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Opinion

Biodiversity Discovery and Taxonomic Data Management in Uncertain Times of Big Data

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The Nagoya Protocol changed the way we work on the biodiversity of insects

The addition of the Nagoya Protocol, which entered into force on 12 October 2014, to the Convention on Biological Diversity, established the ground rules how nations access, cooperate and share the benefits that come from sustainable utilization of genetic resources of living organisms [1]. This protocol changed the way biodiversity researchers work [2], since biodiversity studies used to be an international pre-occupation of museum-based researchers and curators who considered biodiversity science as an open space of international activity rather than a bilaterally restricted and nationally controlled set of rules. The post Nagoyan period critically tested the implications on genetic resources, providers and users [3]. We, biodiversity scientists, are facing fundamental ethical questions whether the science we are representing does not support biopiracy in biodiversity-rich countries, who are authorized to provide the consent to use the genetic resources and how mutually agreed contractual terms can be implemented. The whole community of taxonomists turned into discussions on regulatory impacts of the Nagoya Protocol on taxonomy and perspectives of biodiversity research [2]. Here below, we present our opinion based on the experience of international field work in the Amazonian region, Colombia (July-August 2018) and how the transnational study on insects is essential to advance scientific and taxonomic research which may downstream to other important fields such as agriculture, food security and medicine [4-6].

The consideration of insects as Animal Genetic Resources constituting natural resources of sovereign states challenged a customary view of generations of taxonomists considering insect diversity as a "common heritage of mankind" [7]. It was a custom to deposit primary types in European or USA museums of natural history and protect the taxonomic descriptions by the Intellectual Property Rights [8,9]. The biodiversity-rich countries hit back by "biopiracy" claims and argumentation that a lot of biodiversity, biological and ecological knowledge stored in intellectually protected publications in fact, is based on traditional and local knowledge and unauthorized collection of insects, which from the perspective of signatory countries, would be illegal [10].

We suggest that harmonized agreements on the propriety of insect specimens and on dissemination of knowledge on biodiversity research would stimulate investigations in biodiversity-rich countries, enforcing innovative approaches in traditional museum-based sciences such as taxonomy. Furthermore, in this way, the obtained taxonomic knowledge will be integrated into the global biodiversity science. The rules-based approach towards biodiversity richness will support the much needed conservation of diversity of insects and reward the biodiversity provider countries/institutions with the intellectual property rights on the genetic diversity they possess.

New insect collections in biodiversity-rich countries

The transition of the property rights of insect biodiversity to the sovereign countries raises a dilemma why the valuable natural history collections of insects are so unequally located in Europe or other economically rich areas (Figure 1). The large scale of tropical insect biodiversity is unequalled by those of any other group of animals. Advances in insect metagenomics, imaging, and digitization have demonstrated that the physical location of a collection does not play any role in how entomological data are managed and utilized. Once the collections are considered as a domain of taxonomists and morphologists, at this scientific age they become a foundational research field for many disciplines that rely upon biodiversity, like documenting and describing the distribution of species, their tremendous diversity, impacts to health issues, agricultural practices and food security [11,12]. New technologies transformed the way in which insect collections are utilized. The specimen data become exchangeable in different formats without physically handling the specimens and a new generation of genomic sequencing and morphological imaging such as microcomputed tomography releases such a huge amount of data unimaginable a decade ago [12]. Therefore, the physical presence of types and verified voucher specimens, where the conditions allow, can stay by Nagoya Protocol defined owners, while exchange and study of data can be performed virtually.

Figure 1: *Disproportional representation of the types of the Neotropical Gracillariidae species in natural history collections. Data from the Global Taxonomic Database of Gracillariidae available at www.gracillariidae.net*

The complexity of insect collections and the magnitude of the task to liberate the data are unrivalled: for example, The Natural Museum of Natural History, Smithsonian Institution contains 35 million insect specimens, the 59 CETAF institutions hold 80% of described biodiversity as specimens, GBIF operates with data obtained from 1 billion specimens (see https://entomology.si.edu/Collections, https://cetaf.org/ and https://www.gbif.org/). The research questions that can address the enormous diversity of insects only now begin to use the power of data and only in recent years the entomological community started to understand what it means to operate digitized and diversified data while dealing with tropical diversity of insects [13]. We emphasize the necessity to keep the high standard while gathering digital data on tropical insects, for example: i) correct labelling of specimens with human and machine-readable unique specimen identifiers, ii) correct taxonomic identification based on integral methods, iii) continuous insertion of new data into a database; iv) accurate geo-referencing of data; v) continuously keeping digital data updated in appropriate data standards, etc. The summarized dissemination of species, specimens, and associated taxonomic, distribution and biological data can be shared via publicly accessible global web portals like GBIF, so the community of biodiversity researchers and users can discover the information they search for and use it for environmental and social topics, e. g. environmental change, conservation, public health, invasive species, host shifts and others [14]. Data cleanliness remains a core issue in the application of biodiversity data and requires the cooperative efforts of the whole community of users.

Linking historic and newly established collections

As we suggested above there are important reasons, including legal ones driven by the Nagoya Protocol, to establish well-functioning museums of natural history in biodiversity-rich countries. These collections act and play a different role than the collections at the museums of natural history in economically rich countries (Figure 1). The transitions of work flow and the re-locations of physical specimens are related to technological advances in two fronts: genomic sequencing, and the second generation of morphological imaging. The processing of Big Data obtained from both domains require close collaboration and sharing the data of all involved partners.

Most entomological collections located in Europe and USA were established prior to routine inclusion of molecular evidences into the taxonomic and evolutionary studies, since most collections existed many years prior to the discovery of DNA. Though molecular methods advance very rapidly, and, in many cases, they provide positive results even from old historic specimens despite genetic degradation [15], this can, by no means, become a standard practice for historic, economic and practical reasons and because of the destructive methodology. The newly established collections in biodiversity-rich countries are an excellent source for recovering genes and genomes as sequencing technologies are constantly improving. Freshly collected genetic material stored in biodiversity-rich countries could serve to obtain contemporary genetic datasets in many genome-oriented biodiversity projects. Micro and nano computed tomography and 3D reconstructions will become common approaches in taxonomy and systematics while studying historic and unique type specimens housed in historic collections because of the non-destructive nature of scanning [16].

Biodiversity research and biodiversity education in tropical areas as one integral package

Though biodiversity research faces challenges of a hypercompetitive system in research and financial constraints [17], we witness that insect biodiversity education in the Amazonian region can build strongly cooperative relationships between local authorities, educational staff and international biodiversity researchers based on trust. That kind of relationship ensures a highly positive working atmosphere for biodiversity research. The program included two key elements: 1) a project-based, result-oriented strategy that includes applications for agriculture and 2) direct and practical biodiversity education. The education on the richness of insect diversity in the tropics targets "the most devoted of the devoted", also includes initiatives which help to stimulate the striving for excellence and creating recognition of cultural values. Furthermore, the joint cooperative work of research and education is paramount in helping to understand the complexity of issues related to tropical environment and biodiversity.

New developments in technology require a global biodiversity data management vision

Despite efforts to conserve and restore the habitats, biodiversity continues to decline. Therefore, the present generation of taxonomists have to evaluate the impact on biodiversity loss and prepare strategies which aim to achieve the reliable documentation of the state of the art of biodiversity and reduce the direct pressures on biodiversity facing the global demand for food, wood, water and energy. The biodiversity data on tropical insects gathered from specimens in museum collections are often presented on the basis of pre-set project storylines, while global management of such data would allow achievement of long-term goals.

Efficacy started to be a key word in biodiversity data management, since information packages are immensely big. The data management following the traditional taxonomic divisions per insect orders seems not the best solution when trophic biology and cross-taxa interrelations are studied. Therefore, with the division of data into smaller work packages, the work crosses orders [18] and even kingdoms promoting the condition that these data are related, exchangeable and exportable to different datasets.

Conclusions

The development of new technology and shifts on interests change the entire organization of the collection-based work on biodiversity of insects. Changes are difficult to conceive; they touch issues of people and do not guarantee a certain future. Furthermore, the consequences due to technological applications, rapid increase in productivity, and "soft" people issues related to reputation are difficult to predict. Most resistance to change derives from managing the change itself [19]. The biodiversity data boom sets the goals which need to be understood by a broad community of biodiversity specialists seeking how, and by whom, these goals can be achieved. In this opinion we attempted to present credible proposals to the community of taxonomists and give our vision on how we deal with global tropical insect biodiversity management issues, and how we draft long-term cooperative plans which we feel are likely to succeed.

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