



D6.19 - Activity 6.4, UNIFI-SMA

Climate-related prioritization for the museum's natural history collections (NHCs) and taxa/specimens selection for the "extended digital specimen" descriptors. Digitization of selected NHCs and return of the digital dataset and metadata. Networking of digitized (meta)data



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Author(s) (Partner-OU):	Lorenzo Cecchi, Stefano Di Natale, Enrico Fracassi, Gianna Innocenti, Elisabetta Lori.
Collaborators	Paolo Agnelli, Fausto Barbagli, Luca Bellucci, Marco Benvenuti, Michele Bertoncini, Marta Biaggini, Laura Bonfanti, Paola Camilla Bressani, David Caramelli, Andrea Cerofolini, Simone Cianfanelli, Vanni Moggi Cecchi, Chiara Nepi, Annamaria Nistri, Annamaria Nocita, Giulio Pandeli, Giuseppe Fabrizio Turrisi.
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1. INTRODUCTION

Digitization of Natural History Collections (NHCs), both as imaging/modelling (2D/3D “twins” of physical vouchers) and databasing (basic data and associated metadata), is a priority action to mobilize significant information about bio-geodiversity distribution, thus to assess its dynamics over the widest range of spatial and temporal variation possible. The new Research Infrastructure (RI) DiSSCo (Distributed System of Scientific Collections), which is currently under development and will be fully operational only in 2026, as stated in its homepage, “*aims to create a new business model for one European collection that digitally unifies all European natural science assets, sharing common access, curation, policies and practices across countries while ensuring that all the data complies with the FAIR principles (Findable, Accessible, Interoperable and Reusable data)*”.

Nevertheless, a natural assumption of both DiSSCo RI, while coping with multiple data and providers within the Natural Sciences domain, and the ITINERIS initiative, while aiming to unify standards for data and metadata within a system made up by multiple disciplines and multiple research perspectives, is that tools and workflows devoted to data and metadata cannot work without the data and metadata themselves. This means that a minimum amount of digital objects must be provided, and a minimum set of digitization activities finalized, in order to test and showcase the proper functioning of those tools and workflows. Moreover, the priority way to make a change in the strategic forecasting of natural resources management, while digitization is still in its early stage, is to provide access to as many specimens as possible, instead of getting deep and detailed information from few, selected taxonomic or functional groups.

Based on these assumptions, and despite the infrastructural meaning of ITINERIS put on top of Activity 6.4 (A6.4) goals the achievement and consolidation of shared protocols and policies for data digitization and publication within the Italian DiSSCo community, A6.4 initially focused on data mobilisation itself, then to be channelled as a use case to drive forthcoming activities.

Previously existing landscape analysis of Italian NHCs contents, performed by both the Italian National Association of Scientific Museums (ANMS) on a volunteer basis, i.e. the result of CollMap project (<https://www.anms.it/pagine/contenuto/30/collezioni>), the Italian Network of Botanical Collections (CORIMBO), and the Biomemory project (<https://biomemory.cnr.it/>), suggest that Italian museums and research facilities currently hold more than 30 millions specimens. Even if extraordinarily abundant, available resources in ITINERIS, which mainly impact on personnel and time, only provided opportunity to tackle the digitization, even partial, of a minimum percentage of such an astonishing amount of items: more or less, around 1%. This, unavoidably, leads to the need of prioritizing “what”, based on scoring criteria, i.e., to finally select some collections in respect to others.

In the DiSSCo preparatory phase, both ICEDIG and DiSSCo Prepare projects provided a useful set of such criteria, and defined a rough approach to settle digitization plans within single institutions, based on both theoretical (scientific) and practical (logistic, financial) elements (Bakker & al. 2018, Ahl & al. 2023). Nevertheless, coping with these criteria at a national level, i.e., trying to prioritize collections by comparison of museums assets and, meanwhile, and reaching smart agreements on the methodological approaches and reciprocal commitments with other colleagues and collection managers can represent a significantly harder step toward the final goal. Indeed, as shortly illustrated further on in the text (Chapters 2.2 and 2.3), one of the main lessons learned during the activity is that what can be actually digitized in a limited time window cannot turn out but from a trade-off of speculative and pragmatic factors.

According to the project initial goals, the activity has been carried out in order to achieve the mobilization of new data from as many as 90.000 labels and images from 300.000 specimens, through a job equally distributed along the 24-months ‘operative-phase’ span. In addition, the existing databased/imaged records already stored in the Collection Management Systems (CMSs) of other Italian NHCs, as well as a number of other catalogue resources available, such as published spreadsheets, or even structured textual list of specimens, were started to be mapped to accomplish the technical readiness level needed to join the DiSSCo Data Management Plan requirements.

Based on the mainly methodological purposes of this effort within the ITINERIS project framework, imaging and databasing have been as much as possible performed for each main taxonomic group, from microorganisms to upper plants and vertebrates, even if with a priority focus on climate-sensitive groups (as described in Section 3), on those major reference collections that match the maximum scientific relevance with the minimum costs in terms of logistic solutions (as described in Section 4), and on their mainly non-marine distribution (with complementarities in respect to 6.6 Activity led by CNR-ISMAR-VE). Whenever the first digitization effort has been much more focused on imaging than databasing, it can drive forthcoming AI tools and/or citizen-science projects devoted to data extraction from the imaged labels.

Methodological and strategic aspects have been always shared with people involved in the other two DiSSCo-related UOs, i.e., with colleagues from CNR-IBBR, CNR-IRSA and CNR-ISMAR institutes, and data managing details will be fully described in Deliverable D6.4 “Shared protocols and best practices for acquisition, organization, standardization and long-term maintenance of (meta)data related to NSC; set-up of the centralized IT platform including a bioinformatic toolbox with web-GIS and modeling facilities”, next to be released by CNR-IBBR-BA.

Beyond the internal complementarity of WP6 members activities, the core action of A6.4 has been carried on in tight connection and collaboration with digitization activities planned and performed within the National Biodiversity Future Center (NBFC) Spoke 7 program, an initiative that was equally funded thanks to PNRR (Next generation EU) funds. Despite the sharp complementarity among the two initiatives (see Section 4 for further details), the additional digitization actions performed within NBFC, which will allow to increase the total amount of digitized specimens in Italy to around 6% of the total by the end of 2025, are only accounted here when resulting from shared personnel/equipment resources with ITINERIS.

Once shared on global and open-access platforms, such as the Global Biodiversity Information Facility (GBIF, <https://www.gbif.org/>) and the Earth Science Collections Portal (GeoCASE, <https://geocase.eu/>), such an enormous - and increasing - amount of data will provide a very significant contribution to both Botany, Microbiology and Zoology and other related disciplines, such as Climatology, Ecology and Geosciences.

1.1. Purpose of the document

The present deliverable was to be released to accomplish with ITINERIS Intermediate Objectives no. 6.7 (IO6.7). It is the final output of A6.4 “Italian natural history collections (NHCs)”, carried on by UNIFI-SMA, aimed to provide biodiversity (meta)data linked to Italian natural history collections (NHCs). The main outputs of such an activity, i.e., the data and images mobilised from over 300.000 Italian museum specimens, primarily feed the DiSSCo-ITINERIS data center developed by CNR-IBBR and near to be fully described in D6.4. Then, the latter will represent an entry point for data that will circulate and be shared at national and international level and will be accessible by the scientific community all over the world.

1.2. Why digitize?

The digitization of NHCs provides multiple benefits that can differ based on the main goals of the single stakeholders. A primary benefit is accessibility: converting properties from the physical collection into a digital format, while following shared standards and protocols, enables it to be easily and instantly findable and accessible to a worldwide audience, both researchers and the general public, overcoming the limits of human capacity to analyse and compare by relying on a robust, persistent, universal machine-readable set of information. Another significant advantage is the facility to search: the information linked to digitised specimens allows a more accurate and efficient retrieval of pertinent details. This boosts research output, promotes cooperation among academics and institutions and, notably, eases integration with additional collections, making each single contribution (a whole collection, a partial dataset or even data from a single specimen) much

more informative than it would have been *per se*, as an isolated element. Conservation is another important benefit of digitization: digital copies reduce both the requirement for physical handling of specimens, decreasing the chances of deterioration, and the expenses associated with maintenance and transport. Furthermore, as digital access boosts interest in physical specimens, in-person visits can be arranged more effectively, making the interaction more focused and essential. Another benefit comes from the digitization process as every single specimen needs to be inspected, cleaned and prepared for the image acquisition step. This activity allows the digitization staff to detect any conservation issues and eventually intervene promptly. In general, digitizing collections enhances access and research opportunities while fostering innovation and knowledge growth in crucial fields like biodiversity conservation, climate change, and human health.

1.3. The national and international context

The history of collections “digitization”, in a very broad sense, is rooted in the antique needs of humans to name and classify objects in synoptical arrangement of concept and data and, more recently - since the first artistic or scientific collections were created during the Renaissance - in the common practice to write, and - seldomly - publish inventories and catalogues. Despite the concept of “digital twin” is very often used to suggest its modern meaning, the transfer of information from a physical to a digital medium never consists of an actual copying and/or replacing activity, but just a modelling, or a partial representation of some specific properties that integrate and improve the accessibility to that object.

Indeed, digitization interprets in the contemporary world the original spirit of the Illuministic museums, that of getting people (scholars, students and others) the freest possible access to heritages, thus improving their informative and educational potential. The museums themselves, even from their historical, traditional perspective, broke down physical time and space barriers, both between natural objects and the visitors and between different natural objects themselves, from each other, by collecting them in a single place, open to the public. By digitizing and publishing data the same purpose is aimed to be achieved: to further reduce these distances, which are no longer only those of space and place, but also those of language (digital data can and must obey the same “standards” and follow the same ontology), and are no longer only those between audiences and objects, or between objects, but also those between museums, making it more irrelevant, from the scientific perspective, even the concept itself of multiple and separate collections.

The NHCs digitization, in a broad sense, probably started worldwide around 40-30 years ago, at the beginning just as a tool to support the internal managing activity of the curators. Most of the projects only started with local and short-term perspectives, with scarce attention to standardization and scarce persistence of the resulting files. In other words, the importance of basic principles such as “public access” to data and “open science”, that are now at the base of Next Generation EU initiatives, were widely neglected, or underestimated. Later on, digitization also began to be means to ensure the FAIRness of data and images, but most initiatives, especially in Italy, have been until recently scattered, heterogeneous and somehow “small”. Moreover, with some important exceptions - mainly for the botanical collections and mainly supported by private fundings - digitization very often did not include imaging.

In 2001, GBIF was established to integrate together all biodiversity-related information, either derived from human observations, publications, or museum specimens. It directly answered to the recommendation by the Biodiversity Informatics Subgroup of the Organization for Economic Cooperation and Development's Megascience Forum, a panel of the Organization for Economic Cooperation and Development (OECD), concluding that an international mechanism was needed “*to make biodiversity data and information accessible worldwide*”, thus enabling users “*to navigate and put to use vast quantities of biodiversity information, advancing scientific research ... serving the economic and quality-of-life interests of society, and providing a basis from which our knowledge of the natural world can grow rapidly and in a manner that avoids duplication of effort and expenditure*”.

No matter how much the “Digital Specimens” (DSs) publication rate significantly changed, and grew, during the last few years, also enhanced by technological progresses in massive-digitization tools performance, the creation of GBIF itself represented a turning point in this field. GBIF is still an essential reference infrastructure and data aggregator in the world of biodiversity data providers which, to date, hosts and enables the virtual “exploration” of data from something like 3,121,682,350 occurrences (number updated on 19th June 2025).

As for data standardization, it also had to face contrasting models (such as the European ABCD/EFG - a relational model which stands for “Access to Biological Collection Data” and “Extension for Geosciences” - standard vs. the American Darwin Core one) but, then, the never-ending activity of an international Taxonomic Databases Working Group, nowadays called Biodiversity Information Standards (TDWG, <https://www.tdwg.org/>) provided solid reference tools for databasing in a global perspective.

Some years after GBIF, in parallel with the development and refinement of catalographic standards, other similar initiatives would have emerged, either to focus on specific geographic origin for biodiversity data (such as the Atlas of Living Australia - ALA, <https://www.ala.org.au/> - and the Integrated Digitized Biocollections - iDigBio, <https://www.idigbio.org/> - in the US, both of which still contribute to GBIF as primary data sinks), or to aggregate, in parallel, other kind of digitized resources, such as those deriving from Molecular Biology (as globally represented today by the International Nucleotide Sequence Database Collaboration, INSDC, <https://www.insdc.org/>), Geosciences (GeoCASE) and Scientific Literature (Biodiversity Heritage Library, BHL, <https://www.biodiversitylibrary.org/>).

Meanwhile, a number of metadata repositories devoted to the standardized, digital description of scientific collections themselves, such as Index Herbariorum (<https://sweetgum.nybg.org/science/ih/>), have been settled, which are gradually (and hopefully) converging in the Global Register of Scientific Collections (GRSciColl, <https://scientific-collections.gbif.org/>). The latter was launched in 2016 by extending a work initially started under the umbrella of the International Barcode of Life (iBOL) project (<https://ibol.org/>) but is currently hosted by GBIF itself, thus ensuring a direct linkage between the specimen-level and the collection-level digitization.

Finally, during the second decade of the current century, several international projects launched under the umbrella of the Consortium of European Taxonomic Facilities (CETAF, <https://cetaf.org/>) were “aligned” to feed the preparatory phase for the establishment of a new European RI, DiSSCo, that officialize the role of NHCs holding institutions as research institutes and aims to make them work and cooperate as a unique and cohesive community, i.e., not only from the technical/informatic point of view - by sharing computing tools and platforms - but also for all their other assets, including the physical collections themselves, the facilities and the people with their own scientific and technical expertises. The DiSSCo community has grown up to 23 countries, embedding hundreds, maybe thousands, NHCs holding institutions. Despite only three different countries are needed to create a new infrastructure with the selected European Research Infrastructure Consortium (ERIC) governance model, the first step toward the formal DiSSCo ERIC establishment has been achieved in february 2025 by the submission to the European Commission of a first proposal signed by 8 of these countries. A second step is planned to be accomplished within the end of 2025, with the largest number possible of additional countries among those still excluded, which includes Italy.

As a result of such a long pathway, DiSSCo reached its full maturity. From the technical point of view, this means that DiSSCo will born relying on its innovative, fully operating data architecture (that of the Digital Extended Specimens, DES) and warranting a number of so called “Core services” (https://www.dissco.eu/wp-content/uploads/DiSSCo_community_e-services.pdf), namely: the Authorisation and Authentication Infrastructure (AAI); the Collection Descriptions Dashboard (CDD); the DiSSCo Labs e-service (<https://dissco.tech/labs/>); the European Loans and Visits System (ELViS); the Modelling Framework Policy Self-assessment tool; the Specimen Data Refinery (SDR). In addition, an increasingly large number of additional services is being developed by the DiSSCo community itself to enrich the RI operating value, the very last one being, e.g., the Specimen Label

Automatic Transcription service (SpLAT, <https://www.dissco.eu/dissco-label-text-automatic-transcription/>).

In conclusion, ITINERIS A6.4 (together with A6.5 and A6.6) activity represent a coherent step toward a national and international cooperative landscape that was started to be built several decades ago and is reaching right now its full “explosion”.

1.4. Open accessibility vs. FAIRness

Both Open accessibility and FAIRness aim to increase access information but address different factors: while the first one aims to make the use of digital materials and research free, easier, open and available to all individuals, the FAIR (Findable, Accessible, Interoperable and Reusable) principles focus on arranging data for both human and machine readability, creating well structured datasets following homologated standards, searchable and reusable, even if not necessarily freely available.

Several international projects associated with NHCs place great emphasis on the implementation of FAIR principles to make their data management more effective and accessible to the widest possible audience. With this respect, FAIRness is a pivotal concept for DiSSCo and a wider awareness of it is still one of the main goals to be pursued especially in large and fragmented national communities like the Italian one. There is a need to make existing Italian museum CMSs interoperable with national and international hubs, without losing their particular/local purposes and meaning. Moreover, since the Italian NHCs are also formally acknowledged as cultural heritages, they must be catalogued and managed also within the framework and on behalf of the Central Institute for Catalogue and Documentation (ICCD) of Italian Ministry of Cultural Heritage (MiC).

This forces both the daily and the extraordinary digitization efforts to be aligned, and to ensure that data can be uploaded in single entry-points, without redundancies, and then “flow” in multiple directions. Such an issue has already been dealt with within the Architecture of Knowledge project (ArCo, <http://wit.istc.cnr.it/arco>) following the principles of Linked Open Data (LOD). The effectiveness of data interoperability and their potential, automatic flow between local CMSs and the main reference data “sinks” or “harvester” (namely, the ICCD platform SIGECweb and GBIF) through devoted Application Programming Interfaces (APIs) have been successfully tested, but it’s still to be properly established.

1.5. Collection Management Systems (CMSs)

For the management of NHCs data, local systems offer institutions full control, customization, offline access, making them ideal for specific workflows or sensitive data (e.g., threatened and endangered species localities), but often lack of discoverability, have versatility issues and heavy maintenance implications. Another problem can be that, even within the same NHCs holding institution, different departments adopt individual/personalised management systems. In contrast, centralized systems enhance data accessibility, standardization and collaboration both within the same institution and across institutions, although they may require conformity to strict data standards and involve some loss of control. Older softwares (e.g., Microsoft Excel, Microsoft Access, FileMaker), while stable and familiar to curators and staff, often lack support and integration capabilities, interoperability and scientific-community driven development.

While completing the present deliverable, a survey is going to be finalised by ANMS, on behalf of NBFC, to both improve/integrate the census of Italian NHCs (in respect to CollMap) and to collect additional information about the “digital maturity” of Italian museums. Even if we cannot rely on its results yet, there is evidence (based on existing publications, museums websites and even personal communications) that until very recently most of them still relied on such outdated tools and planned their future activities with the same limited strategies as in the past.

As already stressed, compliance with both the international, scientific communities standards and the specific requirements for national (sometimes even regional or local) repositories and formats,

makes the Italian landscape particularly hard to be tackled with this respect. Increased awareness about such constraints and the need to work toward a new technical readiness is maybe the main reason why the ITINERIS A6.4 was impactful even beyond the single, limited digitization actions. This has been basically achieved through outreach and training activities, especially the training course for the curators held in spring of 2024 in five different cities (see 3.1.2 Paragraph) and the one which is going to be held by the Meta company, in two dates (early July 2025 and October 2025) on a specific CMSs designed to comply with ICCD rules (see 3.1.4 Paragraph).

1.6. OpenDS and MIDS

Since DiSSCo RI is still to enter its operative phase, some details of the so called “Open Digital Specimen” (openDS, <https://github.com/DiSSCo/openDS>), i.e., the “digital twin” of the natural objects that is aimed to represent the hub collecting and networking each single linked datum, is still to be refined. Nevertheless, the DiSSCo data model was mature enough, at the beginning of ITINERIS project, not to represent a limiting factor to practical choices related to data structuring and management. Biological “events” such as collection data on museum specimens can be properly described with simple spreadsheets by means of the Darwin Core standard (DwC, <https://dwc.tdwg.org/>). In addition, most of existing or predictable needs to enrich the datasets including replicable properties, as in the typical “relational databases” familiar to museums curators, have been recently (2024) allowed through the so-called “Darwin Core extensions” (<https://rs.gbif.org/extensions.html>; see also D6.4 from ITINERIS Activity 6.5, led by CNR-IBBR-BA).

Together with imaging, databasing is one of the two integrated activities of the digitization process. Depending on the depth of data transcription from the physical/analogical support (typically, a label) to a digital spreadsheet, that is the number of ontologically different fields that can be valorized in a defined spreadsheet, it can be from relatively quick process to an even much more time-consuming one than imaging. Choosing the degree of such a depth is one of the crucial aspects of digitization planning: it can vary from a collection to another, depends on available resources and, of course, provide a different insight and a different machine-readability of the digital object.

In extensive digitization activities, accuracy is often much more important than precision, if both cannot be achieved together, and a large amount of barely digitized specimens can be preferable in respect to a small sample of perfectly described ones. The reasons why such a quantitative, instead than qualitative, approach should be chosen, especially from the point of view of data providers, are basically two: 1) each shared datum can be enriched through an unlimited number of further updates (so that such a choice is never a definitive one); 2) the data enrichment can be significantly more efficient (both faster and more reliable) if many people are allowed to access the digital resources, even if roughly represented at the beginning of the refining process.

Artificial Intelligence is providing, and will increasingly provide, powerful tools to automate this transfer of information “from paper to silica”, but we’re still far from a condition where databasing depth will completely lose its influence on digitization costs. Until there, limiting the number of information to be transferred (i.e., of spreadsheet fields to be filled) is an unavoidable aspect to be evaluated to both reduce these costs and improve the number of items whose interpretation can be profitably outsourced (e.g., by means of citizen-science programmes).

As for “depth” of databasing we refer to another milestone concept developed within TDWG, that of Minimum Information about a Digital Specimen (MIDS). Four different MIDS (MIDS0, MIDS1, MIDS2 and MIDS3) levels have been defined so far, all of them as an output of decades of discussion and testing. That on MIDS is a still open discussion and a stable ranking of “specimen digitization quality” (i.e., a smart quantitative/qualitative way to perform landscape analysis, to build digitization dashboards and to draft digitization plans) is not yet completely achieved. Nevertheless the substantial meaning and application of MIDS was already quite clear and easily transferable to their propermost usage in the ITINERIS pilot digitization programmes. It has been defined as follows:

- MIDS0 = Bare - A bare or skeletal record making the association between an identifier of a physical specimen and its digital representation, allowing for unambiguous attachment of all other information. Allows for unambiguous attachment of all other information and to allow a user to discover the location of the physical specimen to access additional information or to request access to the physical specimen.
- MIDS1 = Basic - A basic record of specimen information enabling basic discoverability as well as how the user is permitted to use the data. Creates a digital representation of the physical collections. Provides information about the number of specimens present for a taxon as well as some information about the kind of object, enabling curators and other users to find the specimens within the collections. Also enables costing calculations for storage, digitisation and other curation activities. If imaged, it also enables similar search and browsing capabilities online as researchers and curators would have at the cabinets of physical specimens.
- MIDS2 = Intermediate - A regular level of information including data that have been agreed over time as essential for most scientific purposes. Key information fields that have been agreed over time as essential for most scientific purposes.
- MIDS3 = Extended - An extended level of information about a specimen including identifiers enabling connections to be made to other data present or known about the specimen. Enables linked open data.

The most recent assessment for the four MIDS levels “diagnostic” properties (fields) is provided on GitHub (<https://tdwg.github.io/mids/information-elements/index.html>). Roughly, we can say that most of partially database specimens from museums (e.g., those referred to a given geographic context without full collection locality transcription) reach at least MIDS1 level (a “pre-catalogue” *sensu* ICCD), while MIDS2 overlaps with the concept of “catalogue” level in traditional ICCD standards.

2. MATERIALS AND METHODS

2.1. Selection of taxa and collections

2.1.1. General criteria

Based on the complete unavailability of travel funding to plan an extensive external digitization activity, the biological collections held by the Natural History Museum of Florence, which is part of UNIFI-SMA, have been the main target of A6.4 since the beginning. Luckily, since the absolute size of collection was also a main drivers for this choice (more abundant and less heterogeneous data are more impactful for any kind of analysis), this did not turn out to be a real limiting factor, in contrast with a theoretical priority list drafted by respect to the national landscape, because Florence collections are by far the more abundant in most taxonomic groups and, usually, also those spanning the longermost time interval for collection dates.

The “terrestrial biosphere” mentioned in WP6 title was another factor leading our first steps toward the selection of collections, targeting those that could have been mostly represented by land or freshwater representatives. As for the “climate-related prioritization” addressed in the present deliverable, biological collections including taxonomic groups sensitive to climate variations (amphibians, birds, small mammals, freshwater fishes, terrestrial and freshwater molluscs, terrestrial crustaceans, terrestrial annelids and other worms, bryophytes and lichens) and/or coming from geographic or habitats with a sharper “fragility” (such as inner water bodies or soil), has been preferred, together with those known to include many specimens with similar provenance (typically, from Italian territory), which ensures a finer representation of their different distribution along time

and space. Indeed, it is quite hard to rank different organisms based on their presumably higher or lesser sensitivity to climate variations, so that absolute number of specimens per taxon is relevant for the choice.

Despite the abovementioned leading criteria, the physical organization of most collections makes it necessary to “cut” them in a “vertical mode”, instead of on the basis of functional (e.g., ecological) or geographical criteria. In other words, collections were selected trying to maximize the number of included specimens from the targeted domains (terrestrial biosphere, climate-sensitive, Italian territory), but none of the “outsiders” was excluded, because the specimens are usually organised following taxonomic arrangements and such a selection would have implied a single-specimen check with inconceivable and nonsense slowing of the process.

2.1.2. ITINERIS-NBFC collaboration

With the perspective of resource sharing between ITINERIS and NBFC (namely, instruments from ITINERIS, personnel from NBFC), a wider scenario was opened in February 2024, with the potential inclusion of all the Italian NHCs holding institutions in the preliminary overview of digitizable and worthy-to-be-digitized collections. As a consequence, a joint scientific commission, established by NBFC with the participation of ITINERIS representatives, tried to agree on a number of predefined selection criteria, in order to draft a priority list based on objective elements. The CollMap database was screened to assign each of the main (larger) collections scoring values related to their age (temporal coverage), size and the number of type specimens. The main issue turned out to be almost unsolvable, when we also tried to evaluate, in a reasonably short time, more practical properties that were not (or not enough) included in that survey, but could have significantly affected the final priority list. These are aspects related to the collections management (e.g., if there are noticeable legal constraints to access or borrow and transfer the collections elsewhere, or how many curators/technicians could have assisted the activity), logistics (geographic distances, accessibility, conservation status and handling constraints, timing), ethics (such as different opinion on open accessibility, or on sensitive data) and even individual or institutional engagement (digitization awareness and/or cooperation willingness).

In practice, none of the resulting “top” collections was digitized with that cooperation model. The sole “top” collection that was actually digitized, belonging to the Entomological Museum Filippo Silvestri in Portici (see 2.2.1.2 Sub-paragraph), was included only thanks to ITINERIS resources. The ITINERIS-NBFC collaboration produced concrete outputs only outside the “wishlist”, through some agreements on already planned digitization activities at the peripheral NBFC headquarters, involving ITINERIS instruments.

The final list of newly digitised collection and published datasets is available through the DiSSCo-ITINERIS Metadata Catalog (<https://www.dissco-itineris.it/>), but it's also shown here in the Result section, in Table 2, for practical convenience.

2.2. Equipment

The ITINERIS project marked the first large-scale digitization project initiative at UNIFI-MSN. Prior to this, only scattered and very limited parts of the collections – botanical, zoological, geopalaeontological ones – had been already digitized and there was a lack of infrastructures to greatly increase the numbers. The situation in Florence reflected that of many institutions and museums across Italy. Keeping this in mind and having to face the acquisition of images of an ample variety of biological objects, we planned the acquisition of diverse equipment. The tools (Table 1) were selected to meet several selection criteria: ease of use by different operators, adaptability to specimens of varying size and characteristics, and their preservation methods (e.g., dry, alcohol), and portability across the various sites of the Museum itself and, whenever possible, also toward other Italian museums. Moreover, they were chosen for their suitability for packaging in case of shipping for support loan agreements with the other institutions interested in digitization. The project also

addressed the need for reliable infrastructure to store images and data, as well as advanced tools in microscopy. All the equipment was selected according to the principles of sustainability - such as the electric van, the first of its kind at the University of Florence - ensuring a durable and shareable digitization system.

Table 1 - Purchased tools

Category	Equipment	Function within the digitization project
Computing & Storage	DELL Desktop PCs	Workstations for processing, storing, and managing digitized data
	WD Hard Disks (24 TB)	Secure storage and backup of digitized data
Printing & Labeling	Brother DCP-L2660DW laser printers	Production of documentation, labeling, and paper-based support for digital workflows
	ZEBRA QR code and barcode label printers	Creation of labels for digital identification and traceability of materials and files
Photography & Imaging	Nikon Z50 and Z6II cameras (with Nikkor lenses)	High-resolution photographic digitization of objects, documents, and cultural materials
	Manfrotto tripods and Kaiser copy stands	Stable support for cameras and scanners during image acquisition
	Bresser softbox lighting kits and Havox lightboxes	Lighting for photographic digitization processes
Scanning Devices	Bioshare conveyor-driven imaging lines for herbarium sheets and pinned insects	High-resolution automated digitization
	3D laser and structured light scanners Artec (Leo, Spider and Micro)	Three-dimensional digitization of objects, artifacts, and volumetric materials
	BookEye overhead book scanner	Non-invasive digitization of bound books and documents (flat or V-shaped opening)
Microscopy	Epson V850, Epson DS-5000N scanner	High-resolution scanning of photographs, films, and transparent materials
	ZEISS microscopes (Discovery 2.0, AxioScope 5 and 7) with Axiocam cameras	High-precision digital acquisition of microscopic samples for scientific or conservation purposes
	Dino-Lite handheld digital microscopes	On-site digital analysis and documentation of surfaces, materials, and fine details

Logistics	Ford E-Transit van	Sustainable transportation of equipment and staff for mobile digitization activities or off-site projects
Consumables	Batteries, memory cards, replacement lamps, paper/ink rolls, camera bags, colorchecker	Operational support to ensure continuous and optimal functioning of digital equipment (scanners, cameras, printers)

2.3. Digitization rooms adaptations

At the Italian Central Herbarium the planned work included the restoration or replacement of all the windows on both the first and second floor; additional interventions involved either the replacement or new installation of air exchange systems (fans and passive windows); a siphon with a fan have been installed for air exchange. Electrical system updates have been made in Room 4 at the first floor and plasterboard walls dismantled at the second floor in the entrance hall room.

At “La Specola”, the maintenance included repainting rooms in the Ichthyological Collection area following water and humidity damages and the electrical system has been checked and renovated. The room that hosts the Zeiss microscopes and slide scanners has been painted and all the electricity sockets and Wi-Fi connections renovated. New furniture has been arranged in these rooms, for full access to curators and researchers.

2.4. Personnel

Three fixed-term technicians were hired on a fixed-term basis for a period of two years. Two of them mainly worked on the zoological collections at La Specola museum, one on the botanical ones at the Italian Central Herbarium.

All the selected collections’ curators of the Natural History Museum of Florence have been involved in the digitization activities to ensure that the work was carried out properly and to participate in any assessment of the conservation status or recovery/fixing activities of specimens. At the University of Naples Federico II, the personnel of the Centro Museale "Musei delle Scienze Agrarie" - MUSA and the Dipartimento di Agraria were available during the various steps of the organization and the execution of the digitization period performed at the Reggia di Portici (Naples).

Four fellowship holders, involved in a parallel digitization project funded by NBFC, worked on NHCs at both the Botanical and Zoological section of Natural History Museum of Florence.

Two of them firstly focused on the digitization of a very significant 19th century entomological collection by Roger Verity, secondly they put their efforts in developing a system of both automatized numeration and identification of specimens taxa and transcription of specimens labels based on AI technology. The other two fellowship holders worked at the Botanical section on the digitization of historical herbaria, acquiring images and creating new databases at a basic level, or integrating previously existing databases.

After the training activities, several participants have used the ITINERIS instruments by means of using the instruments *in loco* or through loan agreements, to obtain the digitization of 100 specimens from their collections. Such effort will result in a data paper in preparation.

2.5. Imaging and databasing

2.5.1. Digitization planning

Even before that most of available project funding were available, and the first hiring and purchasing procedures could have been finalised, an attempt was made to both test the the best approach to digitize each single Florence target collection and to quantify the relative digitization

rate. Despite the hard-to-handle alcohol fish collection was used as minimum threshold speed reference, and despite the rough estimate for such speed (80-100 specimen imaged per hour) was even halved to secure a reasonable digitization plan over the available project working-months, theory was finally contradicted by practice, with significant slownings caused by unpredictable constraints and disturbing factors.

This efficiency loss was compensated by the much higher digitization rate achievable thanks to multiple specimen shooting/scanning which characterized some of the larger collections, i.e., the cryptogamic herbarium (where several specimens are usually arranged on the same sheet), parts of the ichthyological and amphibian collection (multiple specimens in the same jar) and, mostly, the entomological collections (up to hundreds of specimens in a single box).

After univocal encoding the concerned institutions, collections and subcollections have been checked and encoded in order to be unambiguously mirrored on GRSciColl (Table 2).

2.5.2. Digitization workflow

Before imaging it is worthwhile to check the preservation status of specimens in order to evaluate if some pre-digitization actions are required, which span from simple cleaning to a complete restoration. The sole pre-digitization action that cannot be avoided is ensuring that the concerned specimens are provided with their own persistent identifiers (usually, an alphanumeric code that should physically accompany the specimen itself). If needed, the coding can be extended to the related containers (boxes, folders, jars etc.), in order to provide an unambiguous hierarchical structure to the associated metadata. Whenever an inventory or catalogue number already exist and, eventually, a digital databasing already occurred to some extent, before imaging, there is no need to add a new series of codes, unless the pre-existing one can lead to ambiguities (e.g., when multiple sub-collections with parallel coding are merged).

Then, the digitization workflow does not significantly vary from a collection to another in its main steps. After physically picking up the specimens from their containers, they are moved to the digitization facility/rooms. Then the specimen is imaged (by a simple camera, or a photo-stacking system, or a 3D scanner, etc.) and both the image/graphic file or set of files and the record in a related catalogue spreadsheet are accordingly named, usually with the same code as the one written on the specimen, in order their encoding leads to their unequivocally linkage to the physical object (i.e., its databasing at MIDS0). After moving back the specimens to their original position, further databasing (filling the other fields in the spreadsheet) can be done. Whatever is the MIDS level planned, it can be usually improved later without taking back the specimen.

Beyond such a general sketch, different shrewdnesses are to be taken to solve specific aspects with each given set of specimens, depending on their location, their physical structure, size and shape, their preservation medium, the position of the label, the need to image them from multiple perspectives, etc.

2.5.3. New digitizations

New digitization initiatives were implemented across various institutions, both through the direct efforts of the three technicians at Natural History museum of Florence and Science Agricultural museum in Portici and through digitization activities carried out by other institutions that received equipment via bilateral agreements and by the participants of the training courses.

In each photo taken during this project a number indicating unambiguously the object is clearly readable - enabling MIDS0 and the whole digitization process -, often accompanied by a label with some data (e.g. collector, locality, datum). As these data, photographed together with the specimen, are in most cases partial, we have to look for any support available to reach MIDS1 and to be able later to enrich it.

To transform the data registered in a Microsoft Access database (e.g. the terrestrial and freshwater mollusca, annelids, mammals) into the DwC standard is better to extract the data already organized

in the required columns. The difficulties are represented by the fact that each of these databases (DBs) were, during the years, “personalised” by the curators according to the needs of the collection. The MIDS level that can be obtained reaches MIDS3.

The data of some collections are registered on paper (e.g. Platyhelminthes, Fish, Crustacea, Amphibia), thus initially only MIDS1 data have been reported on an excel file prepared according to DwC standard. To get the rest of the known data associated with each sample, different ways are possible: the data of some families have been published as catalogues several years ago but the original archive is not available anymore; some families are filed on paper cards; some subcollections (e.g. some series of entomological boxes donated by private collectors to the Museum) have no catalogue but many data are registered on the small label under the insect specimen.

A short report of newly digitized collections within A6.4 is provided below, with a short description of their different arrangement and digitization approaches. Collections acronyms, names and Universally Unique Identifiers (UUIDs) are provided as published in GRSciColl (<https://registry.gbif.org/collection/search>).

2.5.3.1. Contribution from Florence

The digitization activities carried out at the Natural History Museum of Florence (UNIFI-MSN) mainly involved two sections: the Italian Central Herbarium, for botanical collections, and the Zoology Section “La Specola” for the zoological ones. Three fixed-term technicians, occupied for a 24-month period, worked on digitizing and cataloging specimens from different selected collections (see 2.2). Furthermore, thanks to the equipment purchased with funds of the ITINERIS project, four research fellows (in the framework of NBFC project) involved in a parallel digitization project contributed to the acquisition of images and data from other NHCs.

The collections of the Natural History Museum of Florence are located in different buildings and the mode of conservation obviously varies between botanical and zoological objects. Therefore, the workflow varies according to several components. Invertebrates and Vertebrates collections are preserved at the Zoological section “La Specola”, while the Botanical collections are kept at the Italian Central Herbarium.

The digitization of the zoological collections is performed using a photo station equipped with a Nikon Z50 camera with a Nikkor Z DX 18-140 lens, black or white cardboard, a color checker, a ruler, and indicators for the collection, including a unique identification code with the acronym of each collection and the catalogue number. For the botanical collections, digitization is carried out using either an HerbScan scanner (Epson 10000XL), with a minimum of 300 dpi resolution, for two dimensional specimens or when necessary a photo station equipped with a Nikon Z50 camera with a Nikkor Z DX 18-140 lens for three dimensional specimens and bound herbaria.

All the images are saved with JPG extension because of storage size problems. Every specimen’s image was renamed with its alphanumeric code and initially uploaded in a shared drive, together with an excel file containing the pertinent data according to DwC standard at MIDS0 for the entomological collection (apart from the type specimens in MIDS1) and at MIDS1 level (ID code, genus, species, lower taxonomic rank when present, type of object (dry/alcohol), and type status for the other zoological collections. All the images are saved with JPG extension/format because of storage size problems. Every specimen’s image was renamed with its alphanumeric code. Data were transcribed in a specific database using MIDS1 level, reporting ID code, genus, species, lower taxonomic rank when present (such as subspecies, variety or form) and, where indicated, either type status or possible type specimen. The following section provides a survey of the digitized specimen collections.

The liverwort collection of the General Herbarium (FI-GEN, <https://registry.gbif.org/collection/c558350a-e9e3-4861-809d-6dd30f970a98>), comprising approximately 25,000 specimens grouped into around 100 bundles, was digitized on-site within the herbarium rooms, on the second floor of Giorgio La Pira headquarter of UNIFI-MSN. The specimens

are part of the Cryptogamic section and include material dating from the early 19th century to the present, with a large portion originating from Levier's Cryptogamic Herbarium.

To optimize workflow, a dedicated digitization station was set up near the collection, equipped with an HerbScan scanner, a PC workstation, and a label printer. Specimens, either mounted directly on herbarium sheets or stored in envelopes, were scanned individually at the MIDS1 level. In cases where sheets contained multiple specimens, each was digitized as a separate image.

A unique alphanumeric identifier (e.g., FI000001) was assigned to each specimen and printed on an adhesive label affixed to the sheet or envelope. When space limitations prevented full image capture, white paper masks were used to cover overlapping parts, ensuring room for the scale bar and color checker. Specimens were occasionally removed from envelopes to allow proper imaging of both the sample and its associated label. When necessary, conservation actions were undertaken, such as replacing or repairing aged paper envelopes and removing or substituting rusted pins. Once all specimens in a bundle were digitized and corresponding metadata entered into a standardized Excel database, the bundle was returned to its original storage location. The digitization process also led to the identification of over 1,000 potential type specimens or original materials within the liverwort collection.

The General helminthological collection of the Natural History Museum of Florence (MZUF-HEL, <https://registry.gbif.org/collection/ed9eaf47-2fb2-4129-8785-069ace83d929>) is located in the Helminthological collection area, organised on some shelves of open racks labeled with an alphanumeric code and a map to easily identify them. About 40 years ago all the samples were decanted from the historical glasses to new jars with tinplate caps, to save historical labels from further deterioration. Every sample is made of 1 or more specimens, kept in alcohol 75% in jars with metal caps. The pre-existing catalogues are handwritten, while the Annelida collection is largely filed on an Access DB and the data vary from MIDS0 to MIDS3.

The Platyhelminthes, representing one of its several sections, were transported in small numbers to the photo lab and relocated to the same position afterwards. The sample has been taken out of the jar and put in a Petri dish with only a little bit of alcohol. After letting the label dry, the material and the labels have been photographed. Then everything has been put back in the jar, topped up the alcohol (75%) level and in many cases changed the cap, as it is subject to rust. For some micro specimens the choice of taking a picture of the whole jar without taking out the biological sample has been made, with the unique identification code clearly readable. The collection is entirely catalogued on paper and for the moment the digitized specimens are registered on a DwC excel file at MIDS from MIDS0 to MIDS1, but it can be expanded in the future.

The digitized annelids are part of Pietro Omodeo's helminthological collection of annelids (MZUF-OMO, <https://registry.gbif.org/collection/805d054f-5293-4eed-a446-779733086ba5>), also known as Omodeo-Rota collection, which was donated to the Museum by the late scientist. His former student, Dr. Emilia Rota, volunteered to continue revising, organizing and checking the preservation status of the specimens. As part of the digitization project, Dr. Rota assigned a number to each of the 2,610 Italian specimens, referencing the corresponding entries in the Access database compiled by the curator of the helminthological collections. In most cases, the material was not removed from the tubes, as the specimens are usually clearly visible through the glass, the catalog number is affixed to the exterior, and opening each tube, sealed with plastic cap and Parafilm, would have been too time consuming. A photo station was set up in the same room, and the data were loaded at MIDS1 level, further improvements are possible since the specimens data are managed on an Access database.

In the Malacological collection of the Natural History Museum of Florence (MZUF-MOL, <https://registry.gbif.org/collection/7be126f4-de22-4f43-a87e-6b222789e986>), almost all the shells of the terrestrial and freshwater molluscs from historical collections are preserved in their original paper boxes, which hold significant historical value: their shape, the color, and the type of cardboard can add information about the original collection donated/sold to the MZUF and the geographical area of provenance. During the last 30 years the material has been cleaned, restored and put into plastic bags to prevent the accidental mixing of the shells and further damage by the dust. They are organized in

chests of drawers according primarily to their systematics and secondarily to the geographic area of collection. The mollusc collection is organized in historical (from 1850 on, till the 1930's) and recent. The digitization has been initially oriented to the dry samples of Gastropoda (labelled with the prefix "MZUF-GC") and Bivalvia ("MZUF-BC") of the historical collection. This includes objects coming from some nineteenth collections donated to or acquired by UNIFI-MSN from: Marianna Panciatici Ximenes D'Aragona Paulucci, Vittorio Pecchioli, Giovanni Caramagna, Vittorio Uzielli. They have been photographed following the systematics order of the drawers. The shells have been arranged to show both apical and apertural vision - when possible, in case the sample was made of more than 1 specimen - together with the historical labels and the printed label from the database with the current catalog's number. The photo set has been set up in the same room. In agreement with the curator some drawers have been rearranged according to a more recent revision of the genus or grouped by provenance, otherwise the samples have been put back in the original position in the drawer.

On the contrary, the non marine molluscs collected in recent years – from the 50's but mostly in the last 30 years – are equipped with labels with a lot of metadata printed directly from the database because, obviously, the registration of data at the moment of the sampling and cataloging has been more accurate. These thousands of samples have been registered at MIDS1 but can reach MIDS3. The samples of the recent collections are preserved in modern paper/plastic boxes and in tubes that have not been included in the photo. The alcohol 75% specimens have been taken out of the jar/vial and arranged clearly in a Petri dish just for the time of the picture then put back in the glass. They are kept in a miscellany according to the sample datum. Sometimes one picture has been taken for the whole batch and for samples made of both dry and liquid specimens, each with its catalogue number.

All the malacological samples are filed on Microsoft Access with all the associated data available, but as a first step only MIDS1 data (genus, species, no. catalogue, conservation method, type level) have been registered on a DwC file and an improvement till MIDS3 is possible.

For the carcinological Collection of the Natural History Museum of Florence (MZUF-CRU, <https://registry.gbif.org/collection/299ca243-4433-4654-858b-f239006c942e>), kept at the first floor of the museum, the same workflow was followed as for the ichthyological collection (see below).

The entomological collections of the Natural History Museum of Florence are systematically organized in alphabetical order by genus and are housed in the "Enrica Calabresi" section on the first floor of the "La Specola" museum. A photo station was installed directly in the room to facilitate digitization. The workflow began with a preparatory step: each entomological box from closed collections was assigned a unique code. To minimize the risk of damaging specimens during handling, the entire box has been photographed as whole. Subsequently, individual specimens were assigned an alphanumeric code through a custom-developed GIMP plugin. To date, digitization efforts have focused on a number of closed and historical subcollections, which are managed separately from the general one, those assembled by the renowned entomologist Piero Abbazzi (1928-2020), Camillo Rondani (1808-1879) and Roger Verity (1883-1959).

The Pietro Abbazzi's entomological collection (MZUF-ABB, <https://registry.gbif.org/collection/8bad6a72-0033-4b60-b6c8-b06f178ff250>) consists of 68 boxes of Curculionoidea mainly from Italy, collected in nearly 60 years of scientific activity during the second half of the 20th century.

The Camillo Rondani's entomological collection (MZUF-RON, <https://registry.gbif.org/collection/bd6c693d-1867-4a39-9af7-ec4e699fd2c4>) is one of the Museum's most important historical collections, was assembled by entomologist Camillo Rondani (1808–1879) and comprises 15,212 pinned specimens kept in 72 entomological boxes, including 279 type specimens of Diptera and Hymenoptera.

The Roger Verity's entomological collection of lepidopterans (MZUF-VER, <https://registry.gbif.org/collection/6f5d0bee-eeeb-4f7a-a98f-90b7573434aa>) is one of the most significant entomological holdings at the Natural History Museum of Florence, comprising nearly 100,000 specimens and over 3,000 type specimens, assembled by Roger Verity through personal collection, acquisition, and exchange in the first half of the 20th century, primarily in Italy -

especially in the Tuscany region and its archipelago. This historically and scientifically important butterfly collection was digitized through the work of two research fellows as part of a parallel project funded by the National Biodiversity Future Center (NBFC).

The Ichthyological collection of the Natural History Museum of Florence (MZUF-PIS, <https://registry.gbif.org/collection/053782f4-c2c1-41c3-9daa-44b23fa2a217>) consists of about 30,000 specimens fluid-preserved, mainly collected between the 19th and 20th centuries and organized in shelves by taxon from orders to species. The collection is located at the ground floor of the museum where it was not possible to set up a photography station, so the samples were transferred to the photography department on the second floor for imaging. The digitization process required removing the samples from the preservation fluid and briefly drying them to obtain clearer images and avoid reflection caused by the liquid. For samples stored in alcohol, the workflow did not include the use of a color checker, as the preservation method often leads to discoloration, making accurate color calibration unreliable. After digitization, the specimens were returned to their jars. When necessary, alcohol was replenished, caps replaced, and a plastic sheet was inserted between the jar and the cap to slow down rusting. Most of the digitized samples belong to the order *Cypriniformes*, a group of particular importance due to its vulnerability to anthropogenic impacts in Italy. The specimen data were recorded in a standardized Microsoft Excel database compliant MIDS1 level.

For the Herpetological collection of amphibians of the Natural History Museum of Florence (MZUF-AMP, <https://registry.gbif.org/collection/78c9dd0a-fdbd-432a-9895-431afaff365d>), located at the second floor of the “La Specola” headquarter, the same workflow was followed as for the ichthyological collection (see above). Such a collection consists of about 26,500 specimens and the majority of them are preserved in liquid. The digitization efforts primarily focused on the *Speleomantes* genus, which is almost entirely endemic to Italy and includes species currently at risk of extinction. All the specimens were collected in the second half of the 20th century. Specimen data are stored in a database compliant with MIDS1 level.

The general theriological collection of the Natural History Museum of Florence (MZUF-MAM, <https://registry.gbif.org/collection/5744f099-c7d2-43ce-be90-04cad3f550d>) consists of approximately 22,000 predominantly dry-preserved samples. Digitization efforts have primarily focused on the pelts and skulls of micromammals, as well as on Italian *Chiroptera* specimens, since mammal samples preserved in alcohol are not well suited for large-scale digitization campaigns, as their wet fur significantly slows down the photography process. Dry samples, which are stored either loose or wrapped in plastic bags and organized into drawers by taxon, are much easier and faster to photograph. They also present fewer handling and preservation challenges compared to fluid-preserved specimens, making them more practical for digitization.

The general ornithological collection of the Natural History Museum of Florence (MZUF-AVE, <https://registry.gbif.org/collection/a4fc30be-1fd7-4e6c-997b-818ba13b57fb>), consists of about 20,000 predominantly dry-preserved samples. The digitization efforts have covered several families, such as *Falconidae*, *Accipitridae*, *Laridae* and others. Notably, the digitization of some specimens holds particular significance, while belonging to extinct or critically endangered species. The workflow applied to the ornithological collections mirrors that used for the mammal collection. Both collections are housed on the first floor of the Natural History Museum “La Specola”. As with the other vertebrates collection, it was not possible to set up a photography station in the same room, so the specimens were transported to the photography department for imaging.

2.5.3.2. Contribution from Portici

The Entomological collections of the Filippo Silvestri Entomological Museum (MUSA-SIL, <https://registry.gbif.org/collection/adbb2e97-e559-4ff2-84de-71091f23dfee>) are housed in MUSA (University Museum of Agricultural Sciences) of the University of Naples “Federico II”. It is located at the Reggia of Portici and contains a huge number of entomological specimens dating back from the second half of the 19th century to present day. The largest part of the collection is made of dried and pinned specimens conserved in entomological boxes. The digitization work was focused on this

type of materials due to very tight deadlines, from 12th to 25th of January 2025, and the need to obtain the greatest number of digitized specimens. The first step was dedicated to familiarization with the collection and a basic reorganization hinged on a previous existing catalog in order to detect any eventual issue and best structure the subsequent digitization workflow. This fundamental action allowed the technicians to count precisely the total amount of boxes and plan a time schedule. Next all the boxes were labelled with a collection code (e.g. MUSA-SIL-B0001) and then the image acquisition step started and took the largest part of the total process. During this activity, whenever possible, all the detected conservation issues have been noted, for example the presence of camphor powder on insects, the repositioning of insect samples detached from their pin, little restorations on damaged boxes, the detection of infestations, even if there is no curator for the collection. However, the best and most precise images possible were acquired.

The workflow used for the entomological collection of MUSA (Federico II University of Naples) was essentially the same as the one applied to the entomological collection of SMA. However, since MUSA and its collections were unfamiliar to the Florentine technicians, a few additional steps were required.

The first step was a preliminary survey to assess the logistical options and available spaces. Subsequently, three photographic stations were set up in a room adjacent to the Silvestri collection, located on the first floor of the Reggia di Portici. The team then followed the same protocol previously adopted in Florence: assigning a code and number to each of the 1,245 boxes. This process was time-consuming, as it also provided the opportunity to better organize the 23 cabinets according to a catalogue in which some of the subcollections had already been registered. Despite a tight schedule, the team decided to invest time in reorganizing the boxes, recognizing it as a valuable opportunity to improve the overall condition of the collection.

Each box was photographed and then returned to its original position. Opening each box for photography also proved beneficial, as it allowed for a full inspection of the preservation status, with any signs of damage or infestation being reported to the responsible staff.

The photographic stations were then relocated to the second floor of the Reggia, where the Miscellany collection is housed. Again, the three technicians worked in parallel, numbering the 1,191 boxes across 14 cabinets, checking their conservation status, taking photographs, and returning the boxes to their respective shelves.

Upon returning to Florence, the metadata registration phase began. Each image was renamed using the alphanumeric code assigned to the corresponding box. Working on duplicate image files, each specimen was then assigned a number using a post-processing software plugin.

The complete set of images (both original and annotated with specimen numbers) will be delivered to the curators of the collections. Having photographs of every entomological box represents a highly valuable resource that will significantly streamline future tasks such as checking or locating specific families or genera.

2.5.3.3. Contribution from out-sourced collections

In March 2025 two small collections - the herbarium (TPCP-BOT, <https://registry.gbif.org/collection/51ce3464-fec8-45f0-92da-04331735a3fe>) and the Paolo Maltzeff's entomological collection (TPCP-MAL, <https://registry.gbif.org/collection/74f2057d-5242-4fb9-ac09-31dc5c2b6bb4>) - from the Presidential Estate of Castelporziano, Natural State Reserve since 1999, were brought to UNIFI-MSN in order to be digitized. Although small in size, both the botanical and entomological collection are of significant importance, as they consist exclusively of specimens collected in the area of Castelporziano and within the park of the Presidential Estate, an area that, especially in recent years, has been under observation due to habitat loss and degradation associated with climate change-related impacts. The images of the 160 herbarium sheets have been acquired with the BookEye 5 overhead scanner, while the 57 entomological boxes have been digitised following the protocol already used for the other entomological collections.

Another botanical collection, the Andrea Batelli's Herbarium (PERU-BAT, <https://registry.gbif.org/collection/ae929672-e498-42b0-9913-2d3835388cba>) from the University of Perugia, has been recently transferred to Florence to start the testing phase of Bioshare herbarium digitization system. This herbarium was assembled between the late 19th and early 20th century and contains approximately 15,000 specimens. The collection is currently housed in one of the rooms of the Italian Central Herbarium of Florence and will be digitized in the coming months using the Bioshare digitization system, permanently installed on the second floor of the Herbarium of Florence.

2.5.3.4. Contribution from ITINERIS-NBFC shared resources

The entomological collections housed at the Natural History Museum of the University of Florence play a crucial role, as part of the Spoke 7 project of the National Biodiversity Future Center (NBFC). These collections provided a wealth of data that is valuable for conservation purposes and for improving knowledge of Italian biodiversity.

Focusing on two notable historical entomological collections, a workflow has been developed to maximize the efficiency, quality, and detail of the data. The protocol started with the acquisition of an image of each entomological box as a whole using a Nikon Z50 digital camera with the aid of a lightbox station; each specimen is then uniquely coded using an automatic GIMP plug-in developed in Python and, finally, a corresponding QRcode is generated with a Zebra ZT231 printer as a single permanent identifier (PID). Each alphanumeric code included the acronyms of the museum and collection and a unique number (e.g., MZUF-VER-000001) which, together with its physical location, represented the lowest level of MIDS (Minimum Information on a Digital Specimen) information, as defined by TDWG (MIDS0).

The second step involved a higher level of digitization. Selected specimens of particular relevance (e.g., type series) underwent complete digitization with individual photographs, complete transcription of labels, and critical review of data with georeferenced information, taking into account original specialist publications (MIDS2/3).

This workflow was initially tested on two collections: the Roger Verity collection (mainly European Lepidoptera from the 20th century) and the Camillo Rondani collection (Diptera and Hymenoptera from the 19th century). Over a period of approximately nine months, two operators digitized the two collections to MIDS0 level, for a total of approximately 140,000 specimens, and began MIDS2/3 digitization of the type series in the Verity's collection (approximately 4,000 specimens). The next step will be to standardize the data according to the DwC and publish it on an open-access biodiversity data platform (e.g., GBIF).

The workflow proved to be well structured and efficient for the large-scale digitization of the two entomological collections examined. This approach is therefore recommended for "closed" historical collections, particularly those containing a significant number of types, ensuring the cataloging of specimens, which is useful for current management, and the detailed digitization of key specimens, which is useful for dissemination and research, keeping in mind that the digitization of data and multimedia content from natural history museum collections is particularly important for data management and sharing, enabling remote access to specimens. Nevertheless, even "open" collections can be managed with this approach as well, providing that both the curator(s) and the other persons allowed to get access to the boxes are aware of it and can accordingly ensure that a physically printed label with the alpha-numeric code always follows its related specimen whenever it's moved elsewhere.

As for the botanical collections, since the parallel running of a mass-digitization project of NBFC (led by the Padua University) would have completely processed the main herbaria kept in Florence, two analogous photographic workstations have been specifically devoted to a number of remarkable historic collections whose arrangement, format and conservation status would have prevented a speed and automatic processing of specimens. Most of these specimens have been encoded by mean of a

post-processing of images, in order to alter their original integrity, or the printed labels were simply placed, not glued, to the sheets.

2.5.3.5. Contribution from loan agreements

Photographic stations made up of a camera Nikon Z50 with Nikkor Z DX 18-140 lens, a copy stand, a softbox lighting kit, colorchecker and a qr-codes printing machine were provided to interested institutions holding NHCs through 6/12 months bilateral agreements, in order to spread and encourage digitization activities.

Despite the achievement of these agreements suffered a slowdown due to a number of bureaucratic and logistic constraints, within the project lifetime five of them have been successfully finalized: one with the Verona's Natural History Museum, for the digitization of the renowned Abramo Massalongo's lichenological collection; one with the Scientific Service of Abruzzo, Lazio and Molise National Park based in Pescasseroli, for the digitization of both the botanical and zoological collections documenting the protected area biodiversity; one with the Lucca Botanical Garden, which is going to provide a significant contribution from several historical herbaria kept within the botanical collections known as "LUCCA"; one with the Natural History Museum in Genoa, which will rely on a number of volunteers' effort to also work on botanical collections; the latter one with the Department of Earth and Marine Sciences of Palermo University, which will be devoted on digitization of outsourced important historical biological collections from the Enrico Pirajno di Mandralisca's Museum in Cefalù and from the Museum of Natural History of the Ragusa-Kiyohara-Parlatore Institute of Higher Education in Palermo.

2.5.3.6. Contribution from the training course

All training courses participants were asked to provide both images with IIIF standard and data in DwC format at least from 100 specimens from their collections of expertise, in order to obtain a certificate of completion of the digitization course. A total of 37 participants provided the required materials and the data will subsequently be published in a joint data paper.

2.5.4. Pre-existing data aggregation

The already digitized collections show a wide range of cataloging methods. Some collections have data fully registered on a DB and the relative unique code/number on the sample, some have samples that haven't been studied yet.

Case study: *The Annelida of the collection Omodeo-Rota.*

The Annelida Oligochaeta collection by the well known zoologists Pietro Omodeo (1919-2024) and his pupil Emilia Rota has been donated to the Natural History Museum of Florence in 2018. The 5 cabinets host nearly 4200 samples from Italy and the rest of the world. The data of each sample was listed on an excel file without a number and the curator of the helminthological collection at La Specola transferred the data on the Access DB already created for the general Annelida collection to better manage them. Dr Emilia Rota sometimes volunteered in her free time to revise the taxonomy, and to amend the DB. The digitization process was the opportunity for her to start again taking care of the collection, adding the necessary step of putting on the sample glass a label with the number of the entry in the DB. Doing so, the digitized sample did not require the technician to dedicate to any preparatory cataloging phase, but the digitization had to be stopped at the point where the check and the labelling of the material had arrived (about 1500/2600 samples from Italy).

2.6. Publishing

Datasets derived from the digitization process are published on GBIF as a list of “occurrences” using the Darwin Core (DwC) standard to ensure interoperability and adherence to the international data publishing protocols. The publication was carried out through the Integrated Publishing Toolkit (IPT) instance managed and shared by the Institute of Biosciences and Bioresources of the National Research Council (IBBR-CNR), a platform that facilitates the standardized mapping, publication of metadata and occurrences records. Taxonomic names were aligned the GBIF taxonomic backbone (<https://www.gbif.org/dataset/d7dddbf4-2cf0-4f39-9b2a-bb099caae36c>) to enhance discoverability and facilitate integration with global data resources. Associated specimen images were uploaded separately to the CNR-IBBR’s MinIO (<https://min.io/>) object storage platform, with stable image URLs integrated into the Darwin Core “associatedMedia” field, allowing continuous access and visualization of digital records directly through the GBIF portal. All published data and media were released under a Creative Commons license (CC BY-NC 4.0), ensuring open access while respecting attribution requirements.

2.7. Training

2.7.1. 3D scanner training course

In February 2024, the first of two sessions of the 3D scanner training course was held, including a theoretical lesson and a practical demonstration of the operation of three different scanner models (Artec Leo, Micro and Spider) purchased as part of the ITINERIS equipment. In October 2025, a training course of two days will be organised again on the scanners, one for each instrument. The lessons are held by the retailer of the product with practical face-to-face courses, with real specimens to be scanned.

2.7.2. BioShare digitization system training course

In April 2025, the first conveyor-belt system for automated digitization of botanical specimens, provided by the BioShare company, was installed in the Webb’s Herbarium room at the Botanical Section of UNIFI-MSN. All system features and capabilities were demonstrated during training sessions attended by curators from various sections of UNIFI-MSN. The system enables the digitization of approximately 1,200 to 1,500 herbarium specimens during an 8-hour work shift, depending on the type of material being processed. Before digitization, each specimen must be labeled with a QR code. The conveyor system requires two operators: one stationed at the beginning of the belt to load the specimens, and another at the end to reassemble the bundles. The system will remain permanently stationed at the Italian Central Herbarium and will be made available to other institutions wishing to digitize their own collections, upon the establishment of specific agreements. In June 2025, the second digitization conveyor system by BioShare, dedicated to the entomological collection, was installed and tested in the entomology room of the Zoology Section of the Natural History Museum.

2.7.3. MetaFAD training course

The training course organized by MetaFad was focused on illustrating the main features of the metaFad system of collection data management, beginning with a introduction to ICCD and its updated cataloging standards, covering the ICCD data formats available (AT, BDM, BNB, BNM, BNP, BNPE, BNPL, BNZ, D, F, FF, OA, PST, S) and the simplified data entry forms designed for specific types of records and objects including ethnographic materials, zoological and botanical specimens, paleontological samples, drawing, photographs and artworks. The training also addresses

the use of authority files, with closed and open vocabulary, to ensure easier data entry and compliance with ICCD standards, as well as the implementation of the repeatable supplementary form. Features for mass import/export of existing Excel or CSV files have been demonstrated, alongside methods for accessing, editing and managing the graphical interface both for back-end and front-end users with multi-tenant management of digital display available to all museums and institutions adopting the system.

2.7.4. Itinera digitization training course

Between May and June 2024, the company ITINERA Formazione ETS organized two-days theoretical and practical free training courses on the digitization of NHC specimens in five Italian cities (Padua, Turin, Florence, Naples, and Palermo). These courses were aimed at museum staff, curators, and students, with the purpose of introducing and teaching participants on the techniques of digitizing NHC specimens, both from a theoretical and practical perspective. During theoretical lessons several topics about digitization have been addressed, such as an overview of the national and international context regarding the digitization techniques and the management of data from naturalistic collections, both national and international validated standards of cataloging (i.e. ICCD) databasing (i.e. DwC standard), image acquisition (i.e. IIF) and data standardization (GRSciColl). The practical lessons covered the operating principles of cameras, image acquisition techniques, and preferred settings for acquiring different types of specimens; demonstration of acquisition of images from several naturalistic specimens with different features, followed by post-processing phase through dedicated softwares (Adobe Lightroom, Adobe Bridge, Gimp). As the final part of the training course, in order to encourage digitization activities in as many Italian NHCs as possible, it has been proposed a pilot initiative involving the collection of images and data from at least 100 naturalistic specimens per participant.

3. RESULTS

3.1. Digitization outcomes

The main contribution here is represented by the digitizations (either imaging or databasing) performed by the ITINERIS staff, both from Florence University Natural History Museum collections and from the outsourced collections (Castelporziano, Perugia and, overall, Portici).

The effort from the four fellowship holders hired within the NBFC initiative is also accounted here, since they could digitize several historical collections using photographic workstations purchased with ITINERIS funds and were trained and supervised by the ITINERIS staff.

A synoptical overview of newly digitized collections within A6.4, either as a pure ITINERIS contribution or as a shared contribution with NBFC, is provided in Table 2.

Table 2 - A summary of newly digitized collections within A6.4, with indication of their overall size, the amount of digitized specimens and the MIDS level reached. Collections acronyms, names and UUIDs as published in GRSciColl (<https://registry.gbif.org/collection/search>). As for the resources contribution, "I" means ITINERIS, "I/N" means a shared effort from ITINERIS (tools and scientific revision) and NBFC (personnel).

Collection	Total no. of specimens	No. digitized specimens	% digitized specimens	MIDS level	Resources
FI-A01 Anonymous herbarium I https://registry.gbif.org/col	39	39	100%	M1	I/N

lection/fb1df67e-7814-4f78-b3e3-47bfe03acf95					
FI-A02 Anonymous herbarium II CG https://registry.gbif.org/col/lection/54a22ff5-957b-403e-9750-6c3a9e4ba8d1	184	184	100%	M1	I/N
FI-A03 Anonymous herbarium III vivum https://registry.gbif.org/col/lection/ce116f16-8a43-43f6-bb42-0a2fa4b5d6db	1,603	1,603	100%	M1	I/N
FI-A05 Anonymous herbarium V of algae on large sheets https://registry.gbif.org/col/lection/52bd8143-4586-4a83-9952-e695cc987e75	11	11	100%	M1	I/N
FI-A08 Anonymous herbarium VIII on large sheets https://registry.gbif.org/col/lection/43b02152-4d76-4161-b1d9-d9bbf5db5fbf	51	51	100%	M1	I/N
FI-A09 Anonymous herbarium IX on medium-sized sheets https://registry.gbif.org/col/lection/1391aada-cdb5-4a63-a91a-a9d2751ee709	33	33	100%	M1	I/N
FI-A10 Anonymous travel herbarium X https://registry.gbif.org/col/lection/32118af7-2855-4480-aacf-8f8cc60d8af8	143	143	100%	M1	I/N
FI-A11 Anonymous algarium I https://registry.gbif.org/col/lection/99859de2-9553-4395-803f-731817a29d57	1	1	100%	M1	I/N
FI-A12	6	6	100%	M1	I/N

Anonymous algarium II https://registry.gbif.org/col/df94c5c9-feb5-4bd6-922b-a41feaa71359					
FI-BON Giuseppe Bonanno Filingeri prince of Cattolica's herbarium https://registry.gbif.org/col/bc1631fc-8bc6-4b75-82c6-4d5736d2a7ed	320	320	100%	M1	I/N
FI-BSV Jean Baptiste Bory de Saint Vincent's herbarium - Flore de Fougères https://registry.gbif.org/col/de2f99ca-cd38-486b-8f69-ff31c24da42d	87	87	100%	M1	I/N
FI-CES Andrea Cesalpino's herbarium https://registry.gbif.org/col/ca9a0540-7f8b-49cd-9aed-81f6f73e5693	768	768	100%	M2	I/N
FI-CLT Agostino Coltellini's herbarium https://registry.gbif.org/col/f9b3f3e9-5749-4f66-96ba-98d2fd0cce9d	12	12	100%	M1	I/N
FI-DAR Darjeeling Pteridological herbarium https://registry.gbif.org/col/fbe83473-6ab7-4975-8cb3-b4c404c6bc7a	100	100	100%	M1	I/N
FI-DEM Bartolomeo De Martinis' herbarium https://registry.gbif.org/col/eb259cc3-17ce-4a77-b483-1f0dbb0dc35f	350	350	100%	M1	I/N

FI-FNZ New Zealand pteridological herbaria https://registry.gbif.org/col/lection/95edf3fe-3eb2-4a2e-83e5-c1328a791ffb	264	264	100%	M1	I/N
FI-GEN General Herbarium of the Natural History Museum of Florence https://registry.gbif.org/col/lection/c558350a-e9e3-4861-809d-6dd30f970a98	1,700,000	23,349	1,4%	M1	I
FI-KEM Mary Kempster's herbarium https://registry.gbif.org/col/lection/b89ba504-acf1-431d-9853-402933566004	219	219	100%	M1	I/N
FI-M Micheli-Targioni Tozzetti herbarium https://registry.gbif.org/col/lection/cadf690e-4aeb-4288-a41f-095a57ca8ee2	21,675	21,675	100%	M2	I/N
FI-MA3 Pier Antonio Micheli's herbarium Appendix III https://registry.gbif.org/col/lection/274669a6-04b5-43af-bd02-8e0844d4bd50	111	111	100%	M1	I/N
FI-MIG Pier Antonio Micheli's grasses herbarium https://registry.gbif.org/col/lection/4649b3ec-4507-4022-8737-e78c30443e5f	158	158	100%	M1	I/N
FI-MIM Miscellaneous Pier Antonio Micheli's herbarium https://registry.gbif.org/col/lection/aefef690-613b-40eb-9cb6-c4f6c1b49af7	3,472	3,472	100%	M2	I/N

FI-PET James Petiver's grasses herbarium https://registry.gbif.org/col-lection/ea808d86-899e-4700-ad2c-b5dfc0ad56e8	100	100	100%	M1	I/N
FI-SIM Herbert Simons' herbarium https://registry.gbif.org/col-lection/ff9c68ad-5829-44c8-a5cf-cd045a0d7f1e	149	149	100%	M1	I/N
FI-SIQ Carlo Siemoni's oaks herbarium https://registry.gbif.org/col-lection/bb4372c8-622d-4a90-ac24-b16dd0c3ac53	126	126	100%	M1	I/N
FI-SVE Swedish botanists' herbarium https://registry.gbif.org/col-lection/c4364dbe-427d-423a-ab0b-95def61f196e	9	9	100%	M1	I/N
FI-TOZ Bruno Tozzi's herbarium https://registry.gbif.org/col-lection/d9c817fd-2e31-42e2-872c-72aeb5603c17	133	133	100%	M1	I/N
MUSA-SIL Entomological collections of the Filippo Silvestri Entomological Museum https://registry.gbif.org/col-lection/adbb2e97-e559-4ff2-84de-71091f23dfce	~300,000	183,536	~60%	M1	I
MZUF-ABB Piero Abbazzi's entomological collection https://registry.gbif.org/col-lection/8bad6a72-0033-4b60-b6c8-b06f178ff250	work-in-p rogress	work-in-p rogress	0	M0	I
MZUF-AMP Herpetological collection of amphibians of the	26,500	2545	9,6%	M1	I

Natural History Museum of Florence https://registry.gbif.org/col/78c9dd0a-fdbd-432a-9895-431afaff365d					
MZUF-AVE General ornithological collection of the Natural History Museum of Florence https://registry.gbif.org/col/a4fc30be-1fd7-4e6c-997b-818ba13b57fb	20,000	1282	6,4%	M0	I
MZUF-CRU Carcinological Collection of the Natural History Museum of Florence https://registry.gbif.org/col/299ca243-4433-4654-858b-f239006c942e	50,000	198	0,4%	M1	I
MZUF-HEL General helminthological collection of the Natural History Museum of Florence https://registry.gbif.org/col/ed9eaf47-2fb2-4129-8785-069ace83d929	7,717	153	2%	M0; M1	I
MZUF-MAM General theriological collection of the Natural History Museum of Florence https://registry.gbif.org/col/5744f099-c7d2-43ce-be90-04cad3f550d	22,436	6783	30,2%		I
MZUF-MOL Malacological Collection of the Natural History Museum of Florence https://registry.gbif.org/col/7be126f4-de22-4f43-a87e-6b222789e986	2,800,000	15,149	0,54%	M1	I
MZUF-OMO Pietro Temistocle Omodeo's	4,189	1,537	37%	M1	I

helminthological collection of annelids https://registry.gbif.org/collection/805d054f-5293-4eed-a446-779733086ba5					
MZUF-PIS Ichthyological collection of the Natural History Museum of Florence https://registry.gbif.org/collection/053782f4-c2c1-41c3-9daa-44b23fa2a217	38,000	5,745	15%	M1	I
MZUF-RON Camillo Rondani's entomological collection https://registry.gbif.org/collection/bd6c693d-1867-4a39-9af7-ec4e699fd2c4	15,212	15,212	100%	M0; M1 (type specimens)	I
MZUF-VER Roger Verity's entomological collection of lepidopterans https://registry.gbif.org/collection/6f5d0bee-eeeb-4f7a-a98f-90b7573434aa	99,948	99,948	100%	M1; M2; M3 (type specimens)	N
TPCP-BOT Botanical Collections of the Castelporziano Presidential Estate https://registry.gbif.org/collection/51ce3464-fec8-45f0-92da-04331735a3fe	160	160	100%	M0	I
TPCP-MAL Paolo Maltzeff's entomological collection https://registry.gbif.org/collection/74f2057d-5242-4fb9-ac09-31dc5c2b6bb4	4,409	4,409	100%	M0	I

On the contrary, we cannot provide but a temporarily account of the outcomes of the above-mentioned loan agreements with NHCs holding institutions in Verona, Pescasseroli, Palermo, Lucca and Genova, since they have just been started, or they are still active, and will provide - depending on the variable availability of dedicated personnel - an increasing number of digitizations, which will hopefully significantly grow until the end of the project (October 2025; Table 3).

Table 3 - List of outsourced digitization outcomes, thanks to the equipment loan agreements signed so far. All these contributions are “work in progress” and the effective achievements from these different institutions cannot be evaluated but at the end of the agreements timelives themselves. Collections and institutions acronyms, names and UUIDs as published in GRSciColl (<https://registry.gbif.org/collection/search>). The two Sicilian collections will be digitized thanks to a single agreement signed with another institution, the UNIPA-DiSTeM (Department of Earth and Marine Sciences of the University of Palermo).

Institution	Collection	No. digitized specimens	MIDS level
HBLU Botanical Garden of Lucca https://registry.gbif.org/institution/6d1aaa84-23dc-4ef3-a888-cb6fa19e00e7	LUCCA Botanical Collections of the Botanical Garden of Lucca https://registry.gbif.org/collection/6c4e1dff-6c40-49a1-8c16-675b28f7d872	0	M3
MANDR Enrico Pirajno di Mandralisca Museum https://registry.gbif.org/institution/0ab52381-2cf1-46fb-8037-f820fafb3d24	MANDR-ZOO Zoological Collections of the Enrico Pirajno di Mandralisca Museum https://registry.gbif.org/collection/c2108b08-1dc5-446b-ba6f-c15eb612dce3	0	M2
MCSN Giacomo Doria Natural History Museum in Genoa https://registry.gbif.org/institution/39b86c1e-d1d7-43f9-955c-65a082235be6	GDOR Botanical Collections of the Giacomo Doria Natural History Museum in Genoa https://registry.gbif.org/collection/90b2d95e-45dc-4422-9fad-f4760cb61736	0	M2
MSNIFP Museum of Natural History of the Ragusa-Kiyohara-Parlatore Institute of Higher Education in Palermo https://registry.gbif.org/institution/6c1d6590-2734-428d-ad8a-36f353504782	MSNIFP-ZOO Zoological collections of the Museum of Natural History of the Ragusa-Kiyohara-Parlatore Institute of Higher Education in Palermo https://registry.gbif.org/collection/d4793300-5e83-4ee2-b2e8-c5ae08e90372	0	M2
MSNVR-SA Arsenal headquarter of the Verona Natural History Museum https://registry.gbif.org/institution/c9c1f94d-b370-4dcd-b8e0-bda9658a152f	VER Botanical collections of the Arsenal headquarter of the Verona Natural History Museum https://registry.gbif.org/collection/2e459d74-19aa-4177-84ad-0cb5aa842dce	1450	M2
SSPNALM Scientific Service of the Abruzzo,	PNALM-COT Antonino Cotta's Herbarium	2500	M2

Lazio and Molise National Park https://registry.gbif.org/institution/1527efa0-327f-4d29-817a-8ea261d7f21d	https://registry.gbif.org/collection/207a79a3-78f2-4b60-83ef-38246e2dfd1e PNALM-HER Modern Herbarium of the Scientific Service of Abruzzo, Latium and Molise National Park https://registry.gbif.org/collection/8e64f71f-e733-4309-b19e-43e56db7ba2f		
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Finally, a small but significant input was provided by the training courses.

The participants to the first sessions of the 3D scanner training course were 20 curators and technicians of UNIFI-MSN, who after this course started the 3D scanning of specimens in the Paleontology and Anthropology sections that will likely increase during the forthcoming ITINERIS stabilization phase.

The features and capabilities of the BioShare digitization systems were demonstrated during training sessions attended by curators from various sections of UNIFI-MSN, as well. Feeding these two large equipments during the testing phase provided small amounts of additional digitized images and data, and their delayed settling significantly reduced the short-term perspective (i.e., within the funded project lifetime) of their usage; nevertheless, there are already many pending agreements that will allow UNIFI-SMA to act a service provider (or hosting facilities) to many external users in the next years.

Above all, the digitization training course organized by Itinera, which was attended by 145 participants, has significantly improved awareness and skills of Italian NHCs curators in respect to digitization principles and workflows, provided solid bases for further collaborations and shared experiences and will prompt a spread effort in digitization for the future. Beyond this, a relatively small (3,416) but significant amount of various digitizations were contributed by 35 trainees as final exercise for the course (Table 3), which is aimed to be published as a collective data paper and was a quite astonishing attempt to harmonize together data and images from quite heterogeneous physical objects, including plants, fungi, animals, fossils and even meteorites.

Table 4 - List of additional digitized subcollections providing datasets as final exercise for the digitization course organized by Itinera. All these specimens were digitized at MIDS level 2. Collections and institutions acronyms, names and UUIDs as published in GRSciColl (<https://registry.gbif.org/collection/search>).

Institution	Collection	No. digitized specimens
BDCF Bordano Butterfly House https://registry.gbif.org/institution/4ead6286-eccb-4757-a6fe-937a072c1b71	MUFFFA-OL Holarctic entomological collection of the Butterfly and Moth Museum https://registry.gbif.org/collection/d7bf7604-b407-4df1-88dc-aece83f12546	200
DDL Museo civico Domenico dal Lago di Valdagno https://registry.gbif.org/institution/6e20fcf2-61f3-4daa-916f-6c0eda2d8ecb	DDL-CDL Domenco Dal Lago's paleontological collection https://registry.gbif.org/collection/ffe226e2-aebc-41fa-b5ec-9a30bdb9ca51	100

<p>HBCT Orto botanico dell'Università degli Studi di Catania https://registry.gbif.org/institution/4b091ce7-deee-4512-86df-a56f08952bbb</p>	<p>CAT-FDU Francesco D'Urso's herbarium https://registry.gbif.org/collection/834c31b7-3256-411f-aaea-eb5f9cf8a875</p>	124
	<p>CAT-HGM Modern general herbarium of the University of Catania https://registry.gbif.org/collection/ae43f57d-3a32-46ad-8706-ac7269bd8e8a</p>	204
<p>HBLU Botanical Garden of Lucca https://registry.gbif.org/institution/6d1aa84-23dc-4ef3-a888-cb6fa19e00e7</p>	<p>HBLU-MV Mycological collection in alcohol of the Botanical Garden of Lucca https://registry.gbif.org/collection/4ec9f61c-08f4-4fe7-9051-67e461549025</p>	103
<p>ISPRA-LEB Benthos Ecology Laboratory https://registry.gbif.org/institution/25fcc3eb-d822-494d-9b92-30d9bec5cc35</p>	<p>ISPRA-CBM Marine Benthos collection of the Benthos Ecology Laboratory https://registry.gbif.org/collection/e9db90fc-84b0-45e6-8dc6-17823265a333</p>	139
<p>MCEA Alba Municipal Museum of Archaeology and Natural Sciences Federico Eusebio https://registry.gbif.org/institution/bfc625dc-a842-4a92-b50f-f309d7b70add</p>	<p>MCEA-P Paleontological collection of the Federico Eusebio Civic Museum of Archaeology and Natural Sciences in Alba https://registry.gbif.org/collection/ca910da1-e868-4b90-8892-9f390ea48cf4</p>	109
<p>MCSB Brescia municipal museum of natural sciences https://registry.gbif.org/institution/2e78981b-ff5f-4c08-adb6-2de430f27a53</p>	<p>HBBS-ALGAE Algological collection of the Brescia municipal museum of natural sciences https://registry.gbif.org/collection/b8ac6471-6506-409e-93a6-62bd8752309d</p>	148
<p>MNAV Vicenza naturalistic archeological Museum https://registry.gbif.org/institution/c7dea4aa-9dd4-4109-8b37-8066410cc016</p>	<p>MNAV-MAL-EQ Ermanno Quaggiotto's malacological collection https://registry.gbif.org/collection/94a93608-07e2-43fb-bcf0-3f1c17b4f4b1</p>	200
<p>MPMV Montevarchi Palaeontological Museum https://registry.gbif.org/institution/f3c892ba-c53d-4486-85ce-ddbe9d374f9b</p>	<p>MPMV-GEO Geo-paleontological collections of the Montevarchi Palaeontological Museum https://registry.gbif.org/collection/606e92c0-7873-4714-a91a-b2d076011f56</p>	98
<p>MSNF-GLP Via Giorgio La Pira headquarter of the</p>	<p>FI-A06 Anonymous herbarium VI</p>	139

Natural History Museum in Florence https://registry.gbif.org/institution/42038f96-5978-474c-9b0b-4e92450cd1d8	https://registry.gbif.org/collection/1dad27b0-13f8-4fd5-b43d-7014264396af	
	FI-A07 Anonymous travel herbarium VII https://registry.gbif.org/collection/85181400-657e-4b31-b05c-94e7d1d455a4	327
	FI-CCD Luigi Guglielmo de Cambray-Digny's herbarium https://registry.gbif.org/collection/22bf1556-e85a-4c1e-835e-7c8e9d28ea06	264
MSNF-SPE La Specola headquarter of the Natural History Museum in Florence https://registry.gbif.org/institution/2ecde f02-566f-43f9-bc94-98ae8a44c498	FIPL Planetological collections of the Natural History Museum in Florence https://registry.gbif.org/collection/25d580e3-d4d0-4377-818b-4323ac900398	105
	MZUF-ECH Zoological collection of echinoderms of the Natural History Museum of Florence https://registry.gbif.org/collection/0701faa5-90be-4189-8f79-6cf6817b6fc8	100
	MZUF-INS General entomological collection of the Natural History Museum of Florence https://registry.gbif.org/collection/09eb17a2-b14c-4c0b-93ee-ed178546b968	203
	MZUF-MOL Malacological Collection of the Natural History Museum of Florence https://registry.gbif.org/collection/7be126f4-de22-4f43-a87e-6b222789e986	100
	MZUF-PIS Ichthyological collection of the Natural History Museum of Florence https://registry.gbif.org/collection/053782f4-c2c1-41c3-9daa-44b23fa2a217	101
MCSNM Milan Natural History Museum https://registry.gbif.org/institution/50aa4c1a-cbf8-471d-9ec4-0e865848f354	MSNM-AV Ornithological collections of the Milan Natural History Museum https://registry.gbif.org/collection/5eaaedfb-e993-4338-b0b4-1d6f7c89f257	127
MSNVE	MSNVE-SAC	100

Natural History Museum of Venice Giancarlo Ligabue https://registry.gbif.org/institution/94fe772b-f0a9-4f7c-b00b-27e1a746270c	Pier Andrea Saccardo's bryological herbarium https://registry.gbif.org/collection/2e0af9d4-bfd0-4efc-b0cb-9987cd7067eb	
PCS Pietro Parenzan Museum of Marine Biology https://registry.gbif.org/institution/040ef314-a952-490f-b556-05455a9303c2	MBM-MEP Pietro Parenzan's collection of ecological Malacology https://registry.gbif.org/collection/fdfd37f5-be7f-4ee6-ad31-3bd7bdce0e9c	100
RO Sapienza University of Rome Herbarium Museum https://registry.gbif.org/institution/50423a04-5b46-43dd-a8ad-dcfe84f37115	RO-HSepv Herbarium of the Liege Exchange Society https://registry.gbif.org/collection/05a724e2-7ba8-495e-8c65-f20a0682aef8	108
UNIFE-BOT Botanical Garden and Herbarium of the University of Ferrara https://registry.gbif.org/institution/9dbf8af5-55a4-409f-b2a5-b7f6ed70b02a	FER-CAM Antonio Francesco Campana's herbarium https://registry.gbif.org/collection/a75402ef-1768-4986-8c38-19af2a7ac6bb	307
UNITS-DSV Department of Life Sciences of the University of Trieste https://registry.gbif.org/institution/29195714-48f3-4582-915a-484b43045964	TSB-PHA General phanerogamic herbarium of the University of Trieste https://registry.gbif.org/collection/32168f27-39e9-4d21-a780-6479003dedfc	110
UNIVPM-DISVA Department of Life and Environmental Sciences of the Marche Polytechnic University https://registry.gbif.org/institution/e543ab27-6577-4cc2-9a65-826548cddf63	UNIVPM-SN-ZOO Zoological Collections of the Department of Life and Environmental Sciences of the Marche Polytechnic University https://registry.gbif.org/collection/081e699a-cb04-4a3a-adce-53a3b83802fc	203

The primary focus during the digitization activities has been on producing new data from natural history collections. However, in the coming months, we will also begin refining and standardizing already-digitized data received from minor institutions holding NHCs. Thanks to existing agreements with these institutions, we aim to harmonize their collections data with current standards and prepare it for publication on GBIF, thereby increasing its visibility and scientific value.

We intend to work on already-digitized-data including them in the results on the digitization efforts, but at present we have focused our work on the production of the deliverable on new acquisitions and this activity will therefore be carried out in the final months of the project, with various agreements already in place with several institutions.

3.2. Dissemination

3.2.1. Publications on GBIF

As of the end of June 2025, only a limited number of datasets have been published on GBIF, due to internal technical issues encountered during the data publishing workflow. The remaining datasets (see 4.2), including associated images and databases, are scheduled for publication by October 2025.

The list of already published datasets is provided in Table 4, with their relative UUIDs and DOIs.

Table 5. List of datasets published on GBIF as an outcome of A6.4. Collections acronyms, names and UUIDs as published in GRSciColl (<https://registry.gbif.org/collection/search>).

Collection	Dataset	No. of occurrences	DOI
FI-GEN General Herbarium of the Natural History Museum of Florence https://registry.gbif.org/collection/c558350a-e9e3-4861-809d-6d30f970a98	<i>Mastigophora</i> collection of the General Herbarium of the Natural History Museum of Florence https://www.gbif.org/dataset/0ddaec86-2701-4a2d-8287-71a7cc0a0c26	101	10.15468/jrrmrsv
FI-A05 Anonymous herbarium V of algae on large sheets https://registry.gbif.org/collection/52bd8143-4586-4a83-9952-e695cc987e75	Anonymous herbarium V of algae on large sheets https://www.gbif.org/dataset/dedf8883-3a21-4911-952e-787db35852c5	11	10.15468/8xtfh3
MUSA-SIL Entomological collections of the Filippo Silvestri Entomological Museum https://registry.gbif.org/collection/adbb2e97-e559-4ff2-84de-71091f23dfce	Alfredo Buonocore's entomological collection of lepidopterans https://www.gbif.org/dataset/2cfaa8c2-a9d6-4acabd1b-3077e8a1bd67	13484	10.15468/g89wrj
FI-M Micheli-Targioni Tozzetti herbarium https://registry.gbif.org/collection/cadf690e-4aeb-4288-a41f-095a57ca8ee2	Micheli-Targioni Tozzetti herbarium https://www.gbif.org/dataset/431ad66c-2306-4cf9-9f89-56ced9942f89	21676	10.15468/5t9hyr

3.2.2. UNIFI-SMA website

On the website of University of Florence, in the area dedicated to the Museum System, an explanatory page about ITINERIS has been created. You can find it here <https://www.sma.unifi.it/p1011.html>. The website will be implemented as soon as new information is available, for instance with the list and pdfs of the publications.

3.2.3. Traditional publication

As of today, the ITINERIS project has been cited in congress abstracts (Di Natale & al. 2024, an overview of digitization efforts at the Natural History Museum of the University of Florence through ITINERIS, with oral presentation; Fracassi & al. 2024, a focus on how digitalization under ITINERIS supports research on the evolution of Italy's freshwater fish fauna, with oral presentation; Lori & al. 2024, emphasis on the scientific value of digitizing museum specimens of community interest, including the *Vertigo* project, with oral presentation) and a peer-reviewed Journal Article (Lori et al. 2025), while two further expanded manuscripts are going to be published on the conference Proceedings of XXXIII Congresso ANMS (Di Natale et al. 2024, detailing the broader ITINERIS digitalization initiative at the Natural History Museum of Florence, and Fracassi et al., more extensively discussing the freshwater fish fauna study presented at the congress).

The Florentine team also took part at the 2nd ITINERIS General Project Meeting, 9-10 July 2024, at the CNR headquarters in Rome, with a poster titled 'Digitization of scientific collections for understanding climate change: a case of study from the Natural History Museum of Florence' and at the Final Meeting DiSSCo-ITINERIS, 17-18 June 2025, at the CNR-ISMAR-VE in Venice with three oral presentations: 'ITINERIS digitization led by UNIFI-SMA', 'The Ecosystem Virtual Museum', and 'Digitization of the entomological museum "Filippo Silvestri" at the MUSA in Portici (NA)'.

A recap of our publications is listed on the ITINERIS website page <https://cnrsc.sharepoint.com/sites/CNR-IMAAITINERISprj/Lists/Catalogue/AllItems.aspx?sortField=field%5F4&isAscending=false&viewid=6d5105f5%2D4911%2D46dc%2Da86f%2D10025ebb9b3>.

3.2.4. Congresses

2nd ITINERIS General Meeting, Rome, 9-10 July 2024;
XXXIII Congresso ANMS "Il rapporto pubblico privato nei musei scientifici" [Public-private relations in science museums], Leghorn, 22-25 October 2024;
Final Meeting DiSSCo-ITINERIS, Venice, 17-18 June 2025.

3.2.5. Events

In September 2024, the University of Florence organized a three-days public event titled "Bright Night - Notte europea delle ricercatrici e dei ricercatori". Together with the University Museum System (SMA), the ITINERIS technicians had the opportunity to present and explain their project to the public. The event also featured live demonstrations of the digitization process, showcasing how various types of specimens, both botanical and zoological, brought in specifically for the occasion, were digitally captured and processed.

4. CONCLUSIONS

The initial project plan was, obviously, drawn up on theoretical knowledge about the feasibility of such a huge undertaking. One example of the initial optimism was that, among the various expected results, it seemed natural to set a specific target of 300,000 digitised copies. However, reality presented so many small obstacles that during the first 12 months of active data collection, this number was a source of stress for the digitizers. Some examples of obstacles? One of the three employees hired on a fixed-term contract left the job suddenly after only three months, causing a two-month delay in the digitisation process of some zoological collections; the arrival of various pieces of equipment was delayed by manufacturers or suppliers, causing knock-on delays in the ability to carry out various tasks; the digitisation workflow itself seemed simpler and faster at the beginning, but it was only through experience that it was defined and adapted to the precise and diverse characteristics of each collection. Each problem prompted us to look for an alternative way to

achieve the expected results. For example, the idea that solved the “300,000 problem” came from a new way of digitising the entomological collection, taking a single photo of the entire entomological box and then working on the image.

Digitization is increasingly acknowledged by curators and museum personnel at world level as an essential instrument for both conservation and scientific advancement. Historically, a degree of protectiveness regarding the data associated to the specific collections within their area of expertise often limited the broader dissemination of digitization initiatives. However, there is now growing recognition of the significant benefits of data sharing, which promotes enhanced collaboration, optimizes collection management and facilitates wider accessibility of invaluable, and for long time untraceable, information. As digitization becomes more widely embraced, it reinforces the critical role of Natural History museums in advancing both biodiversity research and cultural as well as natural heritage for future generations, while ongoing technological advances (e.g. automated digitization systems, OCR technologies, AI applications) continue to simplify and accelerate these efforts.

The two-years digitization activities allowed the curators and technicians to examine and investigate extensively specific taxonomic groups of the NHCs. All the data harvested or rearranged will permit a deeper understanding of the collections composition, highlight previously overlooked specimens and support future research, conservation planning and taxonomic revisions. One of the interesting aspects was the overestimation of some collections, with digitization we now have the real numbers, and not a mere estimate.

By the way, with this project we have achieved the new digitization of 397,496 specimens and started an unexpected series of virtuous processes and activities, thus greatly exceeding our main objective.

Despite some incorrect, initial assumptions, the project was useful because it allowed us to become aware of the possible technical limitations and the buildings/institutions in which a digitizer finds oneself working. It was nevertheless useful in beginning to overcome some of the “barriers” that are pushing (or will push) curators to refrain from digitizing and, above all, publishing data.

Our deliverable is intended to encourage reflection in terms of methodology rather than results, hoping to present useful advice to future users.

5. REFERENCES

- Ahl LI, Bellucci L, Brewer P, Gagnier P-Y, Haston EM, Livermore L, De Smedt S, Hardy HM, Enghoff H. 2023. Digitisation of natural history collections: criteria for prioritisation. *Research Ideas and Outcomes* 9: e114548. <https://doi.org/10.3897/rio.9.e11454>
- Bakker HPAJ, Willemse L, van Egmond E, Casino A, Gödderz K, Vermeersch X. 2018. ICEDIG Deliverable D2.1 - Inventory of criteria for prioritization of digitisation of collections focussed on scientific and societal needs. Zenodo. <https://doi.org/10.5281/zenodo.2579156>
- Di Natale S, Fracassi E, Lori E, Biaggini M, Cecchi L, Innocenti G. 2024. La digitalizzazione al Museo di Storia Naturale dell'Università di Firenze: il Progetto ITINERIS. Abstract of the oral presentation at XXXIII Congresso ANMS “Il rapporto pubblico privato nei musei scientifici”. Leghorn, 22-25 October 2024: 15.
- Di Natale S, Fracassi E, Lori E, Biaggini M, Cecchi L, Innocenti G (submitted). La digitalizzazione al Museo di Storia Naturale dell'Università di Firenze: il progetto ITINERIS. *Atti del XXXIII Congresso ANMS*.
- Fracassi E, Bressani PC, Nocita A, Lori E, Di Natale S, Cecchi L, Innocenti G. 2024. L'evoluzione della fauna ittica dulcaquicola italiana: il contributo offerto dalla digitalizzazione delle collezioni del Museo di Storia Naturale dell'Università di Firenze in ambito ITINERIS. Abstract of the poster at XXXIII Congresso ANMS “Il rapporto pubblico privato nei musei scientifici”. Leghorn, 22-25 October 2024: 29.

- Lori E, Di Natale S, Fracassi E, Cecchi L, Innocenti G, Cianfanelli S. 2024. *Vertigo*: il valore della digitalizzazione di campioni museali di interesse comunitario. Abstract of the poster at XXXIII Congresso ANMS “Il rapporto pubblico privato nei musei scientifici”. Leghorn, 22-25 October 2024: 43.
- Lori E, Talenti E & Cianfanelli S. 2025. Prima segnalazione dell’associazione di *Mytilopsis leucophaeata* (Conrad, 1831) (Bivalvia, Dreissenidae) e *Ficopomatus enigmaticus* (Fauvel, 1923) (Polychaeta, Serpulidae) per l’Italia. *Alleryana* 43(2): 41-48.
<https://doi.org/10.53559/Alleryana.2025.06>

6. ACRONYMS

A complete list of the acronyms used in the text.

- A6.4: [ITINERIS] Activity 6.4 [“Italian natural history collections (NHCs)”, led by UNIFI-SMA]
A6.5: [ITINERIS] Activity 6.5 [“Mining and mapping the functional biodiversity in *in vivo* and *ex-situ* research collections”, led by CNR-IBBR-BA]
A6.6: [ITINERIS] Activity 6.6 [“National network of the aquatic science collections”, led by CNR-ISMAR-VE]
AAI: Authorisation and Authentication Infrastructure [DiSSCo service]
ABCD: Access to Biological Collection Data [standard]
AI: Artificial Intelligence
ALA: Atlas of Living Australia
ANMS: Associazione Nazionale Musei Scientifici [Italian National Association of Scientific Museums]
API: Application Programming Interface
ArCo: Architettura della Conoscenza [Architecture of Knowledge] [project]
AT: Anthropological heritage/object [ICCD cataloguing format]
BDCF: Bordano Butterfly House
BDM: Ethnographic heritage/object [ICCD cataloguing format]
BHL: Biodiversity Heritage Library
BNB: Botanical heritage/object [ICCD cataloguing format]
BNM: Mineralogical heritage/object [ICCD cataloguing format]
BNP: Paleontological heritage/object [ICCD cataloguing format]
BNPE: Petrographic heritage/object [ICCD cataloguing format]
BNPL: Planetological heritage/object [ICCD cataloguing format]
BNZ: Zoological heritage/object [ICCD cataloguing format]
CAT-FDU: Francesco D’Urso’s herbarium
CAT-HGM: Modern general herbarium of the University of Catania
CDD: Collection Descriptions Dashboard [DiSSCo service]
CETAF: Consortium of European Taxonomic Facilities
CMS: Collection Management System
CNR: Consiglio Nazionale delle Ricerche [Italian National Research Council]
CNR-IBBR: Consiglio Nazionale delle Ricerche, Istituto di Bioscienze e Biorisorse [Italian Institute of Biosciences and Bioresources]
CNR-IBBR-BA: Consiglio Nazionale delle Ricerche, Istituto di Bioscienze e Biorisorse, Sede di Bari [Institute of Biosciences and Bioresources in Bari]
CNR-IRSA: Consiglio Nazionale delle Ricerche, Istituto di Ricerca Sulle Acque [Italian Water Research Institute]
CNR-ISMAR: Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine [Italian Institute of Marine Sciences]

CNR-ISMAR-VE: Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine, Sede di Venezia
[Institute of Marine Sciences in Venice]
CORIMBO: Coordinamento della Rete Italiana dei Musei Botanici (Coordination of the Italian
Network of Botanical Museums)
CSV: Comma separated value [a file format]
D: Drawing [ICCD cataloguing format]
DB: Database
D6.4: [ITINERIS] Deliverable 6.4 “Shared protocols and best practices for acquisition, organization,
standardization and long-term maintenance of (meta)data related to NSC; set-up of the centralized
IT platform including a bioinformatic toolbox with web-GIS and modeling facilities”
D6.19: [ITINERIS] Deliverable 6.19 “Climate-related prioritization for the museum’s natural history
collections (NHCs) and taxa/specimens selection for the “extended digital specimen” descriptors.
Digitization of selected NHCs and return of the digital dataset and metadata. Networking of
digitized (meta)data”
DDL: Museo civico Domenico dal Lago di Valdagno
DDL-CDL: Domenico Dal Lago's paleontological collection
DES: Digital Extended Specimens
DiSSCo: Distributed System of Scientific Collections
DOI: Digital Object Identifiers
DS: Digital specimen
DwC: Darwin Core [standard]
EFG: Extension for Geosciences [standard]
ELViS: European Loans and Visits System [DiSSCo service]
ERIC: European Research Infrastructure Consortium
EU: European Union
F: Photograph [ICCD cataloguing format]
FAIR: Findable, Accessible, Interoperable and Reusable
FER-CAM: Antonio Francesco Campana's herbarium
FF: Photographic archive [ICCD cataloguing format]
FI-A01: Anonymous herbarium I
FI-A02: Anonymous herbarium II CG
FI-A03: Anonymous herbarium III vivum
FI-A05: Anonymous herbarium V of algae on large sheets
FI-A07: Anonymous travel herbarium VII
FI-A08: Anonymous herbarium VIII on large sheets
FI-A09: Anonymous herbarium IX on medium-sized sheets
FI-A10: Anonymous travel herbarium X
FI-A11: Anonymous algarium I
FI-A12: Anonymous algarium II
FI-BON: Giuseppe Bonanno Filingeri prince of Cattolica's herbarium
FI-BSV: Jean Baptiste Bory de Saint Vincent's herbarium - Flore de Fougères
FI-CES: Andrea Cesalpino's herbarium
FI-CLT: Agostino Coltellini's herbarium
FI-DAR: Darjeeling Pteridological herbarium
FI-DEM: Bartolomeo De Martinis' herbarium
FI-FNZ: New Zealand pteridological herbaria
FI-GEN: General Herbarium of the Natural History Museum of Florence
FI-KEM: Mary Kempster's herbarium
FI-M: Micheli-Targioni Tozzetti herbarium
FI-MA3: Pier Antonio Micheli's herbarium Appendix III
FI-MIG: Pier Antonio Micheli's grasses herbarium
FI-MIM: Miscellaneous Pier Antonio Micheli's herbarium

FI-PET: James Petiver's grasses herbarium
 FI-SIM: Herbert Simons' herbarium
 FI-SIQ: Carlo Siemoni's oaks herbarium
 FI-SVE: Swedish botanists' herbarium
 FI-TOZ: Bruno Tozzi's herbarium
 FIPL: Planetological collections of the Natural History Museum in Florence
 GBIF: Global Biodiversity Information Facility
 GDOR: Botanical Collections of the Giacomo Doria Natural History Museum in Genoa
 GeoCAsE: Geoscience Collections Access Service
 GRSciColl: Global Register of Scientific Collections
 HBBS-ALGAE: Algological collection of the Brescia municipal museum of natural sciences
 HBCT: Orto botanico dell'Università degli Studi di Catania
 HBLU: Botanical Garden of Lucca
 HBLU-MV: Mycological collection in alcohol of the Botanical Garden of Lucca
 iBOL: International Barcode of Life
 ICCD: Istituto Centrale per il catalogo e la Documentazione [Italian Institute for Catalogue and Documentation]
 ICEDIG: Innovation and consolidation for large scale digitisation of natural heritage [project]
 ID: Identifier
 iDigBio: Integrated Digitized Biocollections
 IIIF: International Image Interoperability Framework
 INSDC: International Nucleotide Sequence Database Collaboration
 IO6.7: [ITINERIS] Intermediate Objectives 6.7
 ISPRA-CBM: Marine Benthos collection of the Benthos Ecology Laboratory
 ISPRA-LEB: Benthos Ecology Laboratory
 ITINERIS: Italian Integrated Environmental Research Infrastructure System [project]
 LOD: Linked Open Data
 LUCCA: Botanical Collections of the Botanical Garden of Lucca
 MANDR: Enrico Pirajno di Mandralisca Museum
 MANDR-ZOO: Zoological Collections of the Enrico Pirajno di Mandralisca Museum
 MBM-MEP: Pietro Parenzan's collection of ecological Malacology
 MCEA: Alba Municipal Museum of Archaeology and Natural Sciences Federico Eusebio
 MCEA-P: Paleontological collection of the Federico Eusebio Civic Museum of Archaeology and Natural Sciences in Alba
 MCSB: Brescia municipal museum of natural sciences
 MCSN: Giacomo Doria Natural History Museum in Genoa
 MCSNM: Milan Natural History Museum
 MiC: Ministero della Cultura [Italian Ministry of Cultural Heritage]
 MIDS: Minimum Information about a Digital Specimen
 MNAV: Vicenza naturalistic archeological Museum
 MNAV-MAL-EQ: Ermanno Quaggiotto's malacological collection
 MPMV: Montevarchi Palaeontological Museum
 MPMV-GEO: Geo-paleontological collections of the Montevarchi Palaeontological Museum
 MSNF-GLP: Via Giorgio La Pira headquarter of the Natural History Museum in Florence
 MSNF-SPE: La Specola headquarter of the Natural History Museum in Florence
 MSNIFP: Museum of Natural History of the Ragusa-Kiyohara-Parlatore Institute of Higher Education in Palermo
 MSNIFP-ZOO: Zoological collections of the Museum of Natural History of the Ragusa-Kiyohara-Parlatore Institute of Higher Education in Palermo
 MSNM-AV: Ornithological collections of the Milan Natural History Museum
 MSNVE: Natural History Museum of Venice Giancarlo Ligabue
 MSNVE-SAC: Pier Andrea Saccardo's bryological herbarium

MSNVR-SA: Arsenal headquarter of the Verona Natural History Museum
 MUFFFA-OL: Holarctic entomological collection of the Butterfly and Moth Museum
 MUSA: Musei delle Scienze Agrarie [Naples University Federico II Agricultural Science Museums in Portici]
 MUSA-SIL: Entomological collections of the Filippo Silvestri Entomological Museum
 MZUF-ABB: Pietro Abbazzi's entomological collection
 MZUF-AMP: Herpetological collection of amphibians of the Natural History Museum of Florence
 MZUF-AVE: General ornithological collection of the Natural History Museum of Florence (MZUF-AVE)
 MZUF-CRU: Carcinological Collection of the Natural History Museum of Florence
 MZUF-ECH: Zoological collection of echinoderms of the Natural History Museum of Florence
 MZUF-HEL: General helminthological Collection of the Natural History Museum of Florence
 MZUF-INS: General entomological collection of the Natural History Museum of Florence
 MZUF-MAM: General mammalogy collection of the Natural History Museum of Florence
 MZUF-MOL: Malacological Collection of the Natural History Museum of Florence
 MZUF-OMO: Pietro Temistocle Omodeo's helminthological Collection of annelids
 MZUF-PIS: Ichthyological collection of the Natural History Museum of Florence
 MZUF-RON: Camillo Rondani's entomological collection
 MZUF-VER: Roger Verity's entomological collection of lepidopterans
 NBFC: [Italian] National Biodiversity Future Center
 NHCs: Natural History Collections
 OA: Artwork [ICCD cataloguing format]
 OCR: Optical Character Recognition
 OECD: Organization for Economic Cooperation and Development
 PCS: Pietro Parenzan Museum of Marine Biology
 PERU-BAT: Andrea Batelli's Herbarium
 PNRR: Piano Nazionale di Ripresa e Resilienza [National Recovery and Resilience Plan]
 PID: Permanent identifier
 PNALM-COT: Antonino Cotta's Herbarium
 PNALM-HER: Modern Herbarium of the Scientific Service of Abruzzo, Latium and Molise National Park
 PST: Scientific and technological heritage/object [ICCD cataloguing format]
 RI: Research Infrastructure
 RO: Sapienza University of Rome Herbarium Museum
 RO-HSepv: Herbarium of the Liege Exchange Society
 S: Printout [ICCD cataloguing format]
 SDR: Specimen Data Refinery [DiSSCo service]
 SIGECweb: Sistema informativo generale del catalogo [Italian General catalogue information system]
 SpLAT: Specimen Label Automatic Transcription service [DiSSCo service]
 SSPNALM: Scientific Service of the Abruzzo, Lazio and Molise National Park
 TPCP-BOT: Botanical Collections of the Castelporziano Presidential Estate
 TPCP-MAL: Paolo Maltzeff's entomological collection
 TDWG: Taxonomic Databases Working Group (today: Biodiversity Information Standards)
 TSB-PHA: General phanerogamic herbarium of the University of Trieste
 UNIFE-BOT: Botanical Garden and Herbarium of the University of Ferrara
 UNIFI-MSN: Università degli Studi di Firenze [Sistema museale di Ateneo], Museo di Storia Naturale [Natural History Museum of the Florence University]
 UNIFI-SMA: Università degli Studi di Firenze, Sistema museale di Ateneo [Museum System of the University of Firenze]
 UNITS-DSV: Department of Life Sciences of the University of Trieste

UNIVPM-DISVA: Department of Life and Environmental Sciences of the Marche Polytechnic University
UNIVPMSN-ZOO: Zoological Collections of the Department of Life and Environmental Sciences of the Marche Polytechnic University
UO: Unità operativa [Operating Unit]
URL: Uniform Resource Locator
UUID: Universally Unique Identifiers
VER: Botanical collections of the Arsenal headquarter of the Verona Natural History Museum
WP6: [ITINERIS] Working package 6 “Terrestrial Biosphere”

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