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96

THE GLOBAL TAXONOMY INITIATIVE IN SUPPORT OF THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK

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Foreword

Taxonomy and systematics are the basis of recognizing and understanding biodiversity and thus fundamental for the implementation of the Convention on Biological Diversity (CBD).

The Global Taxonomy Initiative (GTI) was established by the Conference of the Parties to assist Parties where taxonomic capacity is limited (taxonomic impediment) to implement the broad thematic programmes under the CBD. Removing the taxonomic impediment requires long-term commitments to attain taxonomic knowledge and skills to discover and ascertain the components of biodiversity and analyse their status in the environment.

We are in the Anthropocene, a time where climate change and unprecedented biodiversity loss are threatening Earth's sustainability and health. To address the impacts of human activities on the planet, we must increase our knowledge of our natural ecosystems and production systems. The hard lessons we are learning from the COVID-19 pandemic aspire us to build back better and live in harmony with nature. To ensure our ecosystems services are secure for future generations, we must deepen, broadly share and apply our accumulated knowledge in scientific and taxonomic institutions across all sectors.

Thanks to Parties, taxonomic institutions, expert consortia and countless citizen scientists, the fifth edition of *Global Biodiversity Outlook* revealed that good progress was made over the last decade to share biodiversity knowledge (Aichi Biodiversity Target 19). To further enhance our global efforts towards the 2050 vision, *Living in Harmony with Nature,* and as a stepping-stone to achieve this vision, we need to develop and sustain expertise in all regions by filling the capacity gaps among Parties in line with the post-2020 global biodiversity framework which will be adopted at the Convention's fifteenth meeting of the Conference of the Parties.

This CBD Technical Series contains outcomes of the GTI Forum 2020 held virtually from 2 to 4 December 2020 and co-hosted by the Government of Germany through the Museum für Naturkunde Berlin. It highlights the scientific tools, capacity development activities and services available to Parties with advice given by taxonomic experts. Many such experts have served as GTI national focal points or as Global Strategy for Plant Conservation (GSPC) national focal points under the Convention. Successful examples of capacity and infrastructure development, achieved through international collaboration, can provide insight for further generations and help build evidence-based and effective conservation globally.

It is expected that this CBD Technical Series issue will be useful to the Parties and experts to further enhance and implement GTI activities together, across sectors, in the upcoming decade of the post-2020 global biodiversity framework.

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1 See CBD notification 2020-031.

About the GTI Forum 2020

The Global Taxonomy Initiative Forum 2020, originally planned as a physical meeting to be held from 7 to 9 April 2020 in Berlin, Germany, took place online due to the COVID-19 pandemic from 2 to 4 December 2020.[2] In addition to 18 nominated delegates from Parties and invited expert organizations, the virtual setting allowed for the participation of over 200 self-registered observers from 60 countries.

The three-day meeting consisted of a dedicated symposium on "Best practices and challenges of the Global Taxonomy Initiative in achieving the Aichi Biodiversity Targets" and two days of deliberations and discussions, including individual presentations and statements. During the symposium, workshops and discussions held at the GTI Forum, participants expressed their ongoing strong support for the continuation of the Global Taxonomy Initiative, taking into account lessons learned, advances in DNA technologies for integrative taxonomic approaches, and new perspectives on capacity-building on a global scale, comprising taxonomy training, information exchange and scientific collaborations. Annex 1 below contains the GTI Forum list of speakers and presentations. Readers are encouraged to visit the GTI Forum meeting website (https://www.cbd.int/article/the-global-taxonomy-initiative-forum-2020) for video recordings of the event.

During the symposium, invited speakers presented regional and international initiatives and consortia focusing on global biodiversity data mobilization, the application of DNA barcoding and metabarcoding, the development of a global digital flora database, and the importance of natural history collections in support of increasing taxonomic knowledge at all scales. Presentations of GTI-related activities, at national, regional or international levels (among others, from the Association of Southeast Asian Nations (ASEAN), the Bahamas, Belgium, China, Costa Rica, Mexico, Norway, South Africa, the United Kingdom of Great Britain and Northern Ireland and Viet Nam), provided a global overview of innovative approaches to community engagement, capacity-building, biodiversity education, conservation, taxonomic training and knowledge transmission. Technological, societal, scientific and digital advances have opened up exciting possibilities for the future. These scientifically, digitally and technologically driven advances are of strategic importance to support our collaborative efforts towards the implementation of the post-2020 global biodiversity framework.

The participants in this Forum underlined the importance of the international collaborations and communication that are essential to sustain taxonomic expertise. To further support biodiversity literacy, training and research, and the required development of key taxonomy-related infrastructures, access to and availability of technological and digital tools, taxonomic specimens (including digital) and data, literature and genetic sequences are essential. The GTI Forum also highlighted that national focal points for the GTI can play important roles among governments, existing expert organizations and the national and local communities. Successful cases of taxonomic capacity development were observed in the countries where GTI national focal points have been actively engaged in the national and international biodiversity actions. Participants stressed that the GTI national focal points should be fully engaged in support of the implementation of the post-2020 global biodiversity framework, and the GTI network should be expanded to maximize new and ongoing collaborative efforts, including with the peoples and communities managing biodiversity on the ground.

2 CBD notification 2020-089.

To further highlight the urgency and opportunities offered by ongoing developments to strengthen efforts for the GTI in support of the goals of the Convention, participants in the GTI Forum agreed on a joint "Call for action on recognizing the critical role of taxonomy to underpin transformative change within the post-2020 global biodiversity framework". This statement was released separately following the GTI Forum and is attached as annex 2. The compilation of the present publication benefited greatly from the many valuable contributions and rich discussions by participants in the GTI Forum, but it is not intended to constitute a fully comprehensive account.

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3 CBD notification 2020-031.

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Executive summary – key messages

For Aichi Biodiversity Target 19 – "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied" – progress was achieved in terms of knowledge sharing through workshops and trainings.

The Global Taxonomy Initiative (GTI) and the GTI community have advanced the sharing of taxonomic tools and knowledge for use by Parties (see section IV and annexes). Numerous workshops and training activities were conducted by experts globally on the use and application of these tools for biodiversity management to achieve Aichi Biodiversity Targets (section I).

The ability to accurately recognize species underpins our knowledge of biodiversity. Thus, taxonomy is fundamental to our understanding of biodiversity and to the implementation of the post-2020 global biodiversity framework. Further actions are needed to enable Parties to access and use the shared knowledge and tools on the ground.

The GTI Forum 2020 called for recognition of the critical role of taxonomy and GTI in support of the 2020 global biodiversity framework, and of the activities that are enabling Parties to discover, identify and report on the status of biodiversity and supporting evidence-based decision-making on biodiversity management (sections II and IX).

New technologies, such as digital biodiversity information, including digital specimens and descriptions, DNA barcoding, metabarcoding and whole genome sequencing, became available and affordable to advance taxonomy and the knowledge derived from it.

The technology surrounding taxonomy has enabled the application of taxonomic tools for conservation initiatives on the ground. Rapid and easy-to-use tools have allowed citizen scientists and the public to engage in biodiversity discovery and conservation actions towards the shared goals of the Convention on Biological Diversity (sections III to V).

The need for taxonomic capacity exists across broad sectors to implement the post-2020 global biodiversity framework and relevant actions aligned with the Sustainable Development Goals.

Information on biodiversity is increasingly required across broad sectors: environment, agriculture, health, education and other sectors, including for regulatory purposes. The demand for taxonomic identification services and application of biodiversity data for risk management measures has been growing (section VI).

Further investments are needed to educate biodiversity management officials and young scientists in taxonomy skills as well as the application of biodiversity knowledge and tools, and to generate more biodiversity knowledge to support actions of Parties in line with the post-2020 global biodiversity framework and to sustain biodiversity science.

Actions have been taken by partners of the GTI to build capacity in the application of taxonomic tools and knowledge in many parts of the world. Learning from the examples of best practices presented at the GTI Forum, the GTI community can support implementation by Parties of the post-2020 global biodiversity framework (sections VI to VIII).

The global activities of the GTI community continue to generate biodiversity data that can be used as indicators and to deliver key baseline data for the monitoring in the post-2020 global biodiversity framework.

The biodiversity databases and tools developed by taxonomic institutions are invaluable for the establishment of indicators and monitoring of the progress towards biodiversity goals and targets. Experts in the GTI community provided suggestions for indicator development in relation to biodiversity targets in order for Parties to monitor the progress of the implementation of the post-2020 global biodiversity framework (sections I and IX).

The GTI community is committed to deepening technical and scientific cooperation and capacity development through the relevant GTI networks of experts and GTI national focal points, and to supporting Parties and communities in applying biodiversity knowledge and tools for the implementation of the post-2020 global biodiversity framework.

Networks with collaborating scientific experts and active GTI national focal points have made successful cases of technical and scientific cooperation and capacity-building. International collaborations among researchers and Parties with shared conservation goals can expedite sustained capacity development through technology sharing and transfer (section X).

I. Introduction

The Global Taxonomy Initiative

Taxonomy is the science of discovering, identifying, and classifying the world's organisms.[4] It provides the fundamental information required to observe, understand, monitor and manage species, which in turn provide products and benefits to human societies (agricultural, forestry, fisheries, biosecurity, health benefits and many others). The Conference of the Parties to the Convention on Biological Diversity recognized that the shortage of taxonomic experts, and unequal and limited access to taxonomic information (e.g. taxonomic literature, field guides, species identification aids) and collections of natural history specimens, hinder many Parties from knowing, managing and safeguarding their own biodiversity. The recognition of this taxonomic impediment led to the establishment of the Global Taxonomy Initiative (GTI) in 2000,[5, 6] and the programme of the work of the Global Taxonomy Initiative was adopted in 2002[7] in order to advance taxonomy worldwide and provide capacity-building opportunities for countries where the taxonomic impediment exists.

Since its formation, the GTI has been shaped by voluntary contributions made by the GTI national focal points, scientists and partners, leading to:

(a) The assessment of taxonomic needs and capacity at the national or regional levels;

(b) The establishment, maintenance and provision of taxonomic information systems, species lists and databases that increase public knowledge and understanding on biodiversity;

(c) Capacity-building in taxonomy for sectors reliant on taxonomic skills, through forums, networks, workshops, research, and engagement with governmental bodies; and

(d) The linkage of taxonomic information to thematic areas and cross-cutting issues under the Convention.

Achievements in GTI related activities

Since the Strategic Plan for Biodiversity 2011-2020, with its associated Aichi Biodiversity Targets, was adopted in 2010 (decision X/2), the GTI has made steady progress towards Aichi Target 19, which states that, by 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.[8]

At the global level, the GTI community has developed shared biodiversity information since the adoption of the Strategic Plan. The number of species included in the Catalogue of Life[9] increased from 1,257,735 in 2010 to 1,837,565 living and 63,419 extinct species in the 2019 edition. By 2020, the Global Biodiversity Information Facility (GBIF)[10] held a total of 1,633,212,433 biodiversity occurrence records and the Biodiversity Heritage Library (BHL)[11] had made 58,939,912 pages of biodiversity literature accessible. The Biodiversity Literature Repository (BLR) made 350,000 taxonomic treatments and images available which are directly imported into GBIF. Over 30 scientific journals are now published with tags that allow information to be

4 See https://www.cbd.int/gti/about.shtml.
5 Decision V/9.
6 See CBD Technical Series No. 30.
7 Decision VI/8, annex.
8 For progress prior to 2010, see for instance CBD Technical Series No. 21.
9 http://www.catalogueoflife.org/.
10 https://www.gbif.org/.
11 https://www.biodiversitylibrary.org/.

Figure 1. Examples of GTI activities. Plant specimen collection and field training in Viet Nam (left), and high throughput digitization of physical insect specimens for data integration and mobilization into international data portals (top right: photos courtesy of Thomas von Rintelen). Laboratory set-up for an outreach activity on the microscopic observation of seeds and their preservation (bottom right: photo courtesy of the Conservatory and Botanical Garden of Geneva).

incorporated directly into BLR and GBIF, including 45,000 species that have been added to the GBIF taxonomic backbone. The Barcode of Life Data System (BOLD; version 4),[12] which aims to sequence all living species on the planet, contains over 8,995,000 barcode sequences from animal, plant and fungal species, while the World Flora Online (WFO) provides descriptions, images and distribution data for over 350,510 species of land plants worldwide. All of this biodiversity data is being brought together in the Encyclopedia of Life (EOL)[13] platform to bring the vision of life on Earth into focus.

Urgency for enhanced GTI activities

Despite the scientific progress made in the last decade, the fifth edition of the *Global Biodiversity Outlook* (GBO-5),[14] released in 2020, points to major remaining capacity imbalances and gaps, and limited application of biodiversity knowledge to decision-making processes. Furthermore, the *Global Assessment Report on Biodiversity and Ecosystem Services* of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), published in 2019,[15] comprehensively summarizes the ways in which human activities are responsible for the unprecedented decline in habitats, species and species population sizes. The global community has been alerted by the scientific evidence that indicates that slowing species loss by 2030 and beyond can only be achieved through transformative change across the economic, social, political and technological sectors. Comprehensive and up-to-date information about the state of biodiversity, as well as the means to share, access and use this information, are needed to develop strategies that respond to this threatening decline of global biodiversity and enable transformative change.

One of the most significant achievements of the GTI so far is the broad and collaborative efforts of taxonomists working closely together and their networking activities to discover undocumented and undiscovered components of biodiversity.

12 http://www.boldsystems.org/.
13 https://eol.org/.
14 https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf.
15 https://ipbes.net/global-assessment.

This is reflected in the significant progress made towards Aichi Target 19, compared to all other targets. However, capacity imbalances and information gaps remain among Parties, and thus the significant advancements of the GTI community need to be continued and intensified.

To support the effective implementation of the post-2020 global biodiversity framework and catalyse transformative change, the Global Taxonomy Initiative Forum held online from 2 to 4 December 2020 (a) reviewed activities undertaken by Parties, taxonomic institutions, relevant expert organizations, networks and other entities, including citizen science groups and indigenous peoples, local communities and industry, (b) exchanged information on renewing activities of the Global Taxonomy Initiative, and (c) prepared proposals for the enhancement of technical and scientific cooperation and capacity development under the Convention.

Decade in review: lessons learned in 2011-2020

Activities undertaken by the Parties, expert organizations, specialist networks, and taxonomic institutions, among others, have served to implement the planned actions described in the Capacity-Building Strategy for the GTI;[16] for example:

(a) Workshops and training activities to address the taxonomic impediment;

(b) Facilitation of unrestricted access to ex situ materials and associated data via digital platforms;

(c) Sharing of analytical tools to discover hidden or undocumented components of biodiversity;

(d) Development of information infrastructure at the national and regional levels;

(e) Enhancement of specimen and culture collection infrastructure;

(f) Engagement of young taxonomists in conservation and biodiversity monitoring programmes.

Information provided by GTI Forum participants on such activities can be found in annexes 3 to 11 below, together with website URLs for additional details.

National reports

In its decision XIII/27, the Conference of the Parties adopted guidelines to assist Parties in the preparation of their sixth national report. In paragraph 5 of the decision, the Conference of the Parties invited Parties to provide and develop indicators and use scientifically sound data for reporting and assessing progress in the achievement of national targets. Unfortunately, systematic data collection and measurements were incomplete, and there are inconsistencies in data formats presented across the national reports. Many Parties took broad approaches, often at the ecosystem level, to report qualitative progress made towards the national targets, but often without reference to available taxonomic data. The lack of baseline values and quantitative and standardized data for practical use often hampered concrete assessments of changes in biodiversity. This is one of the major weaknesses in many assessments and derived measures taken by Parties in relation to implementation of the national biodiversity strategies and action plans (NBSAPs).

Taxonomic expertise within countries is key to improving the development of indicators and monitoring of progress and effects of conservation actions. The input collected by Forum participants also indicated that further capacity-building and technology transfer is necessary (see annex 3).

16 Decision XI/29, annex.

Box 1. Regional GTI activities in South-East Asia

In the Southeast Asian region, the ASEAN Centre for Biodiversity (ACB), with the support of the Japan ASEAN Integration Fund (JAIF), helped to strengthen and enhance the capacity of ASEAN member States (AMS) in taxonomy by conducting training workshops on selected plant groups (e.g. bryophytes, pteridophytes, orchids, palms, and alien invasive species), freshwater and brackish water fish, coral, and insects. In addition to the knowledge training, the workshops led to the production of five guidebooks and six training manuals, which were printed and distributed in the ASEAN member States. New discoveries were also made during the courses—for example, an undescribed palm species was found by participants in the herbarium of Lembaga Ilmu Pengetahuan Indonesia (LIPI). These activities helped to reduce knowledge gaps, increased the number of taxonomists in the region, and are contributing to ensuring the conservation and sustainable use of biodiversity.

The ACB is well-positioned to spearhead taxonomic activities in the ASEAN region because it has (a) developed a strong relationship with the Government of Japan and East and Southeast Asia Biodiversity Information Initiative (ESABII), thus ensuring funding for taxonomic activities from 2010 to the present; (b) a strong and productive working relationship with international, regional, and national experts on taxonomy who are willing to provide time and expertise in support of taxonomic activities; and (c) established collaboration with organizations with herbaria, botanical gardens, and research institutions with fully equipped laboratories and facilities for use in hands-on training.

As a full-fledged regional organization and centre of excellence on biodiversity conservation, the ACB has a good working relationship with the ASEAN member States. Likewise, the inclusion of local experts, who are attuned to national conditions and priorities, can resolve issues and concerns among various stakeholders and facilitate increased public awareness and taxonomy-related capacity development. Because experts can generate commitment and support from government officials, colleagues, and indigenous peoples and local communities, the development of a local pool of experts in the ASEAN member States is highly recommended.

To improve the comparability of national reports, Parties may wish to disclose the following information as part of national reporting:

(a) Whether the required capacity exists to monitor, manage and report on biodiversity;

(b) Whether in-country natural history collections, species lists and databases are available to increase public awareness, relevant to country-level priorities;

(c) Whether capacity-building in taxonomy, through various forums, networks and bodies, is present in the country;

(d) Whether the available biodiversity information shared by taxonomic experts and networks is applied in national reporting;

(e) Where needs exist, and the main challenges preventing the implementation of these practices.

Each Party should benefit from the taxonomic tools, knowledge and funds that have been achieved mostly in, and with the aid of, countries relatively advanced in taxonomy. Efforts should be enhanced to enable processes on the ground and in middle-management levels. Existing regional strategies can promote collaborations and fast-track crucial actions, particularly in less-developed countries that currently lack the capacity for evidence-based monitoring of progress towards achieving their national action plans. (See Box 1 for an example.) When all countries can participate and strategically shape their contributions towards national biodiversity targets, we may achieve global biodiversity targets.

II. Proposal for Change – GTI for the Post-2020 Global Biodiversity Framework

This section presents a Transformative Change in actions of the Global Taxonomy Initiative – some already under way – to support Parties in implementing the post-2020 global biodiversity framework.

Across the world, taxonomic institutions, specialist networks and organizations are continuing their efforts in the discovery, description and sharing of biodiversity data (Aichi Biodiversity Targets 9 and 19) through the use of integrated taxonomy approaches using advanced technologies and based on collaborative efforts. To bridge existing capacity gaps, improve national reporting and enable evidence-based biodiversity management decisions under the post-2020 global biodiversity framework, the GTI needs to intensify its activities and collaborations in all relevant areas.

Key areas in this context include:[17]

- **Increased capacity** in countries to develop their endogenous research and to identify, understand, monitor and manage their own biodiversity;
- **Broader capacity-building initiatives/strategies**, adapted and tailored to the needs of each country and research institutions by taking into account the needs and specificities linked with research activities in different types of environments;
- **Secured and appropriate funding and support** to maintain basic scientific infrastructures within countries;
- **Increase in the capacities of universities, ex situ collections, research institutions, natural history institutions, and other relevant basic research infrastructures** to utilize international databases and analyse and process taxonomic data, including digital sequence information, in all countries, particularly in least developed countries;
- **Increase in taxonomic expertise within countries**, especially in relation to analytical capacities in molecular biology, sequencing, data processing, bioinformatics, database management and uploading of digital sequence information to databases;
- **Joint** scientific research, technology transfer, scientific visits, partnerships and collaborations, including those via international networks.

Figure 2 below summarizes how such activities can lead to tangible capacity-building outputs that help Parties to increase internal capacities for identification and monitoring of their own biodiversity. This will in turn increase Parties' capacity to manage species and genetic diversity and inform decision-making processes.

In order to achieve the goal, in which all Parties can practice in the identification and monitoring of biodiversity components under the post-2020 global biodiversity framework, the GTI Forum identified issues to overcome. For instance, biological specimens and scientific information which are necessary to observe the status of biodiversity can be challenging to access for non-experts. Collaboration with taxonomic experts, within the country or outside the country, can facilitate the application of evidence on biodiversity for conservation. To bridge Parties' needed support and taxonomic experts the GTI national focal points play important role to enhance communication between taxonomic

17 CBD/DSI/AHTEG/2020/1/7.

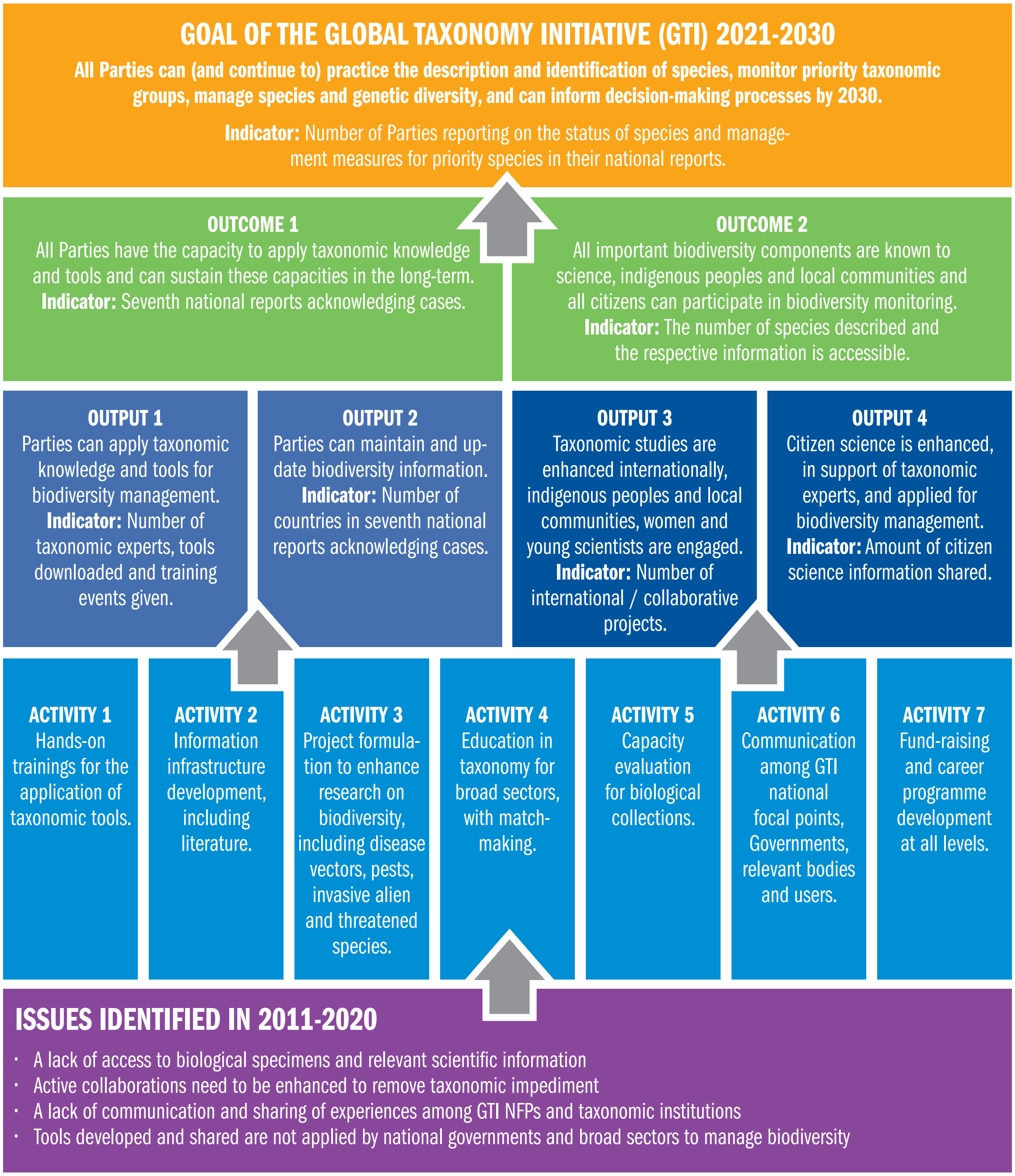

Figure 2. Transformative Change through actions of the Global Taxonomy Initiative (GTI) 2021-2030. Relevant performance monitoring indicators are suggested but can be adjusted at the national or institutional level as appropriate to be consistent with the indicators associated with the post-2020 global biodiversity framework.

institutions and broad sectors, including governments and biodiversity stakeholders.

The activities may include:

- Hands-on training for the application of tools;
- Support for building information infrastructure;
- Project formulation to enhance taxonomic research and generation of biodiversity data;
- Education in taxonomy for broad sectors;
- Capacity evaluation for biological collections to sustain their roles for Parties' implementation;
- Communication within the GTI community, and with broad sectors;
- Fund-raising and career programme development to support young taxonomists providing support for Parties' implementation.

Developing taxonomic expertise, particularly in less developed but biodiversity-rich countries, will also create equitable conditions for collaborative international research. The support of and linkage with structured, sustainable and well-organized national or regional organizations that are anchored in the taxonomic community is useful (e.g. the International Barcode of Life Consortium with BIOSCAN global projects; the Consortium of European Taxonomic Facilities, CETAF; and the International Plant Exchange Network, IPEN). This can foster long-term taxonomy-related outputs beyond the lifespan of individual (often short-term) initiatives and programmes, and thus increase and maintain local taxonomic capacity. This is especially important to facilitate scientific collaborations and access to research samples under mutually agreed terms in compliance with the national measures related to the Nagoya Protocol.

III. New Approaches and Emerging Opportunities for Taxonomy

The past two decades have brought unparalleled advancements in the development of new technologies that are highly relevant for taxonomy. The application of new technologies and approaches, and their integration into taxonomic studies and workflows, have given rise to "integrative taxonomy" (Dayrat 2005) and an innovative way of doing science in the information age (German National Academy of Sciences Leopoldina 2014). These new approaches render taxonomy more open, transparent and participatory, and are closely linked with the "open science" agenda of governments and many scientific institutions. The paragraphs below briefly highlight some of the key developments and aspects, which provide new opportunities for an advanced GTI under the future post-2020 global biodiversity framework.

New genomics and informatics

The rapid development of molecular methods over the past 20 years, leading to a proliferation of DNA and whole genome sequencing technologies, has immensely increased the opportunities to document and inform on the sustainable use of life on Earth across different sectors, such as agricultural and food supply (e.g. aquaculture, animal and plant breeding, food processing), forestry and biomaterials, biomonitoring (e.g. of pests and pathogens) and forensics (e.g. re. illegal trade, contaminants). Advanced sequencing techniques with their ultra-high capacities, scalability and speed, enables researchers to study biological systems at a level never before possible (Baird and Hajibabaei 2012). The molecular revolution has enabled rapid, fully automated identification of organisms based on DNA barcodes (Hebert et al. 2003; Hebert and Gregory 2005) and has made it possible to document and monitor the presence of large numbers of organisms in material samples and substrates (e.g. water, air, soil) via metabarcoding approaches (Deiner et al. 2017).

The application of metabarcoding, metagenomics and quantitative PCR (qPCR) to environmental samples (e.g., pooled tissue and eDNA) accelerated biomonitoring, forensic sciences, such as for the detection of invasive alien species (Thomas et al. 2020) or the tracing of the illegal use of plants and animals (Staats et al. 2016). Metabarcoding and informatics are also helping us to understand the functional composition of ecological communities (Grossart et al. 2020) and reveal hidden diversity in the form of unique DNA sequences (Taberlet et al. 2012; Porter and Hajibabaei 2018). Non-destructive or low-impact sampling allow the monitoring of the genetic diversity of

Figure 3. Researchers can collect environmental DNA in nature; PCR amplification with species-specific DNA primers can determine the species present in a water sample. Photos (left to right): environmental DNA filtration apparatus (courtesy of Katie Millette); PCR machine in the molecular genetics laboratory of the Conservatory and Botanical Garden of Geneva (courtesy of the Conservatory and Botanical Garden of Geneva); gel electrophoresis image of amplified DNA fragments (courtesy of Katie Millette).

entire biological communities, the recovery of the total biodiversity in a given area, its degradation and restoration, or simply the surveillance of the species richness through eDNA signatures (e.g. Andersen et al. 2012; Valentini et al. 2016; Ferguson et al. 2019).

New genetic technologies can indeed generate biodiversity data at fine genomic, spatial and temporal resolutions. However, these tools depend crucially on reliable taxonomic expertise for accurate interpretation. Reference libraries are products of the integrative taxonomic approach and need to be matched with species inventories at several geographical scales and require continuous updating and curation by the respective scientific communities and experts.

Informatics has dramatically altered taxonomic working practices and workflows. Notable changes include how scientists are collaborating on taxonomic revisions (e.g. Scratchpads[18]) and publishing linked, discoverable and reusable taxonomic data (e.g. Pensoft journals,[19] European Journal of Taxonomy[20]). The aggregation of vast amounts of biodiversity data through GBIF, the collation of genetic sequence information by the DNA Data Bank of Japan (DDBJ), the European Molecular Biology Laboratory (EMBL), GenBank and the International Barcode of Life (iBOL), as well as the aggregation of species morphological data (e.g. MorphoBank,[21] TraitBank[22]), has made diverse organismal data available to the world in the public domain (e.g. World Flora Online). Informatics has also enabled primary taxonomic resources such as physical specimens and early literature to be available to researchers, and the move to open access and findable, accessible, interoperable and reusable (FAIR) data principles (Wilkinson et al. 2016) is alleviating the burden of paywalls and reducing the digital divide between data generators and users.

18 http://scratchpads.org/.
19 https://pensoft.net/browse-journals.
20 https://europeanjournaloftaxonomy.eu/index.php/ejt.
21 https://morphobank.org/.
22 https://traitbank-reconnect.hcmr.gr/.

Automation and artificial intelligence

The automation of some parts of the taxonomic workflow can accelerate and optimize species discovery, identification and naming. Automated species identification through the application of machine learning tools to molecular sequence data and images could be used to recognize similarities and differences in character data sets and identify data clusters representative of phylogenetic groups (e.g. Carranza-Rojas et al. 2017). This method, however, requires the physical materials (specimens or sequences) and the help of experts for verification. In the case of image recognition technologies, a deep understanding of morphological features of each group is imperative prior to the utilization of automated processes. The advancement of automated information technologies across many fields indicates that this technology holds much interest and promise as a reliable approach for integration into taxonomic-based initiatives in the future.

A prime example of successful application of artificial intelligence technologies is in taxonomic literature, which is highly structured, yet not easily usable due to its large volume and its format. Recent large-scale efforts in the digitization of printed media involving the application of optical character recognition (OCR) techniques and automated data extraction are helping to make taxonomic literature available and usable in a machine-readable format. This data includes, among others, taxonomic information and citations of type material that in many cases are the only sources of information for rare species. Rapidly developing text and data mining technologies paired with highly sophisticated research publishing systems will improve access to data (e.g. species illustrations, taxonomic traits) and contribute to the continuous updating of species names in the Catalogue of Life and thus also in GBIF.

Figure 4. Initiatives like the "adopt a tree", "forest on a pallet" and botanical field training programmes by the Bahamas National Trust and the Leon Levy Native Plant Preserve in the Bahamas are raising public awareness and providing public biodiversity education. (Photos courtesy of Ethan Freid).

Cloud-based services and programmes for data sharing, storage and digital access can provide cost-effective solutions for biodiversity monitoring. Data can be compiled and processed efficiently, and cloud computing platforms can increase the capacities to analyse large or complex data sets.

To maximize the application of informatics technologies, including machine learning, in biodiversity science, it is vital to enhance open access to biodiversity information (i.e. literature, sequence data and genome annotations, specimen images, biogeographic and temporal observation records, among others).

Community and citizen science

Engaging volunteers and the public in recording biodiversity are low-cost, large-scale, and long-term options for detecting, monitoring, and surveying species. The process itself collects invaluable data while fostering bio-literacy.

Citizens who are engaged in the stewardship of their local biodiversity are more likely to care about biodiversity issues and related policies more broadly.

Community and citizen scientists with smartphones that use geo-spatial and photographic applications, like iNaturalist[23] and eBird,[24] are helping record species geographical distributions. Public data collection events like "BioBlitzes" that implement structured and standardized reporting protocols are recording reliable species occurrence data. With expert collaborations, citizen science data is increasing our knowledge about regional and global biodiversity patterns, for example, phenological changes in species activity as a result of climate change (Clavero et al. 2017).

In the European Union, the EU Citizen Science platform[25] hosts many biodiversity monitoring projects (e.g. the Ladybird Experiment, Capturing Our Coast, BioDiversity4ALL), resources (e.g. "citizen science toolkit for biodiversity scientists",

23 https://www.inaturalist.org/.
24 https://ebird.org/home.
25 https://eu-citizen.science/.

Box 2. A view of indigenous peoples and local communities on taxonomic research provided following the Forum

The involvement of local communities that live among native genetic resources and utilize biodiversity is key to conservation-effective action. Taxonomic identification is better understood when indigenous knowledge and values are included, in the context of the species' "home ecosystem". Indigenous peoples and local communities protect and nurture the functionality of ecosystems by maintaining a balance with all life. The success of indigenous peoples and local communities in biodiversity management demonstrates how important it is to understand that life depends on the entire ecosystem community.

The GTI's goal of discovering, identifying and documenting species should be done in collaboration and respect with indigenous peoples and local communities. GTI activities should be discussed with full and equal participation of indigenous peoples and local communities. The production of information and benefits arising from GTI activities and biological specimens should be discussed with indigenous peoples and local communities and protectors of biodiversity in a transparent manner. Dialogues between local and scientific communities empower local communities to monitor and respond to environmental changes and support conservation and sustainable use of biodiversity. The governance of research, education and financial structures dedicated to supporting generation of sustainability of each species in the indigenous peoples and local communities' home ecosystems should be on the table for discussion under the Convention.

"understanding the citizen science landscape for environmental policy: an assessment and recommendations", video on "citizen science - in researching biodiversity") and training tools for citizens to engage with nature (e.g. Natural History Museum Guide to Citizen Science). A new global coalition for biodiversity and its social media initiative, "#UnitedforBiodiversity", launched by the European Commission, has called for stronger mobilization in raising awareness for the need to protect biodiversity by engaging national parks, aquariums, botanic gardens and zoos, and encouraging citizens to participate. More specific initiatives of natural history institutions and under supervision of their scientists successfully mobilized data from their collections (e.g. Les Herbonautes).

The documentation of biological data by citizens with the subsequent image analyses and assignment of unique stable digital object identifiers is shifting biodiversity observations to taxonomic research objects. As digital technologies are developed and shared, the amount and quality of community-derived data is expected to increase, placing the future of biodiversity management and conservation more actively in the hands of the public.

Indigenous peoples and local communities

Indigenous peoples and local communities informed the Forum that the post-2020 global biodiversity framework would be successfully implemented if governance, work, expertise, and ownership of indigenous peoples and local communities are considered and involved with free and prior informed consent, and in accordance with other internationally agreed instruments.

IV. Taxonomic Tools for Biodiversity Identification and Conservation

The discovery and description of species, the understanding of species boundaries, the elucidation of evolutionary processes, and the placement of species in an established phylogenetic classification system for unequivocal referencing and information exchange, lie at the heart of the science of taxonomy (Wilson 2004) and biological systematics. Access to taxonomic literature, nomenclatural reference databases and natural history specimens underpin taxonomy and taxonomic processes (Funk 2018). Outcomes of taxonomy include the production of tools that allow for the reliable and accurate identification of organisms based on their morphological traits, often combined with phenological or ecological information. National data centres serve to collate data on species and their distributions as well as acting as focus points for the creation and updating of species checklists and red lists. Annexes 4 to 10 provide non-exhaustive examples of the variety of taxonomic keys, guides, DNA sequence-based platforms, institutions, and databases available. The taxonomic backbone that is created and curated by taxonomists forms the foundation for many other disciplines by providing concepts and names for biological entities (one name per species), which in turn play a key role in our understanding of issues such as sustainable development, ecological restoration, evolutionary forecasts, and climate change modelling.

Interactions with biodiversity, biodiversity management and the sustainable use of biodiversity rely on the correct identification of the respective organisms. In some cases, to ensure correct identification, a combination of morphological, phenotypic and genetic approaches may be necessary, as not all species can be determined in the field using pictorial field guides, and not all species have been described. In some cases, particularly in species-rich taxonomic groups, species are ill-defined morphologically and are thus difficult to recognize. Sustained and continually enhanced taxonomic knowledge provides essential services that inform biodiversity assessments and conservation policy. This section documents and describes examples of invaluable taxonomic resources for species identification.

Field guides made accessible for taxonomic identification

Field guides are important tools to enable interested individuals and students without specialist knowledge to familiarize themselves with and reliably identify a particular group of organisms in their country or region. While many field guides are still published and available both in print and digital formats as individual contributions, the application of innovative data management tools increasingly allows for the production of customized applications on demand for individual projects or interests and are shared online.[26] With such technological advancements, the need for comprehensive information about how to recognize and reliably identify particular organisms, based on solid and reliable taxonomic knowledge, increases even further. Annexes 4 and 5 contain just a few examples of the successful sharing of taxonomic data for field guides as attractive and user-friendly identification aides.

DNA sequence-based taxonomic identification

The role of DNA-based taxonomic identification was highlighted in the fourth edition of the *Global Biodiversity Outlook*.[27] DNA barcoding is a tool that distinguishes species by examining sequence variation in the mitochondrial cytochrome *c*

26 E.g. https://fieldguides.fieldmuseum.org/guides; https://www.inaturalist.org/guides.
27 https://www.cbd.int/gbo/gbo4/publication/gbo4-en.pdf.

oxidase subunit I (COI) gene region. Proposed in 2003 as an identification method for animal species, it has been extended to other groups of multicellular life (plants, fungi, protists). Through constant refinement of laboratory, technological and analytical processes over the past decade, DNA barcoding has matured into a fast, reliable, and cost-effective tool for species identification and discovery. The resulting data has enhanced our capacity to catalogue biodiversity and has extended our understanding of species distributions.

The use of DNA barcoding for specimen identification relies on access to well-curated reference DNA sequence databases. Following established international practices, sequence data should be made available through deposition in major online genetic data repositories (e.g. BOLD, GenBank) as it contains essential information on evolutionary relationships and population structure of species that is required for policymakers tasked with conserving species diversity (Centre for Biodiversity and Genomics, University of Guelph 2021).

It is important to note that all new taxa identified by genetic sequences must be linked to physical specimens in publicly accessible natural history collections to allow for future reference and re-examinations of the species record. DNA barcoding does not replace the knowledge held by taxonomic experts and in natural history collections but rather is founded on it (Janzen et al. 2020). The adoption of DNA barcoding into the integrative taxonomic approach, which positions new taxonomic information among reference data, is needed to best describe and understand species diversity.

Special taxonomic interest groups and service providers

Specialist expert groups working collaboratively on particular taxa or species allow for effective exchange of taxonomic knowledge. By pooling their shared knowledge, resources and efforts, specialist expert groups can tackle issues and conduct research collectively. Individual taxonomists or specialist groups are often also responsible for creating and maintaining nomenclature databases, taxon databases and morphological databases, among others. These groups, such as the Taxonomic Expert Networks (TENs) created under the World Flora Online initiative, can become the motors behind biodiversity discovery and the curators of biodiversity data. Professional societies (such as the International Association for Plant Taxonomy, IAPT) also contribute by supporting the taxonomic codes, specialist scientific journals, taxonomic initiatives and training, scientific meetings and field excursions, by offering small research grants and through their support of students.

Whole genome approach

Powerful advances in genome sequencing technology, informatics, automation, and artificial intelligence have propelled humankind to the threshold of a new beginning in understanding, utilizing, and conserving biodiversity. A large project for sequencing all eukaryotic organisms—the Earth BioGenome Project (EBP)—has been launched by major taxonomic and genome institutes. One of the priorities of EBP, for example, is to sequence the genome of more than 23,000 species currently listed as endangered by IUCN (Lewin et al. 2018).

V. Sharing Taxonomic Information and Knowledge of Species Globally

The fifth edition of the *Global Biodiversity Outlook*, in its "summary of progress" for Target 19, reported that major imbalances remain in the location and taxonomic focus of studies and monitoring. Despite the significant progress and advances being made by taxonomists around the world to close the remaining information gaps, actions to promote education and training programmes on biodiversity must be intensified. Natural history collections and botanic gardens around the globe are closely collaborating on different levels, for example to develop and promote scientific research programmes, undertake species inventories, identify key biodiversity areas and generally increase the amount and quality of biodiversity information. These historical collections often date back to the mid or early 18th century, and the various objects, data and information stored provide for benchmarks and baselines of many parameters that should be measured in the post-2020 global biodiversity framework

Natural history collections and museums have long-standing international relations and are often engaged in the education of local citizens and in science communication. Many museums closely collaborate in international networks like Botanic Gardens Conservation International (BGCI) or associations like the Consortium of European Taxonomic Facilities (CETAF) and compile and aggregate data, for example for GBIF, IUCN Red Lists or local or international biodiversity monitoring programmes. Thus, overall, such institutions have been important supporters in reaching Aichi Biodiversity Targets 12, 13, 18 and 19 (e.g., see annex 3), and will continue to play key roles in the post-2020 period (see table 1 below).

Natural history collections have started the task of digitizing physical specimens, with an initial focus on type specimens, and historical data catalogues. Numerous museums and herbaria (see annex 7 for examples) have developed high-resolution digital image data sets for their specimen collections and these are made available on the web. Scientific research conducted on these outputs is populating species databases and nomenclatural resources such as the Catalogue of Life, with specimen data also aggregated in GBIF, as well as revealing new species (e.g. Bebber et al. 2010). Collaborative scientific communities are driving the world's largest online databases of images, specimen records, nomenclature and natural history information on species of algae,[28] ants,[29] birds,[30] fish,[31, 32] plants,[33, 34, 35, 36] and marine, terrestrial, freshwater and brackish organisms,[37] to name a few. Genetic sequence data in the International Nucleotide Sequence Database Collaboration (INSDC) databases (GenBank),[38] European Nucleotide Archive (ENA),[39] DNA Data Bank of Japan (DDBJ),[40] Barcode of Life Data System (BOLD)[41] and SILVA

28 https://www.algaebase.org/.
29 https://www.antweb.org/.
30 https://avibase.bsc-eoc.org/avibase.jsp?lang=EN.
31 http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp.
32 https://www.fishbase.de/.
33 https://plants.jstor.org/.
34 https://www.tropicos.org/home.
35 https://www.ipni.org/.
36 http://www.worldfloraonline.org/.
37 http://www.marinespecies.org/.
38 https://www.ncbi.nlm.nih.gov/genbank/.
39 https://www.ebi.ac.uk/ena/browser/home.
40 https://www.ddbj.nig.ac.jp/index-e.html.
41 https://www.boldsystems.org/.

ribosomal RNA database[42] is growing fast. The Global Genome Biodiversity Network (GGBN)[43] makes non-human DNA and tissue samples, and their associated data, available for the scientific community. At the time of writing of the present publication, there were over 1.6 billion species occurrence records available through GBIF. The proliferation of this data is an excellent example of what can be achieved in our progress towards identifying the world's biodiversity (see annex 8 for additional examples of taxonomic tools and services and annex 9 for additional examples of taxonomic databases). All hold valuable resources for taxonomists and are community-driven, with the aim of working towards a global biodiversity knowledge network (Hobern et al. 2019).

It is important to identify gaps in taxonomic and geographic coverage in the available data sets to allow for the development of taxonomic or specimen collection priorities. To improve the usage of taxonomic information and in order to develop the best adapted training programmes to ensure the longevity of the knowledge needed for the implementation of the post-2020 global biodiversity framework, a good understanding of the state of play is essential. An assessment of taxonomic gaps and expertise gaps across different groups of organisms and regions of the world should accompany this approach in order to better target and focus research and capacity-building programmes. The formation of specialist taxonomic research groups is a best practice addressing the need to foster collaborations as well as to focus scientific efforts to close knowledge gaps and overcome the taxonomic impediment. The World Flora Online is an example where Taxonomic Expert Networks take responsibility for the continuous curation of a broad taxonomic resource. Scientific communities worldwide should adopt this approach widely with full support by governments.

The development of national, regional and international consortia of taxonomic facilities (such as the European natural history institution network CETAF) and their taxonomists, facilitates communication, joint actions, information exchange and outreach activities. Coordination across countries and regions allows for the development of coordinated efforts and creates opportunities for training, joint research and scientific exchange. The organization of meetings, training events, discussions and conferences on taxonomy at national, regional, and international levels (with online participation options) are excellent means to launch collaboration and open up biodiversity discovery and documentation.

Natural history collections and taxonomic institutions

Natural history collections and taxonomic institutions are a source of material for scientific research as well as providing educational material for students and for outreach to the public on the role and importance of biodiversity. The specimens held in publicly accessible collections form the indispensable foundation for the science of taxonomy. Natural history collections document diversity in nature and harbour vast amounts of data on current and past biodiversity on Earth. They are a pivotal globally-distributed infrastructure that can help map a sustainable future and protect the natural systems upon which we depend (e.g. see Suarez and Tsutsui 2004). Natural history collections are used for answering fundamental scientific questions about species as well as about ecological, evolutionary and geological processes. Data derived from natural history collections has also underpinned countless discoveries and innovations, such as bio-inspired inventions and products essential to the economy, as well as databases, maps, species descriptions and scientific observations (see annex 7 for examples).

New methods for openly linking biodiversity data, using unique identifiers for specimens, making data FAIR and connecting biodiversity

42 https://www.arb-silva.de/.
43 http://www.ggbn.org/ggbn_portal/.

Figure 5. The herbarium of the Conservatory and Botanical Garden of Geneva houses ca. 6,000,000 specimens from around the world. This type specimen of *Arnica piloselloides* L. is one of many dried vascular plant specimens housed in its vast collection. (Photos courtesy of the Conservatory and Botanical Garden of Geneva).

data to other information such as environmental data (e.g. land use, pollution, temperature) are leading to new insights into the relationships between biodiversity loss and its causes. Collections are also a prerequisite for the new genomics methods, which rely on the preservation of voucher specimens as a reference for the future.

Ex situ preservation, including in zoos, botanical gardens and their respective conservation and breeding programmes, contributes to the maintenance of living genetic diversity, facilitating scientific research on living organisms, and international exchange and collaboration. Access to and the exchange of the specimens (living and preserved) for scientific research is indispensable for the realization of advanced biodiversity sciences.

Availability and mobilization of taxonomic literature and taxonomic data

Access to taxonomic and biodiversity literature is essential to support efforts to document, understand and monitor biodiversity. The adoption of techniques that allow for machine-readable data allows taxonomic knowledge, but especially species names and descriptions, to be mined, retrieved and used more efficiently. Data connectivity allows for crucial information on species from different sources to be linked (Hobern et al. 2019). Promotion of FAIR and open access publishing[44] of taxonomic literature and biodiversity data underpins the acceleration of taxonomic endeavours as well as successful training and capacity-building efforts.

New methods for documenting, sharing and enriching biodiversity data using collections

Natural history collections document diversity in nature (across time and space) and harbour vast amounts of data on current and past biodiversity on Earth. By tagging natural history specimens with unique identifiers, specimens can be more easily used, linked, cited and retrieved, leading to increased use and access to the collections in a digital form. The systematic revision of taxonomic groups forms the indispensable basis for the science of taxonomy, as collections contain

44 https://www.fairopenaccess.org/.

nomenclatural types, multiple exemplars of species used to understand species variability/diversity, and voucher specimens for biological studies (biodiversity monitoring). Associations that unite collections institutions and coordinate common goals, like the activities and collaboration of scientists in CETAF institutions worldwide and within Europe, are essential in establishing the capacity that is needed to sustain taxonomic and genetic activities in the future.

Flora and fauna projects (see annex 10 for examples) rely on solid taxonomic expertise and may themselves generate further taxonomic research on problematic (hard to identify) species, or on other issues related to the circumscription of biological entities. These projects are a reliable source of specimens that are deposited in publicly accessible collections and present taxonomic knowledge in ways that makes it accessible to the scientific community worldwide.

VI. Engaging with Broad Sectors

As a cross-cutting initiative of the Convention, the GTI connects to many other activities and programme areas of the Convention, which is also reflected in the planned actions of the original programme of work for the GTI.[45] Taxonomic information and services contribute significantly to, and are often key requirements for, successful operations in many sectors of society and in different communities. Under the new global biodiversity framework, it will be important for the GTI to plan for and improve effective interfaces with these sectors and communities in order to maximize beneficial outputs. This chapter highlights some sectors as examples, focusing on the specific opportunities and challenges for the GTI that these interfaces comprise.

Environment

The GTI can support the diverse activities in the environment sector, including in natural resource management (e.g. fisheries, forestry, mining) and conservation efforts across many biomes and habitat types (e.g., forests, deserts, soil, marine and freshwater systems, mountain and islands). Environmental engineers, officers and consultants require basic biodiversity data to make informed decisions for ecosystem protection, assessment, restoration and management. GTI-related information can, for example guide the boundary selection for protected areas by determining the distribution of rare or threatened species' habitats. Species taxonomic information and population status will serve to set baseline values in the post-2020 global biodiversity framework and will require on-going engagement with the environmental sector to monitor long-term biodiversity trends.

In collaboration with the Secretariat, actors of the GTI need to be able to communicate with the national environmental and natural resources implementing authorities to the Convention, including on national biodiversity strategies and action plans. Likewise, GTI national focal points (NFPs) should communicate with taxonomic experts to help them develop scientific and technical advice for national implementing authorities of the Convention.

Education

Meeting conservation targets relies on local education and capacity-building. Education is important to raise biodiversity awareness in the public through sharing knowledge of life on Earth, its status and the potential of nature-based solutions. Universities, research institutes, natural history museums, botanical gardens and zoos have an important role to play in biodiversity education as they are often our first exposure to the diversity of life around the world. In addition, enhancements in domestic biodiversity education should be of high priority to engage citizens to take stock of their own local biodiversity and understand its importance.

There is a need to support the insertion of basic taxonomic literacy into primary and secondary curricula, and enhance taxonomic skills training in relevant Bachelor's and Master's degree programmes. More can be done to support taxonomic career programmes, for example by provision of stipends for PhD and postdoctoral studies that enhance transmission of taxonomic expertise or by subsidizing the training and publication fees of ongoing taxonomic studies. By creating long-term career paths in taxonomy, we can attract more young people to choose a career in biodiversity and keep them in such fields. A constructive alignment of opportunities and funding support is needed to avoid the loss of talented experts that are so urgently needed for the continuity of taxonomic knowledge.

45 Decision VI/8.

Figure 6. Left: Commercial banana (*Musa* spp.) crops are threatened by a fungal pathogen. In order to support banana production, crops require constant monitoring of disease spread and the identification of disease-resistant cultivars. Right: Pollinating insects, including honeybees (*Apis* spp.), are vital for plant reproduction, and information is required on their population sizes in order to maintain our global food systems and agriculture sector. (Photos courtesy of the Conservatory and Botanical Garden of Geneva).

Where possible, collaborations that foster biodiversity education through "South-South" training are recommended (e.g. fellowships to learn taxonomy locally), not only the more traditional "North-South" approaches. Funding local research leads to capacity-building for both the students and the supervisors, as well as providing an incentive for researchers from different countries to create collaborative partnerships. Such programmes should be offered and managed with at least a ten-year vision. In addition, education on biodiversity data analyses and publication should be emphasized and encouraged in biodiversity-rich developing countries, where there is often a lack of published data, and fewer tools with which to conduct analyses of large data sets and publish data.

Agriculture

The average percentage of land dedicated to agriculture is over 37% worldwide; it exceeds 50% in some countries.[46] Profound changes in production systems, farming practices, land use and the design of agricultural landscapes (see also subsection below on land use and landscape development) have led to a decline in biodiversity. Taxonomic knowledge and tools are needed and must be used across this sector to assess the effect of land use on biodiversity, especially as agriculture-related pressure on biodiversity grows. This also applies to the identification and detection of pests and invasive species.

To date, profound knowledge and scientifically reliable conclusions about underlying cause-effect relationships (including how changes in

46 https://data.worldbank.org/indicator/AG.LND.AGRI.ZS

biodiversity affect the performance and stability of agricultural production systems), and assessments of the impact of agri-environmental policy measures to promote biodiversity, have been limited; there is a strong need for reliable taxonomic and monitoring data. Such data should include information on diversity and quality of habitats with different (functional) groups of organisms (producers, consumers, decomposers) that are of particular importance for the performance of agricultural production systems (pollinators, pests, microbes and soil organisms).

Taxonomic input is needed for basic identification of species in agricultural ecosystems, including species with beneficial (e.g. for pollination, soil fertility) and harmful (e.g. pests and pathogens) effects. The identification and detection of pests and crop wild relatives are strong needs in this sector to address food security. Taxonomic research in the agricultural sector should be prioritized as there are clear links between crop yield and pests, invasive species and genetic diversity.

The rapid detection and identification of invasive alien species, pests and pathogenic agents are necessary for safe international trade and biosecurity. National customs authorities are the first line of defence against unwanted biodiversity components that may enter from other countries. In collaboration with national authorities for agriculture and environment, taxonomic identification tools and services can address trade in illegal commodities likely to harm the health of biodiversity, agriculture and human populations. The National Plant Protection Organizations, also in their role as implementing the International Plant Protection Convention (IPPC) and the Veterinary Authorities, are immediate users of taxonomic identification tools and services. Often these officials require prompt species identification services to prevent entries of regulated species. Provision of training for the border officials and species identification services may facilitate the process of removing the taxonomic impediment in this sector. Close collaboration among taxonomists and the national customs authorities and the national authority for the implementation of the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora is required for border control on commodity trade which may involve living organisms or biological samples. Adoption of DNA barcoding and metabarcoding for monitoring illegal trade by national customs and CITES management authorities could expedite species identification and increase accuracy, thus bypassing the taxonomic training impediment faced by customs officials. Partnerships with national universities for DNA barcoding-based authentication could enhance research capacity-building through financial compensation for contracted authentications.

Financial

Investment for biodiversity by the national budget and financial institutions, including development banks, has an important role to play in mobilizing resources for biodiversity conservation. The green economy, which is understood to provide long-term benefits and reduce underlying risks associated with biodiversity loss, should be promoted, with a focus on sound evidence regarding biodiversity and solid cost-estimation of each activity. Informing the financial sector on the status of biodiversity and ecosystem services is therefore critically important for the implementation of the post-2020 global biodiversity framework. For example, nature-based solutions, such as for climate change adaptation and mitigation, stewardship of natural ecosystems, application of indigenous knowledge systems (e.g. ethnobotany and basics in zoology), regenerative land use and an economy that designs out waste and resource depletion (i.e., circular economy) all require close collaboration and input from biodiversity science to ensure the efficacy and efficiency of the funded measures.

Land use and landscape development

Landscape features such as linear, continuous structures (e.g. rivers and their banks, or traditional forests and their field margins) that provide connectivity and networking functions between habitats (e.g. floodplains, mangroves, or woodland) are essential for species' reproduction, migration, geographical distribution and gene flow. Protecting the greatest possible diversity of life on land (at the landscape level) and in water, and controlling the development of anthropogenic project planning, structures and usages (e.g. sustainable urban planning, water and sewerage control, responsible production, waste reduction) is much more effective in halting biodiversity loss than is protecting individual species and habitats in isolation. Initiatives that support the identification and monitoring of species must therefore be implemented with this in mind and at appropriate spatial scales to be successful.

For example, data collected by the European Land Use and Coverage Area frame Survey (LUCAS) provides harmonized information on land use, land cover and environmental parameters for studying a range of socioenvironmental challenges, such as the conversion of land into agricultural or urban areas (land take), soil degradation, or biodiversity. Nowadays, LUCAS soil campaigns are integrating some soil biodiversity indicators, including DNA fingerprinting, which will be applied to analyse soil biodiversity. Microorganisms such as bacteria, archaea, fungi, and microbial eukaryotes will be targeted to explore their distribution in different climatic regions and evaluate the impact of land cover/uses on their diversity across the European Union territory.

Possibilities for direct roles of the United Nations or European Union in national or regional spatial planning are mostly non-existent; so far, respective paragraphs of conventions/regulations are mostly formulated as non-binding invitations to the member States to comply. Renewed activities of the GTI will support in the development of mandatory requirements towards a more effective landscape development strategy and thus biodiversity protection in line with a powerful post-2020 global biodiversity framework.

Maritime and aquatic systems

The United Nations Convention on the Law of the Sea (UNCLOS) provides the global framework by requiring States to work together, "to prevent, reduce and control human caused pollution of the marine environment, including the intentional or accidental introduction of harmful or alien species to a particular part of the marine environment".

The uptake and discharge of ballast water and sediments and the transport of biofouling organisms by ships facilitate the worldwide spread of invasive aquatic species that threaten aquatic biodiversity. The International Convention for the Control and Management of Ships' Ballast Water and Sediments under the International Maritime Organization (IMO) entered into force in 2017. In accordance with Article 6 of Scientific and Technical Research and Monitoring, Parties are individually or jointly called to promote and facilitate scientific and technical research on ballast water management and monitor the effects of ballast water management in waters under their jurisdiction using sets of guidelines. The collaboration of taxonomic institutions and the relevant research community with the maritime authorities and shipping industry has led to effective technical assistance and personnel training to undertake appropriate inspection and monitoring of the coastal marine environment.

The guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines)[47] call for research and training on the impact and control of invasive aquatic species.

47 The Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species (Biofouling Guidelines).

Figure 7. This collection of aquatic invertebrates can inform on the water quality of aquatic systems. The presence and absence of particular microcrustacean species, like *Daphnia*, can indicate water quality such as the presence of pollutants or acidic conditions. (Photo courtesy of Katie Millette).

Taxonomic research is needed in the prevention of micro-fouling and the geographic spreading of biofouling invasive aquatic species as well as the development of diagnostic tools and eradication methods for rapid response to incursions of invasive aquatic species.

Development of a new legally binding instrument on the conservation and sustainable use of marine life in areas beyond national jurisdiction (BBNJ) has progressed under the United Nations Convention on the Law of the Sea. An intergovernmental conference for the instrument was established, and the evaluation of marine protected areas or other area-based management projects, the harmonization of the criteria for the designation of protected areas, and the monitoring of the surveillance and management of those areas are currently being considered by the intergovernmental process. It is likely that data on marine biodiversity and capacity development activities for developing countries to implement the future instrument will be necessary and thus should be included in the process.

Aquatic organisms such as microalgae and microinvertebrates also fulfil an indicator role for the effect of human activities (e.g. acidification, pollution, ocean warming) on water quality. This indicator function of species will be an important component in the implementation of the legal instrument and will require expert knowledge to be developed and deployed.

Health

There are estimated to be around 1.7 million unidentified viruses that exist in mammals and waterfowl, many of which capable of infecting humans. According to the IPBES Workshop Report on Biodiversity and Pandemics[48] released in 2020, the human effects associated with an increased risk of pandemic emergence include land-use change, agricultural expansion and intensification, and the wildlife trade, especially

48 IPBES (2020) Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services.

for consumption. According to the report, biodiversity loss associated with transformation of landscapes can lead to increased emerging disease in some cases, where species that adapt well to human-dominated landscapes are also able to harbour pathogens that pose a high risk of zoonotic transmission.

Taxonomic identification has been used in clinical and forensic medicine, veterinary medicine and plant health organizations. Early detection and rapid response to pathogenic agents to animals, plants and humans are recognized as important measures to prevent the spread of water-borne or communicable diseases. Monitoring of the hygienic status of wet markets, food production systems and domesticated animal production is facilitated by identifying pathogenic agents and reporting to designated disease surveillance authorities, world-wide. Close collaboration with health authorities to provide rapid taxonomic identification is the core service of taxonomic institutions in this sector.

The health sector is increasingly applying molecular technologies (e.g. PCR tests for pathogens, whole genome sequencing), often in combination with morphology-based techniques, for identifying potential pests, disease vectors, viruses and disease diagnoses. Identifying the definitive hosts of pathogens is essential for mitigating repeated and future zoonotic pandemics. By vouchering and maintaining host specimens, the taxonomic work of host-pathogen research can provide a record for current and future pandemics (Thompson et al. 2021).

Developing a sustainable future and avoiding new pandemics will require transformative societal change that goes beyond a business-as-usual approach and one that aims to prevent rather than react to disease outbreaks (see also direct connections to Sustainable Development Goal 3 and indirectly to Aichi Biodiversity Targets 14 and 15). The One Health[49] approach, which recognizes the connectedness of human health with the health of our planet, can help address humanitarian, plant, animal and environmental issues simultaneously. This would require parallel transformations in the work programme of the Global Taxonomy Initiative towards supporting effective management of all types of ecosystems, wildlife regulation, addressing invasive alien species and other cross-cutting issues under the Convention on Biological Diversity.

Science-policy interface

IPBES undertakes various assessments on biodiversity and ecosystem services. The information generated and accumulated at taxonomic institutions, and field-based biodiversity research data, provide important baseline data for undertaking these assessments. Supporting the participation of their respective national governments in each of the assessments should be considered a priority action for all taxonomic institutions. IPBES also supports capacity development through the Biodiversity and Ecosystem Services Network (BES-Net) in line with the themes of IPBES global assessments and using the guidance developed through the platform. Engagement with IPBES through the Europe & Central Asia Network of organisations engaging in IPBES (ECA-Network) also aims to link national platforms working on IPBES-related issues and to facilitate knowledge and resource sharing. Establishing communication with the IPBES national focal points and IPBES registered experts[50] is advised so that the GTI community can be more fully engaged in the IPBES assessments and other activities.

Climate change

Climate change is a major and increasing driver of habitat degradation and transformation (e.g. desertification) and thus biodiversity loss. Projections of future climates suggest combinations of increased average temperatures, decreased permafrost, changes in the global water

49 https://www.cdc.gov/onehealth/index.html.
50 https://www.ipbes.net/experts.

cycle, increasing ocean acidity and rising sea levels, continued loss of polar ice and montane glaciers, and altered weather patterns, including changes in the frequency and severity of extreme events. Biodiversity research has a key role in these areas, for example as field identification of species is implicit in long-term observation studies (migration, population change, altered competition with alien species, release of dormant microorganisms etc.). Close collaboration with broad sectors exists and should be expanded to also include biological invasion risk assessment, disease risk assessment, extinction risk assessment, and promotion of the results of science-based assessments to policymakers. Diverse ecosystems and habitats can contribute to climate change adaptation, mitigation, and disaster risk reduction (DRR) and thus increase the resilience of biodiversity on Earth. Close collaboration with taxonomic institutions to select potential crop species, pollinators and other useful organisms that may be resilient to climate change would be vital to mitigate impacts of climate change and for global food production and security.

VII. Examples of Capacity Development Activities

In response to recommendation 23/6 of the Subsidiary Body on Scientific, Technical and Technological Advice, this section reviews the effectiveness of taxonomic capacity-building activities undertaken in the past decade and proposes the renewal of effective activities for the Global Taxonomy Initiative 2021-2030 (see annex 11 for examples).

international BARCODE OF LIFE

The International Barcode of Life Consortium

The Secretariat, in collaboration with the International Barcode of Life (iBOL) Consortium implemented a capacity development programme in 2015-2020. Briefly, the programme took a "train-the-trainers" approach that began with an online training course on basic DNA barcoding and hands-on laboratory training (2015-2016) and project development training (2017). Back home, the trained trainers then implemented regional or national training courses in ten developing countries (2018).[51] By the end of 2018, a total of 195 trainers were working in developing countries with 166 new trainers from 91 institutions. In 2019 and 2020, the programme introduced metabarcoding techniques and was extended further to include border control officials in the Latin American and Caribbean Group (GRULAC). For the period 2021-2030, the Secretariat may work with established and new partners, including iBOL, CETAF and GBIF, to provide "train-the-trainers" courses on biodiversity data mobilization, basics of taxonomy, DNA barcoding and metabarcoding.

GBIF

The Global Biodiversity Information Facility

The Global Biodiversity Information Facility (GBIF) is an international network and data infrastructure aimed at providing free and open access to biodiversity data. The Capacity Enhancement Support Programme (CESP) of GBIF supports capacity-building initiatives to enhance long-term capacity at the regional and global levels to enable effective mobilization and use of biodiversity information. GBIF also leads Biodiversity Information for Development (BID),[52] a multi-year programme funded by the European Union with the aims of enhancing capacity for effective mobilization and use of biodiversity data in research and policy, covering nations of sub-Saharan Africa, the Caribbean, and the Pacific. The BID programme has supported capacity enhancement activities and projects to mobilize biodiversity data and strengthened national and regional biodiversity information facilities in these regions, particularly in connection with protected areas, threatened species and invasive alien species.

ASEAN CENTRE FOR BIODIVERSITY

The ASEAN Centre for Biodiversity

The ASEAN Centre for Biodiversity has been working in partnership with Japan since 2010 to strengthen taxonomic capacities in the ASEAN region, with funding support from the Japan-ASEAN Integration Fund. Seven GTI projects were implemented in the ASEAN region from

51 CBD/SBSTTA/23/INF/18.
52 https://www.gbif.org/programme/82243/bid-biodiversity-information-for-development.

2010 to 2020, namely: (a) expanded taxonomic capacity-building and governance for conservation and sustainable use of biodiversity; (b) extended taxonomic capacity-building for sustainable use of biodiversity: bryophytes, pteridophytes, and economically important insects; (c) ASEAN Heritage Parks development through capacity enhancement and information development; (d) development of the GTI regional action plan for South-East Asia 2016–2020 and capacity development on the taxonomy of high elevation vascular plants; (e) improving biodiversity conservation of wetlands and migratory waterbirds in the ASEAN region; (f) and improving management effectiveness of the ASEAN Heritage Parks through capacity development and biodiversity information management.

To enhance information sharing and data integration at national, regional, and international levels, the ASEAN Centre for Biodiversity (ACB) maintains the ASEAN Clearing-House Mechanism (CHM),[53] a regional platform for sharing biodiversity information that supports biodiversity-related decision-making of the ASEAN member States (AMS), reporting commitments to multilateral environmental agreements, and policy development needs. The ASEAN CHM contains a number of databases significant to taxonomy. The ACB Species Database currently holds 54,132 records of ASEAN species. The Endemic and Native Species in the ASEAN Region page was developed in 2018 and now holds 14,093 records. The Invasive Alien Species (IAS) Prevention and Management database contains information on modes of IAS introduction. As of April 2020, the ACB has published 77 IAS factsheets with information gathered from the Centre for Agriculture and Bioscience International (CABI) and the Global Invasive Species Database. A total of 28 research references on the effectiveness of biological control in managing invasive weeds have been uploaded to the ASEAN IAS website.[54]

The Consortium of European Taxonomic Facilities

With the aim of promoting training, research and understanding in systematic biology and palaeobiology as well as facilitating access to information (collections) and the taxonomic expertise of its member institutions across Europe, the Consortium of European Taxonomic Facilities (CETAF) acts as a regional taxonomy hub. As the first European network of natural science museums, natural history museums, botanical gardens and biodiversity research centres, with their associated biological collections and research expertise, it has focused on connecting taxonomists and promoting taxonomy inside and outside Europe for over 20 years. CETAF oversees the Distributed European School of Taxonomy (DEST), where young researchers, citizen scientists and users of taxonomic knowledge are trained in taxonomic techniques, field and identification skills, collections management, the use of digitization tools for collections, taxonomic skills and nomenclature etc. CETAF also promotes taxonomic publishing under FAIR publishing principles and adopting progressive publishing in a machine-readable format via the European Journal of Taxonomy.

Numerous projects have been undertaken to help overcome or to remove the taxonomic impediment, regionally and globally. While many projects have been successfully completed and achieved their respective goals during the first 20 years of the GTI, many more need to be continued or renewed in order to reach their declared goals and have a lasting impact.

53 http://chm.aseanbiodiversity.org/.
54 http://chm.aseanbiodiversity.org/invasivealienspecies/

The participants in the GTI Forum highlighted the importance of the following activities for successful and sustainable GTI projects, in particular for capacity development:

(a) Enhanced and sustained taxonomy training that meets the recipient countries' conservation goals and national policies on biodiversity (i.e. national biodiversity strategies and action plans);

(b) Coordination of national and regional projects to scale up the training activities to meet global goals;

(c) Close communication with the national governments, especially through GTI national focal points, is essential to align projects to national biodiversity policies and implementation;

(d) Infrastructure sharing and development are important to apply advanced technologies in developing countries in the longer term;

(e) Shared credit, co-working and co-authorship to build strong trust among participating organizations and individuals;

(f) Career development support should be increased for young taxonomists;

(g) Involvement of local communities to generate and use taxonomic information for local conservation aligned with the national conservation policy;

(h) Long-term funding to sustain the technical capacities attained through trainings and workshops is critically important for developing countries.

VIII. Resources and Collective Support

The GTI Forum showcased numerous examples of best practices for reducing the taxonomic impediment in developing countries through international collaborations. Annex 11 includes examples of projects supported through international financial mechanisms in various parts of the world. Some funding mechanisms are summarized below.

Global Environment Facility

The Global Environment Facility (GEF) is the official financial mechanism for the implementation of the Convention on Biological Diversity.[55] The GTI programme of work explicitly indicated that this resource can be used for the activities of taxonomic capacity development, although the formulation of national projects requires coordination between the implementing agency and the national government. The GEF supports the GTI in a number of ways, including through global initiatives such as multilateral environmental agreements (for instance in support of globally important biomes, e.g., in the Amazon, Congo Basin and the Borneo Forests), and through stand-alone capacity-building programmes on taxonomy and other capacities necessary for Parties to implement national biodiversity policies (i.e., national biodiversity strategies and action plans). For example, Uganda has an ongoing project on the "Development of a National Clearing-House Mechanism and Capacity Assessment for Taxonomy and Indigenous Knowledge," while Mozambique is carrying out the project, "Development of the National Clearing-House Mechanism and Capacity Assessment for ABS and Taxonomy," under the GEF portfolio. As of 2020, numerous GEF projects on the management of invasive alien species with elements of application of taxonomic tools had been approved as project concepts or were already entering implementation, in Argentina, Cameroon, the Caribbean, Chile, Cuba, Fiji, Indonesia, Mexico, Pacific islands, Seychelles, Sri Lanka and Turkey.

The inclusion of taxonomy-related components in the formulation of GEF projects is critically important for successful project implementation, ensuring accurate hazard identification and risk analyses on invasive alien species, agricultural pests or pathogenic agents. Often countries do not have their own expertise, so international collaboration with expert organizations must take place. It is important that the sustainability of the capacity development activities is clear at an early stage of the project formulation in these cases. GTI national focal points have important roles to play here, particularly in the communication of the scientific aspects related to GEF projects and they are essential to ensure that the technical capacity conveyed through international support will remain and continue after project completion. To be fully harnessed to support the GTI work programme, GEF would require a more systematic way of developing project proposals through closer coordination between the GTI and GEF focal points at the national level and in line with the national biodiversity strategies and action plans.

Bilateral development assistance

Official development assistance (ODA) with promotion of economic development and welfare of developing countries may include biodiversity-related programmes. For instance, collaboration between Germany and South-East Asia (Cambodia, Indonesia, Philippines and Viet Nam) supported activities in discovering

55 Countries may be eligible for GEF funding in one of two ways: (a) if the country has ratified the conventions the GEF serves and conforms with the eligibility criteria decided by the Conference of the Parties of each convention; or (b) if the country is eligible to receive World Bank (IBRD and/or IDA) financing or if it is an eligible recipient of UNDP technical assistance through its target for resource assignments from the core (specifically TRAC-1 and/or TRAC-2). See also http://thegef.org/.

biodiversity with standard taxonomic workflows, technology transfer and infrastructure development for specimen collections to enable biodiversity monitoring. The projects funded by those ODA flows are effective for infrastructure development and associated scientific collaboration and trainings.

Bilateral support for science, technology and education also exists to enhance research and educational capacity in developing countries. For example, collaboration between the United Kingdom and Nepal builds trust among scientists through co-working and co-authorship of publications. Such projects further extended the collaboration with expert organizations and lead to multilateral collaborations in the long term.

The Belgian GTI focal point,[56] housed at the Royal Belgian Institute of Natural Sciences, carries out several GTI-related activities with support of the Belgian Development Cooperation. Through the Capacities for Biodiversity and Sustainable Development (CEBioS) programme, institutions and individuals from developing countries in need of taxonomic and curatorial training have received funding and support for taxonomy-based projects. These projects not only strengthen partnerships and increase the curatorial capacity of developing countries but are enhancing the exchange between scientists and policymakers through the production of policy briefs.

National and international project funds

Coordinated research networks focusing on certain thematic areas, such as BIOSCAN, the Global Flora Project and participating organizations like the Group on Earth Observations Biodiversity Observation Network (GEO BON) or GBIF are mostly dependent on their national and international research project funds. Collectively, participating organizations cover the cost of activities within the shared goals and objectives of the networks. The strength of coordinated research networks is their shared expertise and standardized methods to compile data on a global scale, which facilitates funding opportunities, regardless of their geographic region or level of economic development.

56 http://www.taxonomy.be/.

IX. Support for Monitoring the Status of Biodiversity and Progress in the Implementation of the Post-2020 Global Biodiversity Framework

This section connects the Global Taxonomy Initiative, and its proposed activities in 2021-2030, to the post-2020 global biodiversity framework. For instance, for the development of indicators, the GTI community can contribute substantively with provision of species data accumulated in taxonomic institutions and global biodiversity information platforms, e.g. Global Biodiversity Information Facility, Barcode of Life Data systems, among others.

Proposed GTI actions in 2021-2030 in support of the post-2020 global biodiversity framework

Table 1 below summarizes the many potential contributions that GTI actions and activities can make in support of the post-2020 global biodiversity framework. Table 2 presents indicators proposed by participants in the GTI Forum in support of post-2020 goals and targets.

Table 1. Summary of the potential contributions of actions of the Global Taxonomy Initiative.[57]

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 1. By 2030, [50%] of land and sea areas globally are under spatial planning addressing land/sea use change, retaining most of the existing intact and wilderness areas, and allow to restore [X%] of degraded freshwater, marine and terrestrial natural ecosystems and connectivity among them.	Identification of intact and degraded ecosystems based on the data accumulated in natural history collections and species occurrences in biodiversity observation networks	**ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 6** Fund-raising and career programme development at all levels.	Species occurrence data provides the information on biodiversity status in the past and present, which supports identification of targeted areas of restoration. Natural history collections provide a trusted source of such data to set baselines to measure degrees of restoration. They are also vital in providing data on well-documented voucher specimens which serve as key indicator species for the monitoring.

57 Column 1 targets are from the "Update of the zero draft of the post-2020 global biodiversity framework" dated 17 August 2020 (CBD/POST2020/PREP/2/1) and are subject to revision.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 2. By 2030, protect and conserve through well-connected and effective system of protected areas and other effective area-based conservation measures at least 30 per cent of the planet with the focus on areas particularly important for biodiversity.	Support species observation in protected areas to apply area-based conservation measures with close collaboration with the national Governments to identify important areas for conservation based on fauna and flora data	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Fauna and flora data provides baseline data for conservation and identification of priority areas. Taxonomic experts can support the Governments on evidence-based conservation priority selection and long-term monitoring of species, populations and interactions to manage protected areas.
Target 3. By 2030, ensure active management actions to enable wild species of fauna and flora recovery and conservation, and reduce human-wildlife conflict by [X%].	Advising and refining indicators of wild species recovery	**ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Temporal data on fauna and flora, and species occurrences are necessary to inform conservation.
Target 4. By 2030, ensure that the harvesting, trade and use of wild species of fauna and flora is legal, at sustainable levels and safe.	Taxonomic identification at the borders to intercept illegal export and import of wild species	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	With enhanced collaboration between the border authorities and taxonomic institutions identification of illegal trade can be recorded and monitored. DNA and stable isotope technologies to rapidly identify species can support and improve identification accuracy in this area of work.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 5. By 2030, manage, and where possible control, pathways for the introduction of invasive alien species, achieving [50%] reduction in the rate of new introductions, and control or eradicate invasive alien species to eliminate or reduce their impacts, including in at least [50%] of priority sites.	Taxonomic identification to monitor and record new introductions, pathways and impact of invasive alien species	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 2** Information infrastructure development, including literature.	Taxonomic identification services and training on DNA based taxonomic identification to relevant sectors (at the border or post border management authorities) can support cost-effective monitoring on invasive alien species and their impacts.
Target 6. By 2030, reduce pollution from all sources, including reducing excess nutrients [by x%], biocides [by x%], plastic waste [by x%] to levels that are not harmful to biodiversity and ecosystem functions and human health.	Support for monitoring the effect of pollution by advising and observing indicator species in the fields	**ACTIVITY 2** Information infrastructure development, including literature.	Selection of environmental indicator taxa as model organisms for monitoring programmes using species occurrence records and appropriate interpretation of their population trends can only be realised with the collaboration of experts in taxonomy and ecology.
Target 7. By 2030, increase contributions to climate change mitigation adaptation and disaster risk reduction from nature-based solutions and ecosystems based approaches, ensuring resilience and minimizing any negative impacts on biodiversity.	Support for identifying species, genotypes and phenotypes resilient to and/or at risk of climate change-related disruptions.	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 3** Project formulation to enhance research on biodiversity, including disease vectors, pests, invasive alien and threatened species. **ACTIVITY 4** Education in taxonomy for broad sectors, with match-making. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Identifying species and genotypes at risk of environmental disruptions can help inform their conservation. The identification of resilient species can help direct future conservation and disaster risk reduction measures.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 8. By 2030, ensure benefits, including nutrition, food security, livelihoods, health and well-being, for people, especially for the most vulnerable through sustainable management of wild species of fauna and flora.	Support for monitoring on wild species that are important for nutrition, food security, livelihoods, health and well-being with participation of local communities	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 4** Education in taxonomy for broad sectors, with match-making.	Based on the accumulated citizen science best practices, participatory monitoring, recording and reporting on local biodiversity by local communities can be facilitated with training and workshops on species observation and identification.
Target 9. By 2030, support the productivity, sustainability and resilience of biodiversity in agricultural and other managed ecosystems through conservation and sustainable use of such ecosystems, reducing productivity gaps by at least [50%].	Advising on agricultural species and wild relatives for conservation and sustainable use in agriculture and management of ecosystems	**ACTIVITY 4** Education in taxonomy for broad sectors, with match-making. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Collections of organisms, seeds, tissues and microorganisms, with the accumulated knowledge related to them, can provide sound advice on reducing productivity gaps when they are deposited in publicly accessible natural history collections or biobanks.
Target 10. By 2030, ensure that, nature-based solutions and ecosystem approach contribute to regulation of air quality, hazards and extreme events and quality and quantity of water for at least [XXX million] people.	Supporting effective monitoring of air and water quality by using indicator species and providing advice on biological hazard identification	**ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Taxonomic experts can advise on the selection of indicator taxa and support identification of biological hazard materials. Ideally, this would include well-documented voucher specimens (e.g. curated by GTI partner institutions) which serve as model organisms for the monitoring.
Target 11. By 2030, increase benefits from biodiversity and green/blue spaces for human health and well-being, including the proportion of people with access to such spaces by at least [100%], especially for urban dwellers.	Advising on appropriate indicator taxa to identify space for human health and well-being	**ACTIVITY 4** Education in taxonomy for broad sectors, with match-making.	Taxonomic experts can advise on the selection of indicator taxa that supports quality control on green/blue spaces for human health and well-being. Ideally, this would include well-documented voucher specimens (e.g. curated by GTI partner institutions) which serve as model organisms for the monitoring.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 12. By 2030, increase by [X] benefits shared for the conservation and sustainable use of biodiversity through ensuring access to and the fair and equitable sharing of benefits arising from utilization of genetic resources and associated traditional knowledge.	Non-monetary benefit-sharing through non-commercial research collaboration on biodiversity	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 3** Project formulation to enhance research on biodiversity, including disease vectors, pests, invasive alien and threatened species. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users. **ACTIVITY 7** Fund-raising and career programme development at all levels.	International collaboration in scientific research, capacity development and career opportunities for young taxonomists from biodiversity-rich developing countries provide enormous non-monetary benefits to the scientific communities in the provider countries to develop own taxonomic knowledge, skills and expertise in these countries.
Target 13. By 2030, integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies and accounts at all levels, ensuring that biodiversity values are mainstreamed across all sectors and integrated into assessments of environmental impacts.	Provision of knowledge on biodiversity and its ecological values in the ecosystems, habitats and species of the national interests and concerns	**ACTIVITY 4** Education in taxonomy for broad sectors, with match-making.	Biodiversity specimens, literature and knowledge exist in taxonomic institutions and these are made accessible via their networks, research activities and databases. Appropriate interpretations of biological entities given by experts provide basis of policies, regulations, planning etc.
Target 14. By 2030, achieve reduction of at least [50%] in negative impacts on biodiversity by ensuring production practices and supply chains are sustainable	Provision of evidence on impacts on biodiversity by human-activities	**ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 4** Education in taxonomy for broad sectors, with match-making.	Temporal and spatial data on biodiversity occurrences provide solid and reproducible evidence and analyses on the impacts of land-use change, climate change and other human interventions for Parties to consider in production practices and supply chains.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 15. By 2030, eliminate unsustainable consumption patterns, ensuring people everywhere understand and appreciate the value of biodiversity, and thus make responsible choices commensurate with 2050 biodiversity vision, taking into account individual and national cultural and socioeconomic conditions.	Provision of knowledge and evidence on biodiversity to select appropriate local production and consumption	**ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 4** Education in taxonomy for broad sectors, with match-making.	Fauna and flora related biodiversity data and associated knowledge inform Parties and local communities on uniqueness of biodiversity at the national and local levels and ensure that they consider their value in order to make sustainable decisions.
Target 16. By 2030, establish and implement measures to prevent, manage or control potential adverse impacts of biotechnology on biodiversity and human health reducing these impacts by [X].	Providing support for impact analyses on introduction of biotechnology products	**ACTIVITY 4** Education in taxonomy for broad sectors, with match-making. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Taxonomic identification of introduced genetic elements is supported by the provision of phylogenetic and biological information that can be provide by taxonomic experts.
Target 17. By 2030, redirect, repurpose, reform or eliminate incentives harmful for biodiversity, including [X] reduction in the most harmful subsidies, ensuring that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity.	Providing evidence on harmful land-use and impact on biodiversity for Parties to consider harmful incentives	**ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Temporal and spatial data on biodiversity occurrences provide information on impacts on biodiversity associated with land-use change. Multi-layered analyses of geographic distribution of biodiversity with different parameters also provides high resolution maps of impacted biodiversity.

Draft 2030 action targets for the post-2020 global biodiversity framework	Actions of the GTI community	Corresponding activities in figure 2	Rationale
Target 18. By 2030, increase by [X%] financial resources from all international and domestic sources, through new, additional and effective financial resources commensurate with the ambition of the goals and targets of the framework and implement the strategy for capacity-building and technology transfer and scientific cooperation to meet the needs for implementing the post-2020 global biodiversity framework.	Providing information on funds allocated to basic research on biodiversity, maintaining specimen collections and cost of capacity-building, technology transfer and scientific cooperation for Parties to monitor the progress on this target	**ACTIVITY 5** Capacity evaluation for biological collections. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Taxonomic institutions are the major actors in capacity-building, technology transfer and scientific cooperation through international collaborations. The actual financial resources from multilateral resources can be reported to respective Parties, with appropriate coordination.
Target 19. By 2030, ensure that quality information, including traditional knowledge, is available to decision makers and public for the effective management of biodiversity through promoting awareness, education and research.	Provision of quality information of biodiversity for analyses and promoting awareness, education and research Collection and collation of traditional knowledge on biodiversity with establishment of appropriate engagement of indigenous peoples and local communities	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 2** Information infrastructure development, including literature. **ACTIVITY 6** Communication among GTI national focal points, Governments, relevant bodies and users.	Taxonomic institutions (mostly natural history collections) are the providers of biodiversity information, public education opportunities and research outputs. Meeting this target is related to the core activities of the GTI community. Through the network of GTI national focal points, global progress on this target can be directly monitored and reported.
Target 20. By 2030, ensure equitable participation in decision-making related to biodiversity and ensure rights over relevant resources of indigenous peoples and local communities, women and girls as well as youth, in accordance with national circumstances.	Equitable participation of citizens to biodiversity observations at the local level	**ACTIVITY 1** Hands-on trainings for the application of taxonomic tools. **ACTIVITY 4** Education in taxonomy for broad sectors, with match-making. **ACTIVITY 7** Fund-raising and career programme development at all levels.	Promotion of citizen science in biodiversity observation is increasing within the GTI community. Participation of indigenous peoples and local communities is feasible and achievable, with appropriate co-working and co-learning processes. Promotion of women and young scientists is a common approach in the scientific community.

Table 2. Taxonomic indicators for the post-2020 global biodiversity framework, as proposed by GTI Forum participants/contributors. The text in the table is provided in the language submitted.

Target[58]	Suggested indicator	Proposed data source	Data providers
Meeting people's needs through sustainable use and benefit-sharing	Number of internationally recognized certificates of compliance (IRCC) registered	https://absch.cbd.int/search/nationalRecords	The Access and Benefit-sharing Clearing-House
	Number of type materials of new species deposited	Database of culture collections (CBS or similar)	Culture collections at national level
Goal A The area, connectivity and integrity of natural ecosystems increased by at least [X%] supporting healthy and resilient populations of all species while reducing the number of species that are threatened by [X%] and maintaining genetic diversity; Milestone 2: The number of species that are threatened is reduced by [X%] and the abundance of species has increased on average by [X%] Target 3: enable wild species recovery	Indicators in CBD/SBSTTA/24/3/Add.1 that taxonomists contribute to: A.0.5 The proportion of populations maintained within species;*A.4. Increase the population and health of species; A.5. Maintain genetic diversity; A.1.4. Red list index by species group (including terrestrial, freshwater and marine species); A.1.5. Number of species extinctions by species group (including for terrestrial, freshwater and marine species); A.1.6. Species habitat index by species group; A.1.7. The proportion of populations maintained within species (A.0.5) by species group. Other potential indicators taxonomists contribute to: Number/size of intact/wilderness areas identified using indicator species	GBIF, World Flora Online, IUCN Red Lists, reports under legal frameworks, e. g. in Europe: water framework directive, flora fauna habitat directive, INSPIRE directive and infrastructure	Data aggregators and providers to GBIF, such as natural history collections, Scientists worldwide and WFO council member institutions, Nature conservation authorities
Meeting people's needs through sustainable use and benefit-sharing. (i) Nature contributes to the sustainable diets and food security, access to safe drinking water and resilience to natural disasters for at least [X%] million people. (ii) Nature is valued through green investments, ecosystem service valuation in national accounts, and public and private sector financial disclosures.	Indicators in CBD/SBSTTA/24/3/Add.1 that taxonomists contribute to: B.1.1.1. Expected loss of phylogenetic diversity (IPBES phylogenetic diversity indicator); B.1.1.2. Red List Index (pollinating species); B.1.1.12. Change in the quality of inland water ecosystems over time; B.1.1.13. Change in the quality of coastal water ecosystems over time (see also point above on indicator species)	IUCN Red Lists Reports under legal frameworks, e. g. in Europe: water framework directive, flora fauna habitat directive, INSPIRE	Scientists worldwide

58 Column 1 shows targets/target areas, goals and/or milestones adapted/extracted from the updated zero-draft of the post-2020 global biodiversity framework (CBD/POST2020/PREP/2/1, 17 August 2020).

Target[58]	Suggested indicator	Proposed data source	Data providers
Means of implementation are available to achieve all goals and targets in the framework. 2030 Milestones: (i) By 2022, means to implement the framework for the period 2020 to 2030 are identified and committed. (ii) By 2030, means to implement the framework for the period 2030 to 2040 are identified or committed	D.2. Sufficient capacity-building, technology transfer and scientific cooperation; D.3. Access to technology; D.1.1.5. Number of scientists per population; D.1.1.6. Joint scientific papers published (in scientific journals, best open access) by sector; D.1.1.7. Number of marine monitoring stations; D.1.1.8 Number of water quality monitoring stations; Other potential indicators taxonomists contribute to: Number of collaborative research projects with the goal of discovering and/or sustainably using biodiversity	Clarivate analytics, Google scholar, FAIR Open Access publishing, databases of research funding organizations and patent databases	Researchers, developers, research funders
Implementation support mechanisms	Number of graduate and trained students per year; Number of trained trainers involved in national conservation programme/projects	Number of scientific publications; National reports (OIPR)	National universities (Université Jean Lorougnon Guédé, Université de Cocody, Université Nangui Abrogoua); National agencies (OIPR, SODEFOR)
	Number of national institutions and collections trained to share information	Increased number of species occurrences in the National Biodiversity Information System	Network of museums and collections in Brazil
Reducing threats to biodiversity	Number of introduced alien species per year	Invasive Species via Global Biodiversity Information Facility	The Global Invasive Species Information Partnership, IUCN-ISSG, GBIF
	Number of nationally threatened species in any year	IUCN/National evaluations	IUCN, Sweden
	Number of customs incidents involving CITES species	Swedish Customs Authority	Swedish Customs Authority
Virtual collections and database with link to: (a) Nucleotide sequence that was deposited in NCBI GeneBank and iBoL. (b) Malaysia Biodiversity Information System (MyBis), a one-stop repository for biodiversity information in Malaysia.	MyBis as the window to Malaysia biodiversity in support of the new information sharing platform, the Biodiversity Knowledge Alliance	UPM total collections (4 centres)	All Malaysian participating agencies and coordinated by Ministry of Energy and Natural Resources, Malaysia through their agency Forest Research Institute of Malaysia (FRIM) to maintain the database

Target[58]	Suggested indicator	Proposed data source	Data providers
By 2030, [50%] of land and sea areas globally are under spatial planning addressing land/sea use change, retaining most of the existing intact and wilderness areas, and allow to restore [X%] of degraded freshwater, marine and terrestrial natural ecosystems and connectivity among them.	Increase in area of terrestrial, freshwater and marine ecosystems under spatial planning Prevention of reduction and fragmentation of natural habitats due to land/sea use change Priority retention of intact/ wilderness areas Restoration of degraded ecosystems Maintenance and restoration of connectivity of natural ecosystems	Sustainable forest management (SDG indicator 15.2.1) Percentage of spatial plans utilising information on key biodiversity areas Habitat patches located within marine protected areas or integrated coastal zone management (ICZM) Index of Species Rarity Sites, High Biodiversity Areas, Large Mammal Landscapes, Intact Wilderness and Climate Stabilization Areas	Taxonomic input needed in Key Biodiversity Area designation and assessment and indices
By 2030, protect and conserve through well connected and effective system of protected areas and other effective area-based conservation measures at least 30 per cent of the planet with the focus on areas particularly important for biodiversity.	2.0.1 Protected area coverage of important biodiversity areas 2.0.2 Species Protection Index	Status of key biodiversity areas Protected area coverage of key biodiversity areas Protected area coverage of coral reefs IUCN Green List of Protected and Conserved Areas Species Protection Index	Species richness and distribution data needed to underpin KBAs and listings
By 2030, ensure active management actions to enable wild species of fauna and flora recovery and conservation, and reduce human-wildlife conflict by [X%].	3.0.2 Species recovery programmes Status of species captured in Goal A Proportion of conservation dependent species (IUCN Green Status of Species Index)	IUCN Green Status of Species Index by sub-indicators Changing status of evolutionary distinct and globally endangered species (EDGE Index) Percentage of threatened species that are improving in status	Taxonomic rigour needed in species assessments
By 2030, ensure that the harvesting, trade and use of wild species of fauna and flora is legal, at sustainable levels and safe.	4.0.1 Proportion of traded wildlife that is legal and safe (not poached, illicitly trafficked or unsustainable) 4.0.2 Proportion of fish stocks within biologically sustainable level	Proportion of traded wildlife that was poached or illicitly trafficked (T4.0.1) by species group Proportion of fish stocks within biologically sustainable levels (T4.0.2) by fish type Proportion of traded wildlife that was poached or illicitly trafficked (SDG indicators 15.7.1 and 15.c.1) The conservation status of species listed in the CITES Appendices has stabilized or improved Proportion of legal and illegal wildlife trade consisting of species threatened with extinction Illegal trade by CITES species classification The conservation status of species listed in the CITES Appendices has stabilized or improved	Indicators rely on availability of taxonomic expertise to identify organisms or organism parts.

Target[58]	Suggested indicator	Proposed data source	Data providers
By 2030, manage, and where possible control, pathways for the introduction of invasive alien species, achieving [50%] reduction in the rate of new introductions, and control or eradicate invasive alien species to eliminate or reduce their impacts, including in at least [50%] of priority sites	5.0.1 Rate of invasive alien species spread 5.0.2 Rate of invasive alien species impact	Numbers of invasive alien species introduction events An established alert system for prevention and control of IAS Rate of invasive alien species eradication by species type Red List Index (impacts of invasive alien species) Proportion of key biodiversity areas threatened by invasive alien species Number of invasive alien species in national lists as per the Global Register of Introduced and Invasive Species	It is necessary for all IAS monitoring and control that taxonomic identifications be available. Without GTI activity this will not be possible. Indicators will only be valuable if the taxonomy is done effectively
By 2030, ensure benefits, including nutrition, food security, livelihoods, health and well-being, for people, especially for the most vulnerable through sustainable management of wild species of fauna and flora	8.0.1 Number of people using wild resources for energy, food or culture (including firewood collection, hunting and fishing, gathering, medicinal use, craft making, etc.) 8.0.2 Percentage of the population in traditional employment Sustainable management of aquatic wild species of fauna and flora, including fisheries Sustainable management of terrestrial wild species of fauna and flora	Number of plant and animal genetic resources for food and agriculture secured in medium- or long-term conservation facilities (SDG indicator 2.5.1) Red List Index (species used for food and medicine)	For medicinal plants identifications to know what is being harvested are important.
By 2030, support the productivity, sustainability, and resilience of biodiversity in agricultural and other managed ecosystems through conservation and sustainable use of such ecosystems, reducing productivity gaps by at least [50%].	Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities	Red List Index (wild relatives of domesticated animals) Red List Index (pollinating species) Proportion of local breeds classified as being at risk of extinction	There are a number of studies including taxonomy to understand pollinator roles and vulnerabilities.

Target[58]	Suggested indicator	Proposed data source	Data providers
By 2030, increase by [X] benefits shared for the conservation and sustainable use of biodiversity through ensuring access to and the fair and equitable sharing of benefits from the utilization of genetic resources.	12.0.1 Numbers of users that have shared benefits from the utilization of genetic resources and/or traditional knowledge associated with genetic resources with the providers of the resources and/or knowledge 12.0.2 Number of access and benefit-sharing permits or their equivalent granted for genetic resources (including those related to traditional knowledge) 12.0.3 Extent to which legislative, administrative or policy frameworks to ensure fair and equitable sharing of benefits have been adopted		Taxonomy is greatly involved in non-monetary benefit-sharing, and is a major contributor to these indicators, or others that may be developed in this area. GTI activities are of central importance for the delivery of these non-monetary benefits
By 2030, ensure that quality information, including traditional knowledge, is available to decision makers and public for the effective management of biodiversity through promoting awareness, education and research.	19.0.1 Biodiversity information index	Biodiversity information index by type of information Species Status Information Index Biodiversity Barometer Growth in species occurrence records accessible through GBIF Growth in number of records and species in the Living Planet Index database Growth in marine species occurrence records accessible through OBIS Proportion of known species assessed through the IUCN Red List Number of assessments on the IUCN Red List of threatened species GBIF/ Catalogue of life In country networks National reports	These all depend on taxonomic input and baseline data provided by taxonomy. GBIF records are to a great extent aggregated and delivered by taxonomic institutions worldwide Countries with access to updated national species level inventories Countries with completed taxonomic needs assessments Input from taxonomic authorities mediated through GBIF/Catalogue of Life; in country mechanisms GTI focal points
(a) Reducing threats to biodiversity	Growth in species occurrence records accessible through GBIF	GBIF database, but also IUCN red Lists, local assessments in conservation areas	GBIF and connected databases
(b) Meeting people's needs through sustainable use and benefit-sharing	Red List Index – pollinating species (Trends in species that provide essential services (pollinators))	Red List Index (pollinating species)	IUCN and BirdLife International

Target[58]	Suggested indicator	Proposed data source	Data providers
(a) Reducing threats to biodiversity or (b) Meeting people's needs through sustainable use and benefit-sharing	Crop Wild Relative Index (under development) (Trends in the diversity of wild relatives)	Crop Wild Relative Index	Alliance Biodiversity and CIAT & IUCN/CW RSG
(c) Tools and solutions for implementation and mainstreaming	Number and quality of science-policy interface workshops and "fairs/expos" facilitating the exchange of the latest knowledge and developments relevant to taxonomy and biodiversity	Official reports	CSP, IPBES, BES-Net, etc.
Measure growth in species occurrence / availability of biodiversity-related information	Completeness of the world's species catalogue	Zoological Record; Catalogue of Life; International Barcode of Life, BOLD. National Biodiversity reports, NSBAPs & IUCN Red Listings. Baseline: 1970 – annually	
Trends in the diversity of wild species	Completeness of the world's species catalogue	e.g. GBIF, INSDC, BOLD records. Baseline: 1970 – annually.	
Simplified access under Nagoya Article 8a for non-commercial research stimulating research and capacity-building	NP-parties have implemented simplified measures on access for non-commercial research purposes under Article 8a	National focal points; Baseline: 2014 – annually	
Trends in the non-commercial utilization of genetic resources	The increase to access to scientific information relevant to conservation and sustainable use of biological diversity, including biological inventories and taxonomic studies	e.g. INSDC databases or BOLD systems; Baseline: 2014 – annually	
Increases in collaboration, cooperation and professional relationships arising from access and benefit-sharing agreements and subsequent collaborative activities	Trends in the benefits from the access to genetic resources shared	Increased number of joint authorships, annual increase of national research funding programmes directed to CBD / SDG targets such as regional EU-ECOFAC programmes, major research programmes like H3Africa, BIOTA-Africa, IndoBioSys, specific funding schemes (e.g. Programme Advocating Women Scientists), direct scholarships (e.g. DAAD, Humboldt grants but also grants from Providing Countries to support travels of own scientists abroad), programmes realised under the GTI of the SCBD, but also bilateral reports to CNAs of provider countries that could be included in national reporting to the SCBD. Baseline: 2018 – annually.	

Target[58]	Suggested indicator	Proposed data source	Data providers
Trends in the financial resources allocated to basic research infrastructures engaged in biodiversity research. Trends in the mobilization financial resources allocated for the public research sector on national level	Annual national or federal basic funding for research infrastructures as part of the GDP	National data on allocated annual funding (cf. suitability of existing BIOFIN and/or OECD-metrics for potential conversion). Baseline: 2014 - annually	
Increased accessibility to objects and related information (as this is key not only for many post-2020 goals, targets and indicators, but also for AICHI Targets 19 & 9 and SDGs 14 & 15)	Number of specimens accessible in ex situ facilities has increased	Annual increase of specimen records of ex situ facilities. Baseline: 2014 – annually	
	Number of data sets published by ex situ facilities through data aggregators such as INSDC databases, BOLD or GBIF accessible has increased.	Increased data sets on data platforms such as INSDC, BOLD or BOLD. Baseline: 1970 – annually	

X. Conclusions

Taxonomy is the fundamental scientific discipline that delivers fundamental data on biodiversity and essential baseline data for biodiversity monitoring. It is thus key for its discovery and understanding of biodiversity. Without this key data and the taxonomic expertise that generates and aggregates it, the attainment of the goals of the post-2020 global biodiversity framework is impossible. In the past decade, significant progress on Aichi Biodiversity Target 19 (and towards 9 and 11) was closely linked with activities of the GTI. For the successful monitoring of the post-2020 indicators, dedicated action is needed to maintain and increase this taxonomic expertise, and to support the many innovations enabling unprecedented discovery of the Earth's biodiversity as well as to promote the sharing of data and information to support conservation and sustainable development.

Because of its crucial role, taxonomy must be recognized and fully integrated into all components of the post-2020 global biodiversity framework, including its 2030 action targets and implementation support mechanisms – especially the capacity development, technical and scientific cooperation, and knowledge generation.

Increased capacity in taxonomy is critical to the successful implementation of the post-2020 global biodiversity framework. This includes support for developing taxonomic infrastructures and capacities in all countries and regions, and for ensuring that such skills are passed to future generations, to underpin and enhance the understanding of biodiversity in all places on Earth. Increased investment in education, training and career opportunities in taxonomy is urgently needed to prevent an overall decline in taxonomic research, expertise and knowledge.

Innovative and emerging technologies provide unprecedented opportunities for taxonomy in generating and sharing knowledge about the biosphere. Such opportunities include:

(a) Harnessing the immense knowledge base accumulated in natural history collections of all sizes and in all regions, through digitization and sharing of data on preserved specimens using common standards to enable universal discovery, access and use;

(b) Generation and sharing of data arising from technological improvements in genetic sequencing of organisms in nature, for example through environmental metagenomics, enabling planetary-scale understanding of species, surveillance of their dynamics, and acceleration of species discovery;

(c) Providing digital access to taxonomic literature and associated archives, through both digitization of historic materials and rapid integration of newly published taxonomic discoveries and treatments into the global knowledge base;

(d) Engagement of citizens, indigenous peoples and local communities in observation and documentation of evidence on biodiversity occurrence in space and time, through bringing together volunteer networks, taxonomic expertise and user-friendly applications to register, share and access biodiversity data; thereby encouraging bio-literacy and public participation in conservation and sustainable use of biodiversity;

(e) Enabling conservation of all branches of the Tree of Life as an essential component of addressing biodiversity loss, by recognizing the evolutionary framework underlying taxonomy, and incorporating phylogenetic and systematics information with spatial data on species distribution and occurrences;

(f) Enabling improved management, assessment, and surveillance in order to prevent negative impacts on biodiversity and human well-being, including through improved biosecurity measures.

The goals of the post-2020 global biodiversity framework will only be realized through active and effective collaborations and connections among relevant taxonomic initiatives at all scales worldwide.

The existing networks of experts together with active GTI national focal points have made successful cases of technical and scientific cooperation and capacity-building. Well informed and shared conservation goals of the training recipient countries resulted in attainment of technologies and skills and increased the national capacity rapidly and sustainably.

Taxonomy is an essential and vital component of the programmes for technical and scientific cooperation under the CBD. The GTI community is committed to engaging fully with the Parties to the CBD in the post-2020 global biodiversity framework, building on its network of national focal points and partners.

Abbreviations

ACB: ASEAN Centre for Biodiversity
AMS: ASEAN member States
ASEAN: Association of Southeast Asian Nations
BES-Net: Biodiversity and Ecosystem Services Network
BHL: Biodiversity Heritage Library
BID: Biodiversity Information for Development
BLR: Biodiversity Literature Repository
BOLD: Barcode of Life Data System
CABI: Centre for Agriculture and Bioscience International
CBD: Convention on Biological Diversity
CEBioS: Capacities for Biodiversity and Sustainable Development
CETAF: Consortium of European Taxonomic Facilities
CHM: clearing-house mechanism
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
DDBJ: DNA Data Bank of Japan
DEST: Distributed European School of Taxonomy
DRR: disaster risk reduction
ECA-Network: Europe and Central Asia Network
EMBL: European Molecular Biology Laboratory
ENA: European Nucleotide Archive
EOL: Encyclopedia of Life
ESABII: East and Southeast Asia Biodiversity Information Initiative
FAIR: findable, accessible, interoperable, retrievable data principles
GBF: global biodiversity framework
GBIF: Global Biodiversity Information Facility
GBO: Global Biodiversity Outlook
GEF: Global Environment Facility
GEO BON: Group on Earth Observations Biodiversity Observation Network
GGBN: Global Genome Biodiversity Network
GRULAC: Group of Latin America and Caribbean Countries
GSPC: Global Strategy for Plant Conservation
GTI: Global Taxonomy Initiative
IAPT: International Association for Plant Taxonomy
IAS: invasive alien species
iBOL: International Barcode of Life Consortium
IMO: International Maritime Organization
INSDC: International Nucleotide Sequence Database Collaboration
IPBES: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPEN: International Plant Exchange Network
IPNI: International Plant Names Index
IPPC: International Plant Protection Convention
JAIF: Japan ASEAN Integration Fund
LIPI: Lembaga Ilmu Pengetahuan Indonesia
LUCAS: European Land Use and Coverage Area frame Survey
MEA: Millennium Ecosystem Assessment
MOE: Ministry of the Environment
NBSAPs: national biodiversity strategies and action plans
NFP: national focal point
OCR: optical character recognition
ODA: official development assistance
PCR: polymerase chain reaction
qPCR: quantitative polymerase chain reaction
SDG: Sustainable Development Goal
TENs: Taxonomic Expert Networks
WFO: World Flora Online

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ANNEX 1

GTI Forum 2020 programme of speakers (Days 1 and 2)

GTI FORUM 2020 SPEAKERS AND PRESENTATIONS[59]

Recording time (hr:min:sec)	Title	Speaker	Affiliation
DAY 1:[60] 2 December 2020 — Symposium – Best practices and challenges of the Global Taxonomy Initiative in achieving the Aichi Biodiversity Targets			
0:00 – 7:11	Opening remarks	Elizabeth Maruma Mrema	Executive Secretary of the Convention on Biological Diversity (SCBD)
8:00 – 11:59	Welcoming remarks	Ralf Becker	Deputy Head of Division, International Cooperation on Biodiversity, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany
12:34 – 14:51	Welcoming remarks	Toshio Torii	Director-General of the Nature Conservation Bureau of the Ministry of the Environment of Japan
28:27 – 43:56	*BIOSCAN – Towards an Earth Observing System for Species*	Paul Hebert	University of Guelph, Director of the Centre for Biodiversity Genomics in Canada; International Barcode of Life Consortium (iBOL)
44:40 – 1:02:23	Research and collection based taxonomic capacity-building in SE Asia – lessons drawn and future perspectives	Thomas von Rintelen	Museum für Naturkunde; Leibniz Institut for Evolution and Biodiversity Science, Germany
DAY 2:[61] 3 December 2020 — Workshop I – Global Taxonomy Initiative 2021-2030 activities to support the achievement by Parties of the post-2020 global biodiversity targets and the global biodiversity framework			
0:00 – 8:44	Findings of the fifth edition of the *Global Biodiversity Outlook* and advice on capacity development in taxonomy	Tim Hirsch	Global Biodiversity Information Facility (GBIF)
9:28 – 17:32	Application of DNA barcoding and meta-barcoding in conservation and sustainable use of biodiversity	Donald Hobern (on behalf of Paul Hebert)	International Barcode of Life Consortium (iBOL)
17:44 – 25:13	The Consortium of European Taxonomic Facilities (CETAF): a collaborative network for collections and taxonomy	Michelle Price	Consortium of European Taxonomic Facilities (CETAF); International Association for Plant Taxonomy (IAPT); Conservatory and Botanical Garden of Geneva, Switzerland
25:52 – 33:36	In support of achievement of post-2020 biodiversity targets: achievements and further needs in Africa	Ramagwai Sebola	Chief Director, Foundational Biodiversity Science at the South African National Biodiversity Institute (SANBI)
34:05 – 39:12	Good practices and recommendations from the Belgian GTI focal point	Jolien Vennemann	Science Programme Officer, Royal Belgian Institute of Natural Sciences
40:01 – 48:36	BioAlfa in Costa Rica	Daniel Janzen	University of Pennsylvania; Technical Advisor to Area de Conservación Guanacaste, Costa Rica
48:59 – 52:48	GTI in the Bahamas	Ethan Freid	Bahamas National Trust and Leon Levy Native Plant Preserve, Bahamas

59 For presentation recordings and slides, see https://www.cbd.int/article/the-global-taxonomy-initiative-forum-2020.
60 Recordings for Day 1: Symposium YouTube link.
61 Recordings for Day 2: Workshop I YouTube Link.

DAY 2:[62] 3 December 2020 **Workshop I – Global Taxonomy Initiative 2021-2030 activities to support the achievement by Parties of the post-2020 global biodiversity targets and the global biodiversity framework**			
53:01 – 1:01:03	World Flora Online, building a taxonomic resource in global partnership	Thomas Borsch	Botanical Garden and Botanical Museum Berlin; Free University Berlin, Germany
1:01:35 – 1:07:05	Catalogue of species in Mexico: National Biodiversity Information System	Diana Hernández	Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Mexico
1:07:30 – 1:19:15	GTI 2021-2030 activities to support the achievement by Parties of the post-2020 biodiversity targets and the global biodiversity framework	Hai-ning Qin	Institute of Botany, Chinese Academy of Sciences, China
1:19:42 – 1:24:34	Training a new generation of biosystematists to meet society's needs for biodiversity expertise	Hugo de Boer	Natural History Museum, University of Oslo, Norway
1:24:56 – 1:27:56	Taxonomy initiative in Viet Nam	Ta Thi Kieu Anh	Biodiversity Conservation Agency, Vietnam Environment Administration, Ministry of Natural Resources and Environment, Viet Nam
1:28:27 – 1:36:21	GTI experiences from the UK	Mark Watson	Royal Botanic Garden Edinburgh, United Kingdom
Slides[63]	Biodiversity in Turkmenistan	Aleksandr Aleksandrovich Shestopal	Centre for Prevention of Dangerous Infections, Ministry of Health and Medical Industry of Turkmenistan, Turkmenistan
Slides[63]	Morocco's efforts in taxonomy	Mohammed Sghir Taleb	Institut Scientifique, Mohammed V University in Rabat, Morocco

62 Recordings for Day 2: Workshop I YouTube Link.
63 Due to technical difficulties, recordings are not available for these presentations.

ANNEX 2

GTI Forum Statement

Call for action on recognizing the critical role of taxonomy to underpin transformative change within the post-2020 global biodiversity framework[64]

The participants in the Global Taxonomy Initiative (GTI) Forum, held from 2-4 December 2020, agree with the following statement, addressed to CBD Parties and relevant stakeholders involved in drafting and implementation of the post-2020 global biodiversity framework.

Taxonomy is the fundamental scientific discipline underpinning biodiversity discovery and understanding. As such, attainment of the goals of the Global Biodiversity Framework depends on effective action both to maintain and strengthen long-established taxonomic expertise, and to support the many innovations enabling unprecedented discovery of the Earth's biodiversity as well as the sharing of data and information to support conservation and sustainable development.

Taxonomy must be recognized and fully integrated into all components of the global biodiversity framework. This includes, but is not confined to:

- The 2030 action targets of the framework
- The implementation support mechanisms of the framework, especially capacity development, technical and scientific cooperation, and knowledge generation

Development of capacity in taxonomy is critical to the successful implementation of the global biodiversity framework. This includes support for developing taxonomic infrastructure and capacity in all countries and regions, and for ensuring that such skills are passed to new generations, to underpin and enhance understanding of biodiversity in all places on Earth. Increased investment in education, training and career opportunities in taxonomy is urgently needed to prevent an overall decline in taxonomic research, and to promote continued expertise and taxonomic literacy among younger professionals and future generations engaged in conservation.

Innovative and emerging technologies provide unprecedented opportunities for generating and sharing knowledge about the biosphere, when combined with essential taxonomic knowledge, techniques and skills. Such opportunities include:

- Harnessing the immense knowledge base accumulated in natural history collections of all sizes and in all regions, through digitization and sharing of data on preserved specimens using common standards to enable universal discovery, access and use
- Generation and sharing of data arising from technological improvements in genetic sequencing of organisms in nature, for example through environmental metagenomics, enabling planetary-scale understanding of species, surveillance of their dynamics, and acceleration of species discovery
- Providing digital access to taxonomic literature and associated archives, both through digitization of historic materials, and rapid integration of newly-published taxonomic

64 This statement was posted at https://www.cbd.int/gti/doc/gti_forum_2020_statement.pdf, and also appears as annex II to the GTI Forum 2020 procedural report (CBD/GTI/OM/2020/1/3).

discoveries and treatments into the global knowledge base

- Engagement of citizens, indigenous peoples and local communities in observation and documentation of evidence on biodiversity occurrence in space and time, through bringing together volunteer networks, taxonomic expertise and user-friendly applications to register, share and access biodiversity data; thereby encouraging bio-literacy and public participation in conservation and sustainable use of biodiversity

- Enabling conservation of all branches of the Tree of Life as an essential component of addressing biodiversity loss, by recognizing the evolutionary framework underlying taxonomy, and incorporating phylogenetic and systematics information with spatial data on species distribution and occurrences

- Enabling improved management, assessment, and surveillance in order to prevent negative impacts on biodiversity and human well-being, including through improved biosecurity measures

The goals of the global biodiversity framework will only be realized through active and effective collaborations and connections among all relevant taxonomic initiatives at all scales. Such ongoing collaboration must avoid duplication of effort, and enable integration of data and information within a shared knowledge network, based on inclusive participation and transparent governance, as well as effective and efficient use of available resources.

We commit to engaging fully with the Parties to the CBD to ensure that taxonomy is well reflected in the post-2020 global biodiversity framework. In particular, we feel it is essential that taxonomy continues to feature as a strong component of the programmes for technical and scientific cooperation under the CBD, building on the GTI network of focal points and partners, pending the inclusive review process for review and renewal of these programmes, to be submitted for approval at COP15.

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65 CBD notification 2020-031.
66 CBD notification 2020-031.

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Mariela Osorno, Instituto Amazónico de Investigaciones Científicas SINCHI, Colombia;

Mirna Oviedo, Universidad Técnica de Manabí, Ecuador;

Maria Panitsa, Division of Plant Biology, Department of Biology, University of Patras, Greece;

Williams Paredes Munguia, Pontificia Universidade Católica do Rio Grande do Sul, Brazil;

Chan-Ho Park, Genetic Resources Information Center, National Institute of Biological Resources, Republic of Korea;

Alan Paton, Royal Botanic Gardens Kew, United Kingdom of Great Britain and Northern Ireland;

Aura Paucar, Universidad Nacional de Loja, Ecuador;

Carla Simone Pavanelli, Universidade Estadual de Maringá, Brazil;

Simón Pérez Pérez-Martínez, Universidad Estatal de Milagro, Ecuador;

Jenny Phillips, BioAlfa, Costa Rica;

Balakrishna Pisupati, United Nations Environment Programme (UNEP), India;

Shijith Puthan Purayil, Mahatma Gandhi Government Arts College, India;

Aijaz Ahmad Qureshi, Islamic University of Science & Technology, India;

Manzoor Qureshi, Gigit Baltistan Rural Support Programme, Pakistan;

Adriana Radulovici, University of Guelph, Canada;

Kamal Rai, Indigenous Knowledge and Peoples Network Society for Wetland Biodiversity Conservation Nepal in Federation of Kirat Indigenous, Nepal;

Thiago Ramos, Universidad Privada Del Este, Brazil;

Phuttatida Rattana, Office of Natural Resources and Environmental Policy and Planning, Thailand;

Mariana Ribeiro Maia, Brazil;

Mouna Rifi, National Agronomic Institute of Tunisia, Tunisia;

Maria Herminia Cornejo Rodriguez, State University of Peninsula de Santa Elena, Ecuador;

Xavier Astudillo Romero;

Santiago Ron, Pontificia Universidad Católica del Ecuador, Ecuador;

Alix Rosa Mary, Instituto Amazónico de Investigaciones Científicas SINCHI, Colombia;

Sharon Ruthia, Kenya;

Chinara Sadykova, RCE Kyrgyzstan, Kyrgyzstan;

Manda Safavi, Environmental Protection Authority, New Zealand;

Carlos Salas, Universidad Técnica de Manabí, Ecuador;

Brenda Salles, Universidade Estácio de Sá, Brazil;

Serigne Sarr, Université Alioune Diop de Bambey, Senegal;

Edmund Schiller, Natural History Museum Vienna, Austria;

Hendrik Segers, Royal Belgian Institute of Natural Sciences, Belgium;

Gono Semiadi, Indonesian Institute of Sciences, Indonesia;

Bruno Senterre, National Herbarium, Seychelles;

Tatiana Sepulveda, Universidade Federal do Parana, Brazil;

Li Shi, Inner Mongolia Agricultural University, China;

Muhammad Ibrar Shinwari, International Islamic University Islamabad, Pakistan;

Diana Sietz, Potsdam Institute for Climate Impact Research, Germany;

Walter Aurelio Simbaña Ayo, Ecuador;

Paramjit Singh, Botanical Survey of India, India;

Angel Solis, BioAlfa, Costa Rica;

Roxana Solis, Ministerio del Ambiente, Peru;

Douglas Soltis, University of Florida, United States of America;

Pamela Soltis, University of Florida and Integrated Digitized Biocollections (iDigBio), United States of America;

Nike Sommerwerk, Museum für Naturkunde Berlin, Germany;

Ruth Spencer, Barnes Hill Community Development Organization, Antigua and Barbuda;

Carol Stepien, University of Washington, United States of America;

Wataru Suzuki, Secretariat of the Convention on Biological Diversity (SCBD), Canada;

Valeria Terán, Secretaría de Educación Superior, Ciencia, Tecnología e Innovación, Ecuador;

Birthe Thormann, German Federal Agency for Nature Conservation, Germany;

Marija Tomasic, Ministry of Economy and Sustainable Development, Croatia;

Juan Pablo Torres Florez, Instituto Chico Mendes de Conservação da Biodiversidade, Centro Nacional de Pesquisa e Conservação de Mamíferos Aquáticos, Brazil;

Indah Trisnawati, Indonesia;

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Erika Villagómez, Secretaría de Educación Superior, Ciencia, Tecnología e Innovación, Ecuador;

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Peter Wilkie, Royal Botanic Garden Edinburgh, United Kingdom of Great Britain and Northern Ireland;

Peter Wyse Jackson, Missouri Botanical Garden, United States of America;

Mari Yamazaki, Ministry of the Environment, Japan;

Mario H. Yánez-Muñoz, Instituto Nacional de Biodiversidad, Ecuador;

Rachael Young, YAYAYA, Field Notes Food Co LLC, United States of America;

Pramana Yuda, Universitas Atma Jaya Yogyakarta, Indonesia;

Angela Zanata, Universidade Federalda Bahia, Brazil;

Lejia Zhang, Museum für Naturkunde Berlin, Germany;

Martin Zimmer, Leibniz Zentrum für Marine Tropenforschung, Germany;

Alejandro Zuluaga, Universidad del Valle, Colombia.

ANNEX 3

Examples of taxonomic capacity-building measures and needs in countries and regions, as provided by participants in the Global Taxonomy Initiative Forum 2020[67]

Country/Region	Taxonomic capacity measures	Taxonomic needs/what type of activity can help remove taxonomic impediment	Explain which target(s) become(s) achievable in your country / region if the need / taxonomic impediment is resolved
Australia and New Zealand	A decadal plan on current taxonomic and biosystematics capacity in Australia and New Zealand.[68]	Overall aging and declining full-time equivalent (FTE) positions in taxonomy and systematics but establishing opportunities for expansion of capabilities.	Aichi Biodiversity Target 19
Costa Rica	Barcoding expertise, in the form of BioAlfa, is stretching to the national level, but remains heavily reliant on financing from international collaborations.	Reinstate programmes similar in nature to INBio, Full scale budgeting to support staff and coordinators and to carry out barcoding and collateral information facilities for storing enormous amounts of voucher specimens, genome-bearing tissue.	Aichi Biodiversity Targets 1, 2, 4 and 19
Europe (CETAF)	Training opportunities lead to more successful capacity-building, especially in biodiversity-rich regions, but it is costly to run training programmes without an external source of funding, especially when they are done at an international level.	CETAF supports the European Distributed School of Taxonomy that offers taxonomy training opportunities to European and non-European students. Outreach and networking across borders with diverse training offers should be coordinated and made available, in line with a certification process. We should take advantage of mixed training models that can be developed in online learning programmes coupled with field experience.	Aichi Biodiversity Target 19
Germany	The consortium of the German Natural History Research Collections "Deutsche Naturwissenschaftliche Forschungssammlungen" (DNFS) represents and pursues the interests of German Natural History Museums, Herbaria and major Botanic Gardens. The collections archive and hold more than 100 million natural history specimens of organismal life.	Many DNFS members actively engage in environmental genomics, the Barcode of Life initiative and biodiversity monitoring (e.g. metabarcoding). Our research institutions are major aggregators of biodiversity data and among the leading data providers for GBIF and BOLD. Training and knowledge transfer, sampling, voucher deposition and barcoding of lesser known groups. Graduate programmes in place, for example, "Biodiversity and Collection Management" (M.Sc.)	The non-commercial biodiversity research of DNFS members is directed towards the three goals of the CBD, the Aichi Targets and the Sustainable Development Goals. Aichi Biodiversity Target 19 Taxonomic knowledge of lesser known taxonomic groups. Education and knowledge-building.
Guyana	Very few personnel can identify select taxa (freshwater fishes, plants, insects, birds, mammals, reptiles and amphibians) in the field and laboratory using morphological features, behaviours (calls, habitat and food preference), scat, trails, tracks etc.	More training on taxonomic identification, with a focus on bioindicators, keystone species and taxa where the capacity is lacking. Technologies for genetic identification (DNA and genome sequencing, barcoding etc.).	Aichi Biodiversity Targets 11, 13 and 16

67 The information presented here is largely supplementary to information reported in the sixth national reports.
68 https://www.royalsociety.org.nz/what-we-do/our-expert-advice/all-expert-advice-papers/discovering-biodiversity

Country/Region	Taxonomic capacity measures	Taxonomic needs/what type of activity can help remove taxonomic impediment	Explain which target(s) become(s) achievable in your country / region if the need / taxonomic impediment is resolved
Malaysia	Active taxonomists are not engaged or aware of the GTI.	GTI national focal point should invite and include all active taxonomists in the country to understand the true taxonomic capacity in Malaysia. All CBD/GTI activities or programmes should have fair representatives at the national and international level so that the objectives of CBD/GTI is the responsibility of all stakeholders and are achieved collectively. GTI national focal points should meet yearly with representatives of taxonomists from local universities to plan, distribute responsibilities and work closely with them to utilise training opportunities provided by CBD/GTI. GTI national focal points should facilitate young taxonomists in funding/grant opportunities from local authorities and CBD partners.	Aichi Strategic Goal E Enhanced education, public awareness, engagement and collaboration between Parties, Governments and taxonomic institutions that would provide good, inclusive and fair practices in support of GTI initiatives post-2020.
Morocco	Efforts to digitize herbarium specimens. Analysis of the floristic biodiversity of Moroccan wetlands, rare, threatened and halophilic flora. GTI activities only exist in the course of university training.	Strengthening of taxonomic research.	Aichi Biodiversity Targets 12 and 19 GSPC Objectives 1, 2 and 5
New Zealand	Published appendices on National Taxonomic Collections in New Zealand.[69]		
Nigeria	It is expected that at the end of 2020, about 30% of the Nigerian population will be aware of the importance of biodiversity and GTI activities. The awareness on identification, monitoring assessment of species are recommended for implementation.	It is noted that taxonomy expertise is fast declining. Countries should engage in the training of younger researchers to strengthen the future taxonomy workforce by involving them in knowledge sharing on taxonomy techniques. Improvement of collection infrastructure are highly needed. Modern taxonomic methods (barcoding) should be incorporated and promoted in order to enhance the efficiency and taxonomy reputation. A training programme sponsored by Secretariat of the Convention on Biological Diversity (SCBD) through Japan Biodiversity Fund (JBF) workshop on GTI-DNA-Tech using DNA barcoding for species identification was held. Few officers of the various ministries were in attendance using specimens of invasive plants and agricultural pest of Nigeria.	Aichi Biodiversity Targets 1, 4 and 19

69 https://www.royalsociety.org.nz/assets/Uploads/Appendices-National-Taxonomic-Collections-in-New-Zealand-2015.pdf

Country/Region	Taxonomic capacity measures	Taxonomic needs/what type of activity can help remove taxonomic impediment	Explain which target(s) become(s) achievable in your country / region if the need / taxonomic impediment is resolved
Peru/LAC		Increase the number of taxonomists. Modernize laboratories. Develop biodiversity indicators and criteria. Access to biodiversity information.	Aichi Strategic Goal E
Sweden	Well-developed national taxonomic capacity with respect to both infrastructure and knowledge.	Support to developing countries in providing information on what is housed in Swedish museums.	Aichi Biodiversity Target 19 Capacity-building in developing countries if national financing would allow.
United Kingdom of Great Britain and Northern Ireland/European Union/Global	The UK taxonomic institutions support supranational initiatives through the provision of taxonomic and collection data such as the UK Darwin Initiative,[70] GBIF,[71] World Flora Online,[72] the Distributed System of Scientific Collections,[73] and Darwin Tree of Life Project.[74] The Consortium of European Taxonomic Facilities (CETAF) brings together more than 60 museums, herbaria and botanic gardens to support collaboration in taxonomy and collection management.	Provide funding for research and collections improvements.	Aichi Biodiversity Target 19 Provides general biodiversity information, support and capacity.

70 https://www.darwininitiative.org.uk/
71 https://www.gbif.org/
72 http://www.worldfloraonline.org/
73 https://www.dissco.eu/
74 https://www.darwintreeoflife.org/

ANNEX 4

Examples of publicly available relevant taxonomic keys

Country/region	Name/title (of the taxonomic key)	Provider/Author(s)	Taxonomic group(s)	URL
Costa Rica	Birds of Costa Rica; Flora of Costa Rica; Butterflies of Costa Rica; many other field guides	Several different publishers	Birds, plants, insects, agricultural pests, reptiles, marine biodiversity	https://www.acguanacaste.ac.cr/paginas-de-especies http://janzen.sas.upenn.edu/caterpillars/database.lasso https://www.butterfliesofamerica.com
Côte d'Ivoire / Africa	Tadpoles of Africa: The biology and identification of all known tadpoles in sub-Saharan Africa	Alan Channing, Mark-Oliver Rödel & Jenny Channing	Amphibians	https://www.chimaira.de/tadpoles-of-africa-the-biology-and-identification-of-all-known-tadpoles-in-sub-saharan-africa.html
	A review of West African spotted Kassina, including a description of *Kassina schioetzi* sp. nov. (Amphibia: Anura: Hyperoliidae)	Mark-Oliver Rödel, T. Ulmar Grafe, Volker H. W. Rudolf & Raffael Ernst	Amphibians	https://doi.org/10.1643/0045-8511(2002)002[0800:AROWAS]2.0.CO;2
	Trilingual Keys to the Savannah-Anurans of the Comoé National Park, Ivory Coast	Mark-Oliver Rödel & Marko Spieler	Amphibians	https://www.researchgate.net/publication/237331542_Trilingual_Keys_to_the_Savannah-Anurans_of_the_Comoe_National_Park_Ivory_Coast
	Les Mantes de Lamto et des savanes de Côte d'Ivoire	Bulletin de 1'Institut Français d'Afrique Noire (I.F.A.N)	Insecta	https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/b_fdi_10-11/12394.pdf
	Flore du Parc National de Taï – (Côte d'Ivoire) – Manuel de reconnaissance des principales plantes	Centre d'édition et de diffusion africaines (CEDA)	Plantae	http://africultures.com/livres/?no=6852&utm_source=newsletter&utm_medium=email&utm_campaign=482
Global	Visual Identification Guide to the Monitor Lizard Species of the World (Genus Varanus).	BfN-Skripten 552: 1-201. DOI 10.19217/skr552	Genus Varanus	https://www.bfn.de/fileadmin/BfN/
Morocco	Flore pratique du Maroc (3 vol.): Manuel de détermination des plantes vasculaires	Institut Scientifique, Mohammed V University in Rabat	Vascular flora of Morocco	http://www.israbat.ac.ma/
	Inventory of birds	Institut Scientifique, Mohammed V University in Rabat	Birds of wetlands	http://www.israbat.ac.ma/
	Catalogue of chorology: (Catalogue de la flore vasculaire du Maroc: inventaire et chorologie)	Institut Scientifique, Mohammed V University in Rabat	Vascular flora	http://www.israbat.ac.ma/
	Catalogue des plantes vasculaires rares, menacées ou endémiques	Institut Scientifique, Mohammed V University in Rabat	Vascular flora	https://www.herbmedit.org/Bocconea08.html

Country/region	Name/title (of the taxonomic key)	Provider/Author(s)	Taxonomic group(s)	URL
Nepal / South Asia	Catalogue of Nepalese Flowering Plants - III	National Herbarium & Plant Laboratories, Godawari, Lalitpur	Phanerogams	http://kath.gov.np/ https://dpr.gov.np/
	Catalogue of Nepalese Flowering Plants Supplement-1	K. R. Rajbhandari, Ganga Datt Bhatt, Rita Chhetri & Sanjeev Kumar Rai National Herbarium & Plant Laboratories, Godawari, Lalitpur	Phanerogams	http://kath.gov.np/ https://dpr.gov.np/
New Zealand	Online identification tools	Manaaki Whenua – Landcare Research	Algae, Fungi, Invertebrates, Plants	https://www.landcareresearch.co.nz/tools-and-resources/identification/
Peru	Annotated checklist and key to the species of amphibians and reptiles inhabiting the northern Peruvian dry forest along the Andean valley of the Marañón River and its tributaries	ZFMK	Amphibians and reptiles	https://www.biotaxa.org/Zootaxa/article/view/zootaxa.4385.1.1
Peru / LAC	Fish Key	IMARPE	Fish	http://biblioimarpe.imarpe.gob.pe/handle/123456789/3327
Southeast Asia and the Indo-Australian Archipelago	Distribution, Threats, and Conservation Status of the Monitor Lizards (Varanidae: *Varanus* spp.) of Southeast Asia and the Indo-Australian Archipelago	Herpetological Conservation and Biology	Varanidae: Varanus spp.	http://www.herpconbio.org/Volume_8/monographs/Koch_etal_2013.pdf
Sweden	Species key	SLU Swedish Species Information Centre	Various	https://www.artfakta.se/
United Kingdom of Great Britain and Northern Ireland	Handbooks on British insects	Royal Entomological Society	Insects	https://www.royensoc.co.uk/publications/handbooks
	Online Atlas of the British and Irish Flora	Botanical Society of Britain & Ireland and the Biological Records Centre	Plants	https://www.brc.ac.uk/plantatlas/
Various (Africa, Asia, Central / South America)	AbcTaxa (series of manuals/guides, 20 volumes so far)	Royal Belgian Institute of Natural Sciences (including Belgian GTI Focal Point); Royal Museum for Central Africa, Belgium; National Botanic Garden, Belgium; The Belgian Development Cooperation	Various	http://www.abctaxa.be/volumes

ANNEX 5

Examples of field guides to facilitate taxonomic identifications by non-specialists

Country/region	Title of the field guide	Taxonomic group(s)	Contributors, authors	URL/ISBN
Argentina	Catalog of Vascular Plants from Conosur	Tracheophytes (it is not a recognized taxonomic category)	Instituto de Botanica Darwinion	http://www.darwin.edu.ar/Proyectos/FloraArgentina/fa.htm
ASEAN	Field guide to the Pteridophytes in Chiang Mai, Thailand	Pteridophytes	ASEAN Centre for Biodiversity	https://aseanbiodiversity.org/wp-content/uploads/2017/05/FieldGuide-02-Pteridophytes.pdf
	Guide to the bryophytes in the limestone glass house of Queen Sirikrit Garden	Bryophytes	ASEAN Centre for Biodiversity	https://aseanbiodiversity.org/wp-content/uploads/2017/05/FieldGuide-01-Bryophytes.pdf
	Field Guide to the Plants of the Deer Cave Trail Gunung Mulu National Park Sarawak	Trees, Herbs and Shrubs, Vines and Lianas, Palms and Pandans, Ferns	ASEAN Centre for Biodiversity	https://aseanbiodiversity.org/wp-content/uploads/2017/05/FieldGuide-03-GunungMulu.pdf
	Field Guide to the Vascular Plants along Nature Trails on the Summit of Doi Inthanon National Park, Thailand	Vascular Plants	ASEAN Centre for Biodiversity	https://aseanbiodiversity.org/wp-content/uploads/JAIF/High%20Elevation%20Vascular%20Plants_DNP.pdf
	Selected Monocot Plants of Northern Thailand and Southeast Asia	Monocot Plants	ASEAN Centre for Biodiversity	https://aseanbiodiversity.org/wp-content/uploads/2017/05/FieldGuide-Monocot.pdf
Brazil	Catálogo das Unidades de Conservação do Brasil	Plantae		https://catalogo-ucs-brasil.jbrj.gov.br
China	Field Guide to Wild Plants (FGWP) of China	Wild Plants of Beijing	Liu Bing, Lin Qinwen, Li Min	ISBN 978-7-100-15980-7
	Field Guide to Wild Plants (FGWP) of China	Wild Plants of Qinling mout.	Cai Jing, Liu Peiliang, Du Cheng, Lu Yuan	ISBN 978-7-030-37865-1
	Field Guide to Wild Plants (FGWP) of China	Wild Plants of Hainan	Xing Fuwu, Chen Hongfeng, Qin Xinsheng, Zhang Rongjing, Zhou Jinsong	ISBN 978-7-560-99307-2
	Notes of Life	Birds, butterflies, fungi	Institute of Zoology, Chinese Academy of Sciences	http://nol.especies.cn/
	Biology Expert System Online: image identification system	Insects	Institute of Zoology, Chinese Academy of Sciences	http://bes.biodinfo.org/Pages/ByImage/imgDemo1.aspx
Costa Rica	Many	Plants, invertebrates, vertebrates	Many	Some are URLs, many are hard copy for sale in bookstores or other outlets
Côte d'Ivoire / Africa	Field guide to the frogs and other amphibians of Africa	Amphibians	Alan Channing & Mark-Oliver Rödel	https://doi.org/10.1080/21564574.2019.1700442 ISBN (print): 978 1 77584 512 6, ISBN (ePub): 978 1 77584 699 4
	Herpetofauna of West Africa: Amphibians of the West African Savanna	Amphibians	Mark-Oliver Rödel	https://books.google.se/books/about/Herpetofauna_of_West_Africa_Amphibians_o.html?id=X-hIHAAAAYAAJ&redir_esc=y, 393061216X, 9783930612161, ISBN: 393061216X, 783930612161

Country/region	Title of the field guide	Taxonomic group(s)	Contributors, authors	URL/ISBN
Côte d'Ivoire / Africa	Conservation de la nature et aires protégées en Côte d'Ivoire	Flora / Fauna	Centre d'éditions et diffusion Africaine (CEDA) / Nouvelle Edition Ivoirienne (NEI)	https://books.google.ci/books/about/Conservation_de_la_nature_et_aires_prot.html?id=J30fAQAAIAAJ&hl=fr, ISBN: 2844873138, 9782844873132
	Poissons de Côte d'Ivoire (eaux douces et saumâtres)	Fishes	Publications des scientifiques de l'Institut de Recherche pour le Développement (I.R.D.) France	https://www.documentation.ird.fr/hor/fdi:10371
	Les oiseaux du Parc National du Banco et de la Forêt Classée de l'Anguédédou, Côte d'Ivoire	Birds	Olivier Lachenaud	https://www.friscris.be/en/publications/les-oiseaux-du-parc-national-du-banco-et-de-la-foret-classee-de-languededou-cote-divoire(4a92e9aa-140d-4523-b0c6-9f4cc2bfa542).html
Georgia, Armenia, Azerbaijan, Russia	The millipede family Polyxenidae in the faunas of the Crimean Peninsula and Caucasus, with notes on some other Polyxenidae.	Polyxenida	Short, Vahtera, Wesener, Golovatch (ZFMK, Brisbane University, Russia Academy of Sciences)	https://doi.org/10.11646/zootaxa.4772.2.4
Germany	Rothmaler - Exkursionsflora von Deutschland, Gefäßpflanzen	Vascular plants - Clear line drawings of more than 3000 plant species occurring in Germany	Eds: Jäger, E., Müller, F., Ritz, C.M., Welk, E., Wesche, K.	https://www.springer.com/de/book/9783662497098
Germany, Saxony-Anhalt	Fungal flora of Saxony-Anhalt. Ascomycetes, Basidiomycetes, Aquatic Hyphomycetes	Fungal flora - Basidiomycetes, Aquatic Hyphomycetes	Ulla Täglich	http://www.weissdorn-verlag.de/PilzfloraS_A222.html
	Fungal Flora of Saxony-Anhalt - Phytoparasitic Small Fungi	Fungal Flora - Phytoparasitic Small Fungi	Horst Jage with the collaboration of Dieter Frank, Dorothea Hanelt, Heidrun Richter, Udo Richter and Horst Zimmermann	https://www.naturundtext.de/shop/gesamtliste/pilzflora-von-sachsen-anhalt-phytoparasitische-kleinpilze.html
Guyana	Selected fishes of the Rupununi (Region 9)	Fishes	Field Museum Chicago, Leslie DeSouza	https://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/1202_guyana_selected_fishes_of_the_rupununi.pdf
	Selected Birds Guyana	Birds	Leon Moore	https://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/1220_guyana_selected_birds.pdf
	Common Snakes of the Rupununi (Region 9)	Reptiles	Field Museum Chicago, Andrew Snyder	https://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/1203_guyana_common_snakes_of_rupununi.pdf
	Frogs and Toads of the Rupununi (Region 9)	Amphibians	Field Museum Chicago, Andrew Snyder	https://fieldguides.fieldmuseum.org/sites/default/files/rapid-color-guides-pdfs/1204_guyana_frogs_and_toads_of_rupununi.pdf
India	A species checklist of the millipedes (Myriapoda, Diplopoda) of India	Diplopoda	Golovatch & Wesener 2016 (ZFMK and Russian Academy of Sciences)	http://doi.org/10.11646/zootaxa.4129.1.

Country/region	Title of the field guide	Taxonomic group(s)	Contributors, authors	URL/ISBN
Indonesia: Java	The Myriapoda of Halimun-Salak National Park (Java, Indonesia): overview and faunal composition	Diplopoda, Chilopoda, Symphyla	Wesener, Akkari, Hilgert (ZFMK, NHMW)	https://doi.org/10.3897/BDJ.7.e32218
Malaysia	Orchids of the Peat Swamp Forests in Peninsular Malaysia (2007). 136p	Orchidaceae	Rusea Go & Khali Aziz Hamzah	978-983-3985-04-3
	Orchids of Perlis: Jewel in the Forests (2010). 152p	Orchidaceae	Rusea Go, Wendy Y.S. Yong, Joanis Unggang & Ridzuan Salleh	978-983-3175-02-4
	Paya Indah Wetlands – An Array of Plant Life (2010). 100p	Lycophytes, Pteridophytes and Angiosperms	Rusea Go, Kenny H.E. Khor, Pauzaih Abdul Ghani, Norain Mohd Arif and Mohd Azroie M. Yusuf	978-967-0205-17-5
	Orchidea Selangoreana (Wild Orchids of Selangor) (2014). 208p	Orchidaceae	Rusea Go, Mohd Basri Abdul Manaf & Mohd Puat Dahalan	978-967-10268-4-7
	Orchids of The Montane Forests in Peninsular Malaysia (2015).	Orchidaceae	Rusea Go. Janna Ong Abdullah & Siti Fatimah Md Isa	978-967-344-519-6
	Discovering the Wonders of Malaysian Orchids (2018). 100p	Orchidaceae	Rusea Go & Akmal Raffi	978-967-344-932-3
	Sarawak Limestone Forests Orchids (2018).	Orchidaceae	Rusea Go & Runi Sylvester Pungga	
	Enchanted Orchids of Fraser Hills: A Pictorial Guide (2019). 124p	Orchidaceae	Rusea Go, Farah Alia Nordin & Mohd Puat Dahalan	978-967-10268-6-1
	Ethnobotanical Plants of Malaysia (2019). 304p (With Korean Translation)	Lycophytes, Pteridophytes and Angiosperms	Nam Sook Lee, Sang Mi Eum, You Mi Lee & Rusea Go*	979-11-88720-75-0
	Notable Plants of Malaysia, Vol.1 (2020). 200p	Lycophytes, Pteridophytes and Angiosperms	Rusea Go, Mohd Nazre Salleh, Christina SY Yong, Sangho Choi, Jn-Hyub Paik & Sang Mi Eum	978-89-6709-149-1
	Magnificent Wild Flowers of Selangor State Park, Fraser's Hill (2020). 125p	Angiosperms	Rusea Go	978-967-10268-7-8
Morocco	Les Oiseaux du Maroc - Guide d'identification	Birds	Groupe d'Ornithologie du Maroc's scientific contributions	978-2-910728-84-7
Myanmar	A species checklist of the millipedes (Myriapoda, Diplopoda) of India	Diplopoda	Wesener & Moritz (ZFMK)	https://doi.org/10.15560/14.6.1131
Nepal / South Asia	Flora of Nepal (vol. 3) Magnoliaceae to Rosaceae	Angiosperms	Royal Botanic Garden, Edinburgh	978-1-906129-78-1
	Fern & Fern Allies of Nepal (vol.1)	Pteridophytes	C. R. Fraser- Jenkins, Dhan Raj Kandel & Sabina Pariyar	www.dpr.gov.np; http://kath.gov.np/home; 978-9937-2-9496-6
	Plant Resources of Kailali, West Nepal	Vascular Plants	K. R. Rajbhandari, Madhu Shudan Thapa Magar, Dhan Raj Kandel & Chetana Khanal	978-9937-0-1362-8

Country/region	Title of the field guide	Taxonomic group(s)	Contributors, authors	URL/ISBN
Nepal / South Asia	A Handbook of Flowering Plants of Nepal (vol.1)	Phanerogams	K. R. Rajbhandari, Sanjeev Kumar Rai	978-9937-0-3401-2
	Flowering Plants of Nepal- An Introduction	Phanerogams	K. R. Rajbhandari, Sanjeev Kumar Rai, Ganga Datt Bhatt, Rita Chhetri & Subhash Khatri	978-9937-0-3148-6
	Fern & Fern Allies of Nepal (vol.2)	Pteridophytes	C. R. Fraser- Jenkins & Dhan Raj Kandel	978-9937-9248-1-8
	A Handbook of Flowering Plants of Nepal (vol.2)	Phanerogams	K. R. Rajbhandari, Sanjeev Kumar Rai	978-9937-9248-4-9
	Flowering Plants Discovered from Nepal	Phanerogams	K. R. Rajbhandari, Sanjeev Kumar Rai, Mohan Dev Joshi, Subhash Khatri, Ganga Datt Bhatt, Rita Chhetri	978-9937-9248-3-2
	Fern & Fern Allies of Nepal (vol.3)	Pteridophytes	Dhan Raj Kandel & C. R. Fraser- Jenkins	978-9937-9248-5-6
	Algal Flora of Nepal (vol.1) Cyanobacteria	Algae	Shiva Kumar Rai & Sajita Dhakal	978-9937-9248-6-3
	A Handbook of the Gymnosperms of Nepal	Gymnosperms	K. R. Rajbhandari, Lajmina Joshi, Rita Chhetri & Subhash Khatri	978-9937-9248-7-0
New Zealand	A field guide to field guides	Forests, Edible Plants, Fungi, Alpine biodiversity, Birds, Seashore biodiversity, Seaweeds, Reptiles & Amphibians, Insects, Spiders	Diverse authors, collated by Linda Keegan	https://thespinoff.co.nz/books/30-10-2019/a-field-guide-to-field-guides/
Norway	Norwegian Biodiversity Information Centre	All terrestrial	AI identification of images	https://orakel.artsdatabanken.no/
	Norwegian Biodiversity Information Centre	All	Reporting database for observations	https://www.artsobservasjoner.no/
	Norwegian Biodiversity Information Centre	All	Map for locating species records	https://artskart.artsdatabanken.no
Peru / LAC	Listado de Especies de Flora Silvestre CITES - Peru	Cactaceae, Cyatheaceae, Dicksoniaceae, Euphorbiaceae, Fabaceae, Lauraceae	CITES Peru MINAM Peru	https://cdn.www.gob.pe/uploads/document/file/475307/Listado_Flora_CITES_Per%C3%BA_2018.pdf
Sweden / Nordic countries	Encyclopedia of the Swedish Flora & Fauna	Various	SLU Swedish Species Information Centre	https://nationalnyckeln.se/ often available at https://www.artfakta.se/
United Kingdom of Great Britain and Northern Ireland	Field Studies Council guides, information packs etc	Insects, plants, mammals, birds, reptiles, amphibians etc		https://www.field-studies-council.org/product-category/publications/
	Grasses of the British Isles	grasses		ISBN: 9780901158420
	Botanical Society of Britain and Ireland Handbooks and Plant Cribb	Plants		https://bsbi.org/bsbi-handbooks; https://bsbi.org/plant-crib

ANNEX 6

Examples of DNA sequence-based platforms for taxonomy

Country/region	Platform/ organization name	Taxonomic group(s)	Application	URL
Argentina	Portal de datos genómicos	Animalia, Plantae, Fungi, Chromista, Protozoa	Species inventory, genome, biotechnology	https://datos.sndg.mincyt.gob.ar/
China	Institute of Botany, CAS/DNA Barcode of Rare and Endangered Plant	2,600 species of seed plants	Identify rare & endangered species with DNA sequence and morphological characters	http://www.iplant.cn/rep/dna
	Kunming Institute of Botany,CAS/National Wild Plant Germplasm Resource Center	305 families, 2,885 genera, 18,428 species of plants	DNA sequence of wild plants in China	https://seed.iflora.cn/
Costa Rica	International Barcode of Life (iBOL)	Animalia, Plantae, Fungi	eDNA regulated species identification, species inventory	http://www.ibol.org
Estonia	UNITE	Mainly fungi	Database and sequence management environment for the molecular identification of fungi, centred on the eukaryotic nuclear ribosomal ITS region. UNITE serves as a data provider for a range of metabarcoding software pipelines and regularly exchanges data with all major fungal sequence databases and other community resources.	https://unite.ut.ee/index.php
European Union	European and Mediterranean Plant Protection Organization/ EPPO-Q-bank	Plant pathogenic fungi also other organisms covered in the database (arthropods, bacteria, nematodes, phytoplasms, plants, viruses and viroids)	Agriculture, horticulture	https://qbank.eppo.int/
France	ATGC bioinformatics platform/different kind of programmes and services related to NGS & phylogenetics	All	Phylogenetic & NGS analysis	http://www.atgc-montpellier.fr/
Germany	GBOL	All taxa	DNA reference library, biodiversity monitoring	https://www.bolgermany.de/
	ZFMK, GBOL	Insects, Vertebrates, Plants, Arthropoda	DNA barcoding, DNA metabarcoding, alpha taxonomy	http://www.bolgermany.de
Global	Global Amphibian Assessment	IUCN SSC Amphibian Specialist Group	In general, many more amphibian taxa have been sequenced for 16S rDNA	http://www.iucn.org
Malaysia	DNA sequence (chloroplast and nuclear)	Orchidaceae	Species identification	http://www.ncbi.nlm.nih.gov/Genbank/

Country/region	Platform/ organization name	Taxonomic group(s)	Application	URL
New Zealand	Ecogene / Ecological Genetics Lab	Plants, Animals, Fungi, Bacteria, Chromists	Diagnostics, phylogenetics, whole genomes Most data uploaded to Genbank	https://www.landcareresearch.co.nz/partner-with-us/laboratories-and-diagnostics/ecological-genetics-laboratory/research-projects/
	Environmental Protection Authority (EPA) in collaboration with Wilderlab	Aquatic life – all kingdoms	Wai Tūwhera o te Taiao – Open Waters Aotearoa: Citizen science and bridges between people and nature	https://www.epa.govt.nz/community-involvement/open-waters-aotearoa/
Peru / LAC	GenBank	Mollusca	Species identity, comparison of genetic distances	http://www.ncbi.nlm.nih.gov/Genbank/
Sweden	SWEBOL iBOL	Biota	Barcoding, species identification, species inventory, eDNA processing, regulatory activity	http://swebol.org/ http://boldsystems.org
United Kingdom of Great Britain and Northern Ireland	European Bioinformatics Institute (EMBL-EBI)/maintains the world's most comprehensive range of freely available and up-to-date molecular data resources/tools	All	Sharing data, performing complex queries and analysing the results	https://www.ebi.ac.uk/services
United States of America	National Center for Biotechnology Information (NCBI) / GenBank, BLAST	All	Annotated collection of all publicly available DNA sequences; BLAST tool finds regions of similarity between sequences (sequence similarity searching)	https://www.ncbi.nlm.nih.gov/ https://blast.ncbi.nlm.nih.gov/Blast.cgi

ANNEX 7

Examples of biological collections in museums, universities and other institutions supporting taxonomic identifications and studies

Country name	Collection / institution name and place	Collection size (total number of specimens/samples, type specimens/referenced specimens)	Specimen loans (in 2011-2020)	Remarks, if any
Argentina	Universidad de Buenos Aires Herbario (BAFC)	4000		
Brazil	Rio de Janeiro Botanical Garden (RB)	850 mil total /12 mil typus	ca. 9 mil	
China	Herbarium (PE), Institute of Botany, Chinese Academy of Sciences	2.8 million / 22,000 / 40,000	200,000	Largest herbarium in China & Asia; collection covers all of China, with ~0.25 million specimens collected in other countries; http://pe.ibcas.ac.cn/en/
	Zoological Museum in Chinese Academy of Sciences	8,227,000		https://web.archive.org/web/20110430185706/http://www.nzmc.org//
	Fungarium of Institute of Microbiology, Chinese Academy of Sciences (HMAS)	540,000 specimens; 4,481 type specimens	90,717	HMAS holds the richest fungal collections in China and is the largest one in Asia.
Europe	CETAF member institutions	15 billion natural history specimens, including of Earth sciences, from over 60 taxonomic facilities in 22 European countries and associated states		The information on the collections that are held in CETAF member institutions is available through the CETAF Institutional Profiles database, see https://www.cetaf.org/services/institutional-profiles
Germany	Herbaria in Germany	22.8 million		
	Museum für Naturkunde Berlin (MfN) - Leibniz Institute for Evolution and Biodiversity Science	27.5 million zoological (recent + paleontological) specimens	>200,000	https://www.naturkundemuseum.berlin/
	Staatliches Museum für Naturkunde Stuttgart (SMNS)	7.9 million botanical and zoological specimens		https://naturkundemuseum-bw.de/en/research/collection
	Fungarium of the Herbarum Senckenbergianum (GLM)	>130,000 fungal specimens		https://www.senckenberg.de/ en/science/research-infrastructure/collections-2/herbarium-senckenbergianum/
	German Collection of Microorganisms and Cell Cultures (DSMZ)	The world's most diverse collection of biological resources (bacteria, archaea, protists, yeasts, fungi, bacteriophages, plant viruses, genomic bacterial DNA as well as human and animal cell lines, >73,700 bio-resources, >28,900 fungal strains		https://www.dsmz.de/collection/catalogue; As a patent depository, it offers the only possibility in Germany to deposit biological material in accordance with the requirements of the Budapest Treaty
	Zoologisches Forschungsmuseum Alexander Koenig, Leibniz-Institut für Biodiversität der Tiere, ZFMK	5.6 million objects, 200,000 DNA & tissue samples / ca. 7,000 primary types	ca. 84,000	

Country name	Collection / institution name and place	Collection size (total number of specimens/samples, type specimens/referenced specimens)	Specimen loans (in 2011-2020)	Remarks, if any
Guyana	University of Guyana Centre for Study of Biological Diversity (CSBD)	Total specimens - app. 10,000 fish, 700 amphibians, 300 reptiles, 350 mammals, 820 birds, over 20,000 insect and 50,000 plant specimens	2018: Whole fish to Royal Ontario Museum	
Malaysia	Herbarium Code: UPM; Biology Department, Faculty of Science (UPM – Biology); Various Collectors Series	~15,000 specimens	Malaysia	Herbarium Code: UPM; Biology Department, Faculty of Science (UPM – Biology); Various Collectors Series
Morocco	Zoological collection of Institut Scientifique, Mohammed V University in Rabat	The reference zoological collection is the most complete, richest and varied collection in North Africa with more than 280,170 specimens representing the different zoological groups from small invertebrates to large vertebrates represented in Morocco in its terrestrial ecosystems, from inland waters and marine waters. Entomological collections (2,440 boxes) of Moroccan fauna, exotic specimens and in 65 boxes of preparations between slide and slide relating to agricultural entomology with many types. >1,000 specimens of wild mammals in the form of samples of skins or skulls, nearly 1,700 specimens of avifauna preserved in the form of skins, and a large collection of eggs and nests. Birds and over 1,200 reptile specimens, fauna of rivers, lakes, dayas, lagoons, estuaries and marine ecosystems.		
	Herbarium of Institut Scientifique, Mohammed V University in Rabat	The botanical reference collection is represented by the National Herbarium which constitutes a fundamental tool for scientific research and its database on the flora of Morocco is unique. It contains more than 160,000 specimens of which 1,100 are Types. It is regularly enriched by an annual contribution of approximately 500 samples. In qualitative terms, this herbarium maintains many types and it is considered the richest for the North African region.		
	Institut Agronomique et vétérinaire Hassan II, Rabat	Over 30000 herbarium specimens were collected throughout the country		
	Herbier Régional 'Mark' de la Faculté des Sciences Semlalia - Université Cadi Ayyad - Marrakech	Total richness: 25,000 specimens (Bryophytes, Lichens, Marine algae); plant seed bank		

Country name	Collection / institution name and place	Collection size (total number of specimens/samples, type specimens/referenced specimens)	Specimen loans (in 2011-2020)	Remarks, if any
Nepal / South Asia	National Herbarium and Plant Laboratories (NHPL)	165,000 specimens	No specimens on loan	http://kath.gov.np/home
	National Herbarium and Plant Laboratories (KATH)	118 type specimens (114 phanerogams & 4 pteridophytes); 700 museum specimens		
New Zealand	The NZ Government through Ministry of Business, Innovation, and Employment (MBIE) is currently reviewing the state and funding of all NZ collections & databases.	Numbers in national collections held by Landcare Research: Plants 620,000; Invertebrates 6.5 million; Fungi 105,000; Living cultures of fungi & bacteria 22,000		Current update of MBIE Collections & Databases review at: https://www.mbie.govt.nz/dmsdocument/5918-scientific-collections-and-databases-review-update-report For Landcare Research's national collections: https://www.landcareresearch.co.nz/search/?tag=nationally-significant-collection
	National Taxonomic Collections in New Zealand Appendices			Pages 8-14 covers all collections by museums and other institutions: https://www.royalsociety.org.nz/assets/Uploads/Appendices-National-Taxonomic-Collections-in-New-Zealand-2015.pdf
Sweden	Swedish Museum of Natural History			https://www.nrm.se/en/16.html
	Biological Museum, Lund University			https://www.biomus.lu.se/en/biological-museum
	Gothenburg Museum of Natural History			https://www.gnm.se/en/
	Herbarium UME, Umeå University			https://www.umu.se/institutionen-for-ekologi-miljo-och-geovetenskap/forskning/herbarium-ume/
	Museum of Evolution, Uppsala University			http://www.evolutionsmuseet.uu.se/besokeng.html
	Various			https://www.nrm.se/ommuseet/samverkansparter/namsa/medlemmar.8516.html
United Kingdom of Great Britain and Northern Ireland	Royal Botanic Gardens, Kew	8,250,000	50,000	Data of Herbarium holdings globally can be found here Index Herbariorum - The William & Lynda Steere Herbarium (nybg.org). For plant and fungal collections see also Paton, A., Antonelli, A., Carine, M., Forzza, R. C., Davies, N., Demissew, S., ... & Jones, M. (2020). Plant and fungal collections: Current status, future perspectives. Plants, People, Planet, 2(5), 499-514. https://nph.onlinelibrary.wiley.com/doi/abs/10.1002/ppp3.10141
	Natural History Museum	62,820,000 specimens (life sciences) / 1,103,000 type specimens in Life Sciences	ca. 280,600 in ca. 120,000 loans	Information on holdings can be found at https://data.nhm.ac.uk/ NHM also hosts visiting scientists, at ca. 6,000 visitor-days per annum
	Royal Botanic Garden Edinburgh	3,000,000 (plants, algae and fungi)	4,000	https://www.rbge.org.uk/science-and-conservation/herbarium/

ANNEX 8

Examples of additional publicly available tools and services relevant for taxonomic identification and work

Country/region	Name of the tool/service	Host institution / organization	Description of the tool	URL
Europe	European Registry of Taxonomic Expertise	CETAF / Pensoft / IUCN	Based on the methodology to identify Red Lists of taxonomic expertise (currently in progress)	
Global	Living Planet Index (LPI)	WWF & ZSL	The LPI is a measure of the state of the world's biological diversity based on population trends/time-series data of vertebrate species (mammals, birds, fish, reptiles & amphibians) from terrestrial, freshwater and marine habitats	https://www.livingplanetindex.org/home/index
	International Code of Nomenclature for algae, fungi, and plants	International Association for Plant Taxonomy (IAPT)	Nomenclatural code for algae, fungi, and plants	https://www.iapt-taxon.org/nomen/main.php
	International Code of Zoological Nomenclature	International Commission for Zoology	Nomenclatural code for animals	https://www.iczn.org/the-code/the-international-code-of-zoological-nomenclature/the-code-online/
Switzerland	SwissBryophytes	Bryophytes	Centre national de données et d'informations sur les bryophytes de Suisse (OFEV)	https://swissbryophytes.ch/index.php/fr/
	InfoFlora	Vascular plants	The National Data and Information Centre on the Swiss Flora	https://www.infoflora.ch/en/

ANNEX 9

Non-exhaustive summary of taxonomic databases

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
Brazil	Brazilian Biodiversity Information System	Darwin Core, EML	Animalia, Plantae, Fungi, Chromista, Protozoa, Bacteria, Archaea; Gaps: mainly microorganisms	Public policies, research and education	https://www.sibbr.gov.br/
	ICMBio: SINTAX - Sistema de Informações Taxonômica	PostgreSQL, Darwin Core, API	Animalia, Archaea, Bacteria, Chromista, Fungi, Plantae, Protozoa	Sintax-java	https://sintax.icmbio.gov.br/sintax/
	JBRJ: Flora of Brazil 2020	PostgreSQL, Darwin Core, API	Fungi, Plantae	Flora of Brazil 2020-Java	http://floradobrasil.jbrj.gov.br/reflora/listaBrasil/
	JBRJ: JABOT3	PostgreSQL, Darwin Core, API	Fungi, Plantae	JABOT2 - PHP	http://jabot.jbrj.gov.br/v3/consulta.php
	JBRJ: REFLORA Virtual Herbarium	PostgreSQL, Darwin Core, API	Fungi, Plantae	REFLORA Virtual Herbarium-Java	http://reflora.jbrj.gov.br/reflora/herbarioVirtual/
Caribbean (Western Atlantic and Gulf of Mexico)	Atlantic and Gulf Rapid Reef Assessment (AGRRA), Ocean Biodiversity Information System (OBIS)	Darwin Core	Reef communities	Marine systems	https://obis.org/#/node/23
China	Chinese Academy of Sciences		All	Integrated database of scientific information	https://bio-one.org.cn/
	Chinese Virtual Herbarium (CVH)	Darwin Core	7 million specimens of plants	Digital plant specimens query	https://www.cvh.ac.cn
	Biological collections of Chinese Academy of Sciences	Darwin Core	9.46 million collections	Search for CAS biological collections	http://www.casbrc.org/committee/specimencenter
	Species Catalogue of China (Col-China)	–	44,905 species of plants in China	Plant name usage query	http://www.sp2000.org.cn
	Plant Photo Bank of China (PPBC)	–	37,532 species of plants in China	Plant photo query	http://ppbc.iplant.cn
	Chinese Academy of Sciences	Catalogue of Life	Animalia, Bacteria, Chromista, Fungi, Plantae, Protozoa, Viruses	Catalogue of Life, China	http://www.sp2000.org.cn/
	Institute of Zoology, Chinese Academy of Sciences		Animalia, Fungi, Plantae	Map of Biodiversity	http://map.especies.cn/
	Fungarium of Institute of Microbiology, Chinese Academy of Sciences (HMAS)	Standard for checklist data of fungi	15 phyla, 56 classes, 192 orders, 585 families, 3,534 genera, 26,642 species	Checklist	http://nmdc.cn/fungarium/

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
China	Fungarium of Institute of Microbiology, Chinese Academy of Sciences (HMAS)		584,042 fungal names at all ranks	Name register	http://www.fungalinfo.net/
China (Shanghai, Jiangxi, Jiangsu, Tianjin, Fujian, Shaanxi, Heilongjiang and Liaoning)	Provincial Virtual Herbarium (PVH)	-	Vascular plants from different regions	Provincial plant checklist and digital plant specimens query	http://site.nsii.org.cn/pvhindex.html
Colombia	DATAves	Darwin Core	Aves	Bird observation data	https://sibcolombia.net/socios/red-nacional-observadores-de-aves-rnoa/
Côte d'Ivoire / Africa	Université Jean Lorougnon Guédé	Research/ Education	Amphibians (information gap concerns DNA barcoding)	Capacity-building	https://www.ujlog.ci/formation.php
Europe, Asia, El Salvador	Virtual Herbaria JACQ	ABCD 2.06	Botany	Museum specimens	https://herbarium.univie.ac.at/index.htm
Europe Mediterranean Area, Caucasus	Euro+Med PlantBase	Darwin Core, EDIT Common Data Model	Vascular plants, bryophytes to be included in 2021	Taxonomic checklist with distribution data at country level based on published literature	https://www.emplantbase.org/
Germany	BfN: FloraWeb		Vascular plants (ca. 3500 spp.)		https://www.floraweb.de/
	BGBM (+ 14 partners: Virtual Herbarium Germany		Herbarium specimens from German institutions (ca. 440,000)		http://vh.gbif.de/vh/
	SysTax- Database System for Systematics and Taxonomy (Univ. Ulm)		1.1 million data sets, including 77,377 images	Storage and administration of an unlimited number of collections (herbaria and zoological collections)	http://www.biologie.uni-ulm.de/systax/
	ZFMK: Digital collection catalogue	ABCD / GGBN	Animals (>500,000 data sets), insects, vertebrates, biobank	Diversity Collection and Diversity Taxon Names	https://collections.zfmk.de
	German Mycological Society (DGfM)		approx. 3.6 million distribution data, >10,000 images and information on >13,000 fungi spp.	From this, assessments for Red Lists and responsible species can be derived, for example.	www.pilze-deutschland.de; https://www.dgfm-ev.de/naturschutz-und-kartierung/kartierung
Germany, Europe	Senckenberg Görlitz (and partners): Edaphobase	ABCD	Soil biodiversity, animals (>380,000 data sets)		https://portal.edaphobase.org/
Germany, Global	MfN Berlin: Animal Sound Archive	ABCD	Animal vocalizations, >120,000 recordings (>1,800 bird spp., >580 mammal spp., etc)		https://www.tierstimmenarchiv.de/
Global	AlgaTerra	Darwin Core, EDIT Common Data Model	Micro-algae	An information system for micro algal biodiversity; a synthesis of taxonomic molecular and ecological information	http://www.algaterra.org/

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
Global	Biodiversity Heritage Library (BHL)		Literature on all taxa	The Biodiversity Heritage Library improves research methodology by collaboratively making biodiversity literature openly available to the world as part of a global biodiversity community.	https://www.biodiversitylibrary.org/
	Biodiversity Literature Repository (BLR)	Darwin Core, Taxpub, MODS	Taxonomic treatments, figures, materials citations, taxonomic names and synonyms	Bacteria to plants and animals; Liberation of taxonomic treatments, figures from publication.	http://zenodo.org/communities/biosyslit
	GBIF	Darwin Core	All species	Free and open access to biodiversity occurrence data	https://www.gbif.org/
	Index Muscorum & Index Hepaticarum (Index of Bryophytes)	Missouri Botanical Garden, Field Museum, Chicago and the Conservatory and Botanical Garden of Geneva	Bryophyta, Marchantiophyta, Anthocerotophyta	Nomenclatural references for mosses, liverworts and hornworts	https://www.tropicos.org/home
	International Plant Names Index (IPNI)	The Royal Botanic Gardens, Kew, The Harvard University Herbaria, and The Australian National Herbarium	Nomenclature Code for plants, fungi and algae	IPNI provides nomenclatural information (spelling, author, types and first place and date of publication) for the scientific names of Vascular Plants from Family down to infraspecific ranks. You can search for plant names, authors or publications	https://www.ipni.org/
	Mycobank		Fungi	Mycological nomenclatural novelties (new names and combinations) and associated data (e.g. descriptions and illustrations)	https://www.mycobank.org/
	Natural History Museum (UK) data portal		All taxa	Makes specimen data from the collection freely and openly available	https://data.nhm.ac.uk/
	New York Botanical Garden		A worldwide index of herbaria and staff where 390 million specimens are housed	Index Herbariorum	http://sweetgum.nybg.org/science/ih/

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
Global	PREDICTS: Projecting Responses of Ecological Diversity In Changing Terrestrial Systems (Natural History Museum, UK)		All organisms	Analyses a global database of ecological communities (raw data) to understand how human activities, such as land use, affect local biodiversity worldwide. This understanding lets us estimate the global status of local biodiversity now and under different possible future scenarios - predictions that can inform conservation policy.	https://www.nhm.ac.uk/our-science/our-work/biodiversity/predicts.html
	RBG Kew: Plants of the World Online		Online portal for plant species information held by RBG Kew. With over 8.5 million items, RBG Kew's Herbarium and Fungarium house the largest and most diverse botanical and mycological collections in the world. They represent over 95% of known flowering plant genera and more than 60% of known fungal genera but only 20% of this knowledge is currently online.		http://www.plantsoftheworldonline.org/
	Royal Botanic Garden Edinburgh		Plants, algae and fungi	All databased specimens are freely accessible via the Online Herbarium Catalogue with ability to download images, make loan requests, etc.	https://data.rbge.org.uk/search/herbarium/
	Smithsonian Institution		Generic names for organisms covered by the International Code of Nomenclature for Algae, Fungi, and Plants	Index Nomenum Genericorum	https://naturalhistory2.si.edu/botany/ing/
	World Flora Online (WFO)	Darwin Core	Land plants (flowering plants, ferns, bryophytes)	Comprehensive taxonomic information system on the world's plants	http://www.worldfloraonline.org
	Solanaceae Source		Solanaceae	Solanaceae Source aims to provide a worldwide taxonomic monograph of the nightshade family whose species that are used as food (potatoes, tomatoes and eggplants), medicines (henbane and deadly nightshades) and in horticulture (petunias).	http://solanaceaesource.org/

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
Greece	Flora of Greece	Darwin Core, EDIT Common Data Model	Vascular plants	E-flora including taxonomic backbone, descriptions and keys plus an expert-annotated specimen database	http://portal.cybertaxonomy.org/flora-greece/
Guatemala	USAC Mammals Collection: Museo de Historia Natural de la USAC MUSHNAT	Darwin Core	Mammals (Rodentia, Chiroptera, Artiodactyla, Soricomorpha)	Collection database of specimens (e.g. skin, skull, skeleton, fluid-preserved)	https://www.gbif.org/dataset/fee15ebc-27ce-4aff-b912-2657bbd493d2
Guyana	Centre for the Study of Biological Diversity working with the Guyana Environment Protection Agency	Darwin Core	Only whole specimens of plants, insects, birds, mammals, reptiles and amphibians	Research and Education	CSBD Database, Internal and https://www.gbif.org/country/GY/summary
	Environment Protection Agency	Darwin Core		Decision-making, Research and Awareness	http://biodivguyana.org
International	IUCN SSC Amphibian Specialist Group	Global Amphibian Assessment	Amphibians	Assessing threats to amphibians – habitat destruction and degradation, emerging infectious diseases, climate change, invasive species and overexploitation	https://www.globalwildlife.org/project/global-amphibian-assessment/
Morocco	Flora Maroccana		Flora	Floral species	http://www.floramaroccana.fr
Mexico	UNAM (Instituto de Biología)	Darwin Core and other	Protoctista, Fungi, Plantae, Animalia	Compile curatorial information of national collections of the Instituto de Biología	http://unibio.unam.mx/html/unibio.htm
	CONABIO	Darwin Core and other TDWG standards	Protista, Protocista, Fungi, Plantae, Animalia	Occurrence of species (curatorial, observed, citizen science)	https://www.snib.mx/
Nepal / South Asia	Flora of Nepal		Flora of Nepal encompasses record of all the vascular plants found in Nepal	Publication Related to Nepal Flora (DPR) and (Other institutions)	http://www.floraofnepal.org/
	National Herbarium and Plant Laboratories (KATH)		33,032 digitized specimens	Search Herbarium Plant Database	https://plantdatabase.kath.gov.np/
New Zealand	Hosted by Manaaki Whenua – Landcare Research	XML	Plants, Fungi, Animals, Bacteria, Viroids, Chromista, Virus, Protozoa	New Zealand Organisms Register (NZOR) 154,000 taxon names, 457,000 taxon concepts	http://www.nzor.org.nz/
	Manaaki Whenua – Landcare Research		Plants, Animals, Fungi, Bacteria, Chromists	Systematics Collections Data (SCD)	https://scd.landcareresearch.co.nz/
Norway	University of Oslo	GBIF Norway	All (collections and observations)	Public and private	https://www.gbif.no/
	University of Oslo	DiSSCo Norway	All (collections)	Public and private	https://www.dissco.uio.no/
Sweden	SLU Swedish Species Information Centre	Darwin Core	Biota	Taxonomic database	https://www.dyntaxa.se/

Country/ Region	Name of database/ organization	Data standards	Taxonomic coverage	Application	URL
Sweden	SLU Swedish Species Information Centre	Darwin Core	Biota	Observations	https://www.artportalen.se/
	SLU Swedish Species Information Centre	N/A	Multicellular	Species information and Conservation	https://www.artfakta.se/
	SLU/NRM	Darwin Core	Biota	Biodiversity	https://biodiversitydata.se/
United Kingdom of Great Britain and Northern Ireland	Royal Botanic Gardens Kew	International Code of Nomenclature and TDWG	Global	World checklist of Vascular Plants: Taxonomic checklist	https://wcvp.science.kew.org/
	National Biodiversity Network Gateway		All organisms		https://nbn.org.uk/the-national-biodiversity-network/archive-information/nbn-gateway/
Uruguay	Biodiversidata		Tetrapods, Amphibia, Reptilia, Aves, Mammalia, Vascular plants	Comprehensive biodiversity database	https://biodiversidata.org/en/
Venezuela	Museo del Instituto de Zoologia Agricola, Universidad Central de Venezuela (MIZA-UCV)		Arthropods	Insect occurrence data sets	http://www.miza-ucv.org.ve/

ANNEX 10

Examples of fauna and flora information shared on Internet platforms

Country/region	Fauna/flora project/ initiative	Taxonomic coverage	Application	Platform / URL
Austria	Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK)	Invasive species among fungi, plants and animals	Information and reporting-tool regarding invasive species in Austria	https://www.neobiota-austria.at/
	Naturhistorisches Museum Wien	Fungi, plants and animals	Austrian species that have been registered by means of DNA barcoding	https://www.abol.ac.at/abol-projekt/
	Österreichische Mykologische Gesellschaft	Fungi	Database of Austrian Fungi	http://austria.mykodata.net/Taxa_0.aspx
Brazil	JBRJ	Flora	Flora of Brazil 2020	http://floradobrasil.jbrj.gov.br/reflora/listaBrasil/
	JBRJ	Fauna	Taxonomic Catalog of the Brazilian Fauna	http://fauna.jbrj.gov.br/fauna/listaBrasil/
	Taxonomic Catalog of the Brazilian Fauna (TCBF)	Fauna	List of fauna species in Brazil	http://fauna.jbrj.gov.br/fauna/listaBrasil
	Brazilian Flora 2020	Flora	List of flora species in Brazil	http://floradobrasil.jbrj.gov.br/reflora/listaBrasil
China	Flora Reipublicae Popularis Sinicae	Pteridophyta, Gymnospermae, Angiospermae	Online Flora for vascular plants in China	http://www.iplant.cn/frps
	Shanghai Digital Flora	Vascular plants	Online Flora for vascular plants in Shanghai	http://shflora.ibiodiversity.net/pages/taxon.html
	Institute of Zoology, Chinese Academy of Sciences	Animalia	Chinese Animal Scientific Database	http://www.zoology.csdb.cn/
Côte d'Ivoire / Africa	OIPR	All Animalia	Wildlife conservation of Côte d'Ivoire	http://oipr.ci/
European Union	Natura 2000	Plants & Animals	The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive. The Natura 2000 Viewer is an online tool that presents all Natura 2000 sites. It provides key information on designated species and habitats, data on population sizes and information on conservation status.	https://ec.europa.eu/environment/nature/natura2000/data/index_en.htm
Germany	ZFMK	European Fishes	DiversityWorkbench	https://fredie.eu
	ZFMK/Uni Bremen	European Fishes, Molluscs, Mammals	Biodiversity Data Warehouse	https://biodiv-atlas.de
Global	World Flora Online	Global	Access to digitized Floras	http://about.worldfloraonline.org/

Country/region	Fauna/flora project/ initiative	Taxonomic coverage	Application	Platform / URL
International	Amphibian species of the World 6.1, an Online Reference (American Museum of Natural History)	Amphibians	Compendium of world's amphibians	https://amphibiansoftheworld.amnh.org
Jamaica	Institute of Jamaica	Plantae	Herbarium specimens housed in the Natural History Museum of Jamaica, Institute of Jamaica	http://www.gbif.org
Morocco	E-ReColNat project	Vascular plants	Digitization of herbarium samples	https://www.recolnat.org/en/
Nepal	Flora of Nepal	Plants	Online information of Nepal flora and information about collecting localities	http://www.floraofnepal.org/
New Zealand	Manaaki Whenua – Landcare Research	Flora; Invertebrates; Fungi	Several hard-copy and electronic volumes	https://floraseries.landcareresearch.co.nz/pages/index.aspx https://www.landcareresearch.co.nz/publications/fauna-of-new-zealand-series/ https://www.landcareresearch.co.nz/publications/fungi-of-new-zealand-series/
Nicaragua	Museo Entomologico de Leon (MEL)	Arachnida, Insecta	Terrestrial arthropods (1850-2012)	https://www.gbif.org/
Norway	Norwegian Biodiversity Information Centre	All	Map for locating species records	https://artskart.artsdatabanken.no
Peru/LAC	MINAM	Species diversity	Biodiversity in numbers	https://cdn.www.gob.pe/uploads/document/file/360831/La_ Biodiversidad_en_Cifras_final.pdf
	CITES - PERU	Fauna	Threatened species	https://cdn.www.gob.pe/uploads/document/file/ 475307/Listado_Flora_CITES_Per%C3%BA_2018.pdf
Sweden	SLU Swedish Species Information Centre	Biota	Information about Swedish species	https://www.artfakta.se/
Trinidad and Tobago	Centre for Agriculture and Bioscience International (CABI)	Lepidoptera	Butterfly species data occurrences from 1907 to 1999	https://cloud.gbif.org/bid/archive.do?r=cabilepidoptera
	University of the West Indies Zoology Museum (UWIZM)	Bivalves, Crustacean, Molluscs, Fish, Insects, Reptiles	Species records contained in local collection	https://www.gbif.org/

ANNEX 11

Examples of taxonomic activities, initiatives and projects to be continued or renewed for 2021-2030, subject to review and the availability of financial resources

Country/region	Activity category	Project name (providers/actors)	Outputs and indicator	Costs to initiate / implement / enhance	Funding source
Aotearoa New Zealand	Connecting nature and people	Te Mana o te Taiao: Biodiversity Strategy 2020	Goal 7.2, page 51, link below: An analysis of gaps and future needs, training, capacity-building and job creation are ensuring that enough people have the right skills to protect and manage biodiversity into the future https://www.doc.govt.nz/globalassets/documents/conservation/biodiversity/anzbs-2020.pdf	Subject to annual Government Budget allocations	New Zealand Government
	Connecting nature and people	Biodiversity in Aotearoa – an overview of state, trends and pressures	https://www.doc.govt.nz/globalassets/documents/conservation/biodiversity/anzbs-2020-biodiversity-report.pdf		New Zealand Government
ASEAN member States (AMS)	Enhancing the capacity of the ASEAN member States in using the DNA-based approach in species identification and discovery	Taxonomic Capacity-building on DNA Barcoding of Common Vascular Plants in the Tropics	Improved knowledge and skills of selected staff and researchers of botanic gardens, academe, and research institutions on the use and application of DNA barcoding for taxonomic identification of vascular plants Indicator: Regional training workshop on DNA barcoding and the traditional taxonomic approaches for vascular plants in the tropics conducted; at least 25 staff from the national botanical gardens and academe, and researchers or staff who are responsible for the conservation of native species, received training on the DNA barcoding tool	Proposed project	Japan ASEAN Integration Fund
Belgium	Capacity-building (& awareness-raising) in taxonomy and collection management	Belgian GTI – CEBioS/Royal Belgian Institute of Natural Sciences (RBINS)	Improved taxonomic and curatorial knowledge and capacities of institutions and/or selected researchers in partner countries of the Belgian Development Cooperation Indicators: number of internships in Belgium related to taxonomy and collection management (at least 10 per year), number of taxonomy-based research and training projects of Belgian researchers in developing countries (at least 4 per year), number of workshops/courses focused on improving taxonomic skills (at least 1 per year), number of students/researchers/staff trained, number of new species described, number of *Abc Taxa* manuals published (at least one per year), number of scientific publications (with co-authorship)	Belgian Development Cooperation	Belgium
Brazil	Increase in taxonomic capacity	Protax – National Council for Scientific Technological Development (CNPq)	Continuing training of human resources in taxonomy; filling knowledge gaps about Brazilian biodiversity, digital platforms for microbiological collections, among others.		Governmental

Country/region	Activity category	Project name (providers/actors)	Outputs and indicator	Costs to initiate / implement / enhance	Funding source
Côte d'Ivoire / Africa	Book writing	Atlas of the amphibians of Côte d'Ivoire	Closing an important gap		Own funds/ Other partners
	Research / training / capacity-building	Taxonomy and life history	Production of scientific publications; Training graduate students (MSc and PhD)		Université Jean Lorougnon Guédé/ Other partners
Europe	Research / training / capacity-building	BIOTALENT, open-source virtual learning platform (CETAF, RBINS, EduFor, HNHM, UOC, NHMC)	Production of scientific publications; Training graduate students (MSc and PhD)		ERASMUS+ programme of the EU
	Creating an integrated infrastructure for natural history collections	SYNTHESYS(+)	Collection digitization, digitization workflows and collection access will have improved, and new ways of integrating infrastructure, working on collections together, and sharing best practices and knowledge will have been developed Indicator: Number of funded researcher visits; Number of digitized specimens/ collections; Number of newly developed services/tools/technologies		European Commission
Germany	Address taxonomic impediment	GBOL [German Barcode of Life] (ZFMK)	Vouchers, Publications, genetic barcodes		BMBF – German Government
	Building networks of taxonomic experts in Central Europe	FörTax Project (ZFMK, Univ. Bonn, Taxonomic Societies)	Overview of existing offers on taxonomic education, number of courses, number of participants		BMBF – German Government
Global	E-learning/ blended learning (e-modules, online training material)	Biodiversity E-Learning Platform (United Nations System Staff College (UNSSC))	Website visitors will be able to apply the acquired knowledge on a specific topic in their research or their daily activities related to biodiversity conservation and management Indicator: Number of visitors of the site on a daily/weekly/monthly basis; Number of downloads/ views of a specific module		Japan Biodiversity Fund
	New proposed activity	International Code of Nomenclature for algae, fungi and plants	Revision every six years		International Association for Plant Taxonomy (IAPT)
	New proposed activity	Publishing Taxon and other resources	IAPT publishes the journal Taxon and monograph/book series Regnum Vegetabile		IAPT
	New proposed activity	Research grants to students and early career scientists	Approximately 20 research grants are funded each year	40,000 USD	IAPT
	New proposed activity	Collections improvement grants to small collections	Approximately 10 small collections grants are funded each year	20,000 USD	IAPT
	New proposed activity	Nomenclature short courses	IAPT teaches short courses and workshops on botanical nomenclature, in English and Spanish. In the near future we intend to record the workshops and make them available on the IAPT website		IAPT

Country/region	Activity category	Project name (providers/actors)	Outputs and indicator	Costs to initiate / implement / enhance	Funding source
Global	New proposed activity	Short courses on the taxonomy of selected large families	IAPT intends to develop short courses on the taxonomy, identification, and classification of selected large families that are known to be confusing to botanists. They will be recorded and offered online.		IAPT
Global-Europe	New proposed activity	CETAF-DEST	Young researchers, citizen scientists and users of taxonomic knowledge will be trained in taxonomic techniques, field and identification skills, collections management, digitization tools of collections, taxonomic tools use, nomenclature etc.	60,000 EUR	CETAF member institutions
Malaysia	Research collaboration	Bioprospecting of Malaysian Biological Materials – Plants (MoA KRIBB – UPM)	Herbarium collections, databases, capacity-building (undergraduate & post-graduate); publications (co-authored journal publications, guidebooks); co-owner of new compound patent		Malaysia Government (UPM – in kind: human resources and facilities, State Forestry Departments – in kind: logistics and human resources), Korea Government, (KRIBB –Funds)
Norway	Teaching / training	ForBio – Research School in Biosystematics	15 annual courses focused on taxonomic skills	250,000 EUR/yr	Norwegian Biodiversity Information Centre
	Teaching / training	Norwegian Taxonomy Initiative	Species mapping projects; Identification and description of new taxa	1,000,000 EUR/yr	Norwegian Biodiversity Information Centre
	Teaching / training	BIOSCAN Norway	Species discovery, interactions and symbiomes through DNA barcodes	1,200,000 EUR/yr	Norwegian Research Council
	Teaching / training	NORBINA	Biobank for nature. Genomic grade preservation of biodiversity samples, including eDNA	1,200,000 EUR/yr	Norwegian Research Council
Philippines/ Cambodia	Taxonomic Capacity-building	BIO-PHIL (MfN/ AdMU/NMP)	Established university training courses, exchange of scientists, joint projects	70,000 EUR	DAAD – German Government
Sweden		Swedish Taxonomy Initiative	Research, Taxonomic database, Museum support, Encyclopedia	$5,000,000/ year	Swedish Government
		Swedish Biodiversity Data Infrastructure (SBDI)	Research infrastructure		Swedish Science Council
Viet Nam	Taxonomic capacity-building and establishment of infrastructure	VIETBIO (MfN/ VNMN/IEBR/SIE/ ITB)	Number of Vietnamese trainees, information portal, transferred equipment	123,000 EUR	BMBF – German Government

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