taxa. In addition, an increase in research intensity of some groups may lead to the formation of interests in others, which increases the volume of searches.

The relationship between the number of samples and the number of taxa is well known in biodiversity studies, where the use of similar sample sizes is important [Protasov 2002]. In general, this is called 'equality of research effort', i.e. comparisons of samples are only valid if they were created with approximately equal research effort. Furthermore, it is incorrect to compare diversity estimates for samples that are obviously different in size.

In fact, by analogy with diversity estimates, the author uses the concept of 'Research Effort' (RE) in this study. It is clear that a large effort will be directly proportional to the number of samples and the number of taxa recorded. Graphically, this corresponds to the greatest distance of the sample point from the beginning of both axes (Fig. 2). The larger the two values, the larger the generalised result, which can be represented by their product (RE): RE ~ fa × sp. In particular, the intensity of trapping, or research effort, can be represented in different ways, including the following:

- RE1 (geometric mean) = SQRT ($N_{fam} \times N_{sp}$)
- RE2 (root mean square) = SQRT [($N_{fam}^2 + N_{sp}^2$) / 2]
- RE3 (diversity after Simpson) = $1 / \sum (p_i)^2$

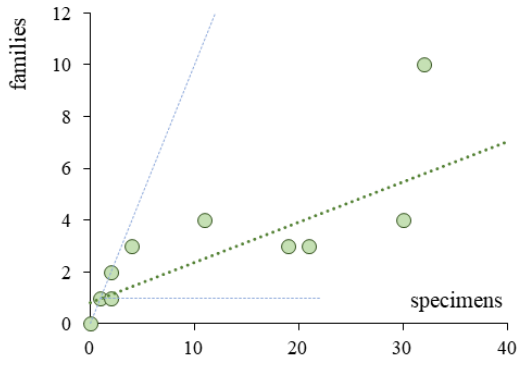

Fig. 2. The relationship between the number of specimens collected per decade and the number of families they represent (based on data from Table 2). The data distribution has two limitations, indicated by the side dashed lines: • isoline-1 (all samples represent only one family), • isoline-2 (each family is represented by one specimen).

Рис. 2. Взаємозв'язок між кількістю зібраних зразків за десятиліття і кількістю родин, які вони представляють (за даними з табл. 2). У розподілу даних є два обмеження, позначені бічними пунктирами: • ізолінія-1 (всі зразки представляють лише одну родину), • ізолінія-2 (кожна родина представлена одним зразок).

The calculations of the three analysed indices are presented in Table 3. As it can be seen, all indicators are similar and highly correlated. The RE1 and RE2 indices are essentially identical, but both of them are highly dependent on sample size and therefore vary widely. The latter imposes a limitation on their use: a significant increase in sample size (including for few species), without changing the understanding of diversity, leads to large values of both indices.

Three interdependent concepts can be assessed using the selected indicators:

- in terms of field work — completeness of trapping (census),
- in terms of the history of research — the intensity of research,
- in terms of museology — the abundance of collections.

The dynamics of research effort indicators (RE1 and RE3) over time is shown in the graph (Fig. 3). In general, the trends are similar. Two trends are clearly visible on both graphs: 1) a distinct periodicity, and 2) the decay of the waves over time. However, there are also differences.

In particular, the Simpson index shows a much flatter distribution and a redistribution (shift) of peaks. The latter is due to the high sensitivity of the diversity index to dominance or evenness. For example, in the RE3 variant, the peak value of the '1930+' class disappears, as this class has a clear dominance of one of the diversity elements (see Table 3), in particular, 37 out of 50 specimens represent two families, and there are three fewer families.

Table 2. Distribution of the total sample by families and decades (families in alphabetical order; period designations: '1910' = 1910...1919, etc.)

Таблиця 2. Розподіл сумарної вибірки за родинами і десятиліттями (родини за абеткою; позначення періодів: «1910» = 1910...1919 і т.д.)

Family	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	n/d	Total
Arvicolidae	–	11	6	–	1	8	–	4	1	–	–	–	31
Canidae	–	2	–	–	–	–	1	3	1	–	–	–	7
Castoridae	–	–	–	–	–	–	5	–	–	–	–	1	6
Cricetidae (s. str.)	–	5	1	–	–	–	–	–	–	–	–	1	7
Gliridae	–	4	2	16	–	2	–	21	–	–	–	5	50
Leporidae	–	2	2	–	–	–	–	–	–	–	–	–	4
Muridae	1	1	18	1	–	–	–	2	–	–	–	–	23
Mustelidae	–	–	2	–	–	–	4	–	–	–	–	–	6
Sciuridae	1	1	19	–	–	–	–	–	–	–	2	3	26
Sminthidae	–	1	–	–	–	–	–	–	–	–	–	–	1
Soricidae	–	1	–	–	–	–	–	–	–	–	–	–	1
Vespertilionidae	–	4	–	2	–	11	1	–	2	–	–	–	20
Total	2	32	50	19	1	21	11	30	4	0	2	10	182

Table 3. Changes in different estimates of the volume of collections over time: number of specimens and taxa and three integrative indices (period designations: '1910' = 1910...1919, etc.)

Таблиця 3. Зміни різних оцінок обсягу колекцій у часі: число зразків і таксонів і три інтегративних індекси (позначення періодів: «1910» = 1910...1919 і т.д.)

Estimate	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	n/d	Total
Sums													
• families	2	10	7	3	1	3	4	4	3	0	1	4	12
• specimens	2	32	50	19	1	21	11	30	4	0	2	10	182
Indices													
• RE1	2.0	17.9	18.7	7.5	1.0	7.9	6.6	11.0	3.5	0.0	1.4	6.3	46.7
• RE2	2.0	23.7	35.7	13.6	1.0	15.0	8.3	21.4	3.5	0.0	1.6	7.6	129.0
• RE3	2.0	5.4	3.4	1.4	1.0	2.3	2.8	1.9	2.7	0.0	1.0	2.8	6.3

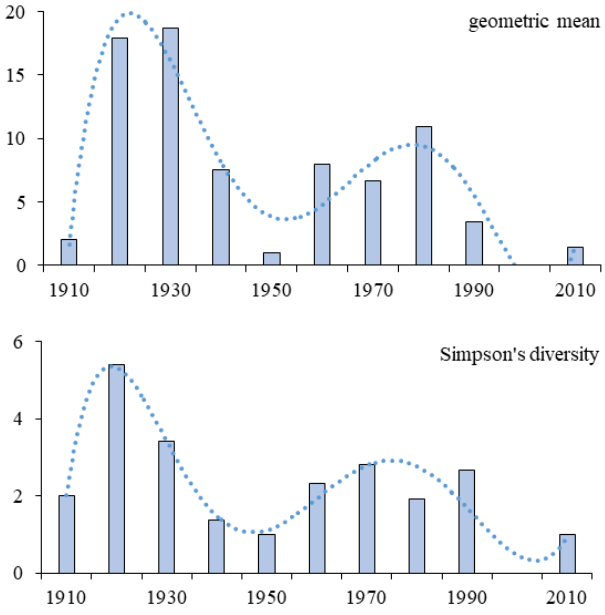

Fig. 3. Dynamics of research effort indicators in the formation of collections: RE1 (geometric mean) and RE3 (diversity, according to Simpson).

Рис. 3. Динаміка показників дослідницьких зусиль при формуванні колекцій: варіант RE1 (середнє геометричне) та RE3 (різноманіття за Сімпсоном).

Discussion

The algorithm for estimating population dynamics and proportions of rare species based on collection series of different ages has been used by the author many times, in particular, on the example of bats. Based on the proportions of species in collections of different times, the author made both forecasts of changes in the abundance of individual bat species in Ukraine [Zagorodniuk & Tkach 1996]) and estimates of changes in the number and distribution of such groups as horseshoe and long-eared bats. For example, the analysis of ancient and more modern collections showed the invasive status of *Plecotus austriacus* [Zagorodniuk & Postawa 2007], and 10 years later, in support of this assumption, the author discovered this alien bat species on the estate of the Kaniv Nature Reserve [Zagorodniuk 2018].

Thus, such algorithms, based on the study of collections, are important for the analysis of those groups whose abundance cannot be estimated by standard methods of detection and recording. In addition, it is the most accessible method for estimating faunal structure and changes in species proportions in all cases where other abundance estimates are not available.

The search revealed that a similar concept to the one developed here is described as 'collecting effort' [McCarthy 1998]. In particular, collecting effort as an integral assessment proved to be important for adjusting data in rarity studies based on museum collections. For example, the threat status and its changes over time for a number of species of monotremes and marsupials were determined using museum collections [ibid.]. Similar calculations can be made based on the analysis of the sums of observations and other records, but only collection data are subject to unambiguous verification. There are also studies that consider collecting effort in the context of how adequately collections reflect the actual distribution of taxa [Ponder *et al.* 2001]. Similar studies have been carried out in Ukraine, including by the author, based on the analysis of the total … and verified by the collections data set (and the boundaries of geographical distribution) for such groups as pine voles, birch mice [Zagorodniuk 2015], and mole rats [Korobchenko *et al.* 2018].

The above example of the analysis of regional collections is only an exploration that should be further expanded to include the collections of other institutions, including the Zoological Museum of Kyiv National University, the collections of the Department of Population Ecology of the Institute of Zoology of the National Academy of Sciences, which holds more than one hundred mammalian specimens from Cherkasy Oblast, especially from the Kaniv Nature Reserve, as well as the collections of the Cherkasy Regional Museum of Local Lore, which probably houses valuable materials.

Such additions can more clearly outline the second wave of research that took place in the 1970s and 1990s. However, they are unlikely to reveal the beginning of the third wave, as it is *de facto* extremely vague and essentially means the end of a 100-year research cycle.

Regarding the latter, it is important to note the following: the decline in interest in collecting and field research in general does not eliminate the need to create a series of voucher specimens that confirm the presence of a species in a particular place at a particular time [Duckworth *et al.* 1993]. This is especially true of the monitoring system in nature reserves [Zagorodniuk & Shydlovskyy 2023]. Such voucher collections are the only source of knowledge available for verification, including by modern alternative methods (e.g. DNA sequence analysis), which are important for correcting and developing our knowledge about current biotic diversity and its changes. Of course, the accumulation of collections requires efforts that are often unproductive in terms of current tasks, but important for the development of future research. In fact, it is with gratitude to the collectors and researchers of the past who created the collections that this report was prepared.

Conclusions

1. The analysis of natural history museum collections allows to estimate the diversity of biota in different periods of its study and to identify changes in species abundance and taxonomic richness of communities, the importance of which is enhanced by the possibility of verifying collection data. In a certain case, such materials are valuable for the identification of little-known taxa.

2. The analysis of collections over time is a valuable source of data on changes in the proportions of species and changes in diversity indicators at the level of suprapecies groups, primarily families, which allows for certain reconstructions and, if clear trends are identified, also for making predictions about changes in the status of certain species and overall diversity indicators.

3. The dynamics of the collections is an assessment of the intensity of research efforts, and these data can be used to identify periods of greatest attention to the study of a group or region, and in some cases provide important information about the history of research and general trends in the development of research interests.

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