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ITINERIS

The Research Infrastructure DiSSCo-Italy and the PNRR ITINERIS project: advancements, results and prospects

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BOOK OF ABSTRACT

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The Research Infrastructure DiSSCo-Italy and the PNRR ITINERIS project: advancements, results and prospects

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Francesca Maggiore, Lucilla Capotondi, Luciana Ferraro, Elisa Camatti, Laura Giordano, Simona Armeli Minicante, Roberta D'Onofrio, Edoardo Di Russo, Irene Guarneri

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The Research Infrastructure DiSSCo-Italy and the PNRR ITINERIS project: advancements, results and prospects – Technical Program

Tuesday 17th June 2025 - Headquarters: Venice, Institute of Marine Sciences (CNR-ISMAR) Tesa 104, Arsenale2737/f Castello – 30122 Venice, Italy	
10.00-10.30	**Participant registration and welcome coffee**
10:30-10:45	**Institutional greetings *Mario Sprovieri,*** *Director of CNR-ISMAR*
Topic 1 10.45-13.00	**The natural science collections: history, value, new technologies and policies** **Chair: *Lucilla Capotondi,*** CNR-ISMAR
10.45-11.15	***Invited lecture*: Natural Science Collections in Italy: between Scientific Interest and Social Value** ***Fausto Barbagli****, President ANMS*
11.15-11.30	**ITINERIS digitization led by UNIFI-SMA: a pilot experience to promote the mobilization of data from Italian NHCs holding institutions** ***Lorenzo Cecchi****, Stefano Di Natale, Enrico Fracassi, Gianna Innocenti, Elisabetta Lori*
11.30-11.45	**Digital infrastructures and FAIR standards for the management and valorisation of plant genetic resources: experiences from the documentation system of the CNR-IBBR germplasm bank** ***Eleonora Fornaro****, Gabriele Bucci, Marina Tumolo, Domenico De Paola, Massimo Ianigro*
11.45-12.00	**Naturalistic slide collection of Italian Ephemeroptera: the value over time** ***Simona Cislaghi****, Marcello Cazzola, Stefania Erba, Carlo Belfiore, Andrea Buffagni*
12.00-12.15	**ISMAR Collections, from the specimen to the dataset** ***Edoardo Di Russo****, Simona Armeli Minicante, Elisa Camatti, Lucilla Capotondi, Roberta D'Onofrio, Luciana Ferraro, Laura Giordano, Irene Guarneri, Francesca Maggiore, Marco Sigovini*
12.15-12.30	**Linosa Island: from priority benthic habitat to museum collection** ***Laura Giordano****, Roberta D'Onofrio, Edoardo Di Russo, Simona Armeli Minicante, Elisa Camatti, Lucilla Capotondi, Irene Guarneri, Francesca Maggiore, Marco Sigovini, Luciana Ferraro*
12.30-13.00	**Questions and discussion**
13:00-14:00	**Lunch**
Topic 2 14.00-16.00	**The importance of RI DiSSCo in the study of functional biodiversity** **Chair: *Marco Sigovini,*** CNR-ISMAR
14.00-14.30	***Invited lecture:* The study of functional biodiversity: challenges and opportunities** ***Ilaria Rosati,*** *Technologist CNR-IRET*
14.30-14.45	**The digitization as an opportunity to share biodiversity data of natural science collections at the CNR-IRSA of Taranto** ***Loredana Papa****, Antonella Petrocelli, Lucia Spada, Ester Cecere*
14.45-15.00	**Preserving the "seed of resilience": mobilising Plant Genetic Resources** ***Marina Tumolo****, Eleonora Fornaro, Massimo Ianigro, Gabriele Bucci, Domenico De Paola*
15.00-15.15	**Data on the Italian mayfly (Ephemeroptera): a basis for detecting subtle changes in river ecosystem function** ***Andrea Buffagni****, Marcello Cazzola, Simona Cislaghi, Simone Cardoni, Stefania Erba*
15.125-15.30	**Dese collection: recording reproductive traits from the bibliography as functional biodiversity tool** ***Francesca Maggiore****, Edoardo Di Russo*
15.30-16.00	**Questions and discussion**

16:00-16:30	**Coffee break**
Topic 3 16.30-18.45	**The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms** **Chair: *Roberta D'Onofrio,*** *CNR-ISMAR*
16.30-17.00	***Invited lecture:* The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms** ***Diego Fontaneto****, CNR-IRSA*
17.00-17.15	**Incorporating ecological studies into data platforms infrastructures to improve biodiversity information availability** ***Stefania Erba****, Simone Cardoni, Marcello Cazzola, Simona Cislaghi, Vanessa De Santis, Andrea Buffagni*
17.15-17.30	**Digitization of the entomological museum "Filippo Silvestri" at the MUSA in Portici (NA)** ***Stefano Di Natale****, Lorenzo Cecchi, Enrico Fracassi, Gianna Innocenti, Elisabetta Lori*
17.30-17.45	***Enhancing the scientific collections data of CNR-ISMAR through the ITINERIS project*** ***Simona Armeli Minicante****, Valentina Grande, Edoardo Di Russo, Elisa Camatti, Lucilla Capotondi, Roberta D'Onofrio, Luciana Ferraro, Irene Guarneri, Francesca Maggiore, Marco Sigovini, Laura Giordano*
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18.15-18-45	**Questions and discussion**
20.00	**Social dinner**
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Topic 4 9:00-12:30	**The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms** **Chair: *Laura Giordano,*** *CNR-ISMAR*
9.00-9.30	***Invited lecture:* Being a European Research Infrastructure – critical aspects and national strategy** ***Dario Papale****, Director of Research CNR-IRET*
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10.00-10.15	**The Ecosystems Virtual Museum. A bridge between DiSSCo and Lifewatch toward digital object sharing and valorization** ***Lorenzo Cecchi****, Stefano Di Natale, Enrico Fracassi, Gianna Innocenti, Elisabetta Lori*
10.15-10.45	**Questions and discussion**
11:00-12:30	**Round table: Prospects for the development of the RI DiSSCo-Italy. Discussion on the post-ITINERIS project** Speakers: ***Mario Sprovieri*** CNR-ISMAR; ***Diego Fontaneto****, CNR-IRSA*; ***Irene Olivè,*** S Z N ; ***Alberto Basset,*** UNISALENTO, ***G. Matteucci,*** CNR-IBE; ***Luigi Bubacco,* UNIPD; *Fausto Barbagli,*** *ANMS*
12:30-14:00	**Lunch**

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Preface

The present book comprises the abstracts of the oral presentations delivered at the meeting "The Research Infrastructure DiSSCo-Italy and the PNRR ITINERIS project: advancements, results and prospects" organized by the CNR-Institute of Marine Science (CNR-ISMAR). This meeting was supported by the ITINERIS project "Italian Integrated Environmental Research Infrastructures System", which aims to create the Italian Hub of Research Infrastructures (RIs) in the environmental science sector, providing access to data and services. ITINERIS coordinates a network of national nodes from 22 RIs among which DiSSCo (Distributed System of Scientific Collections).

DiSSCo aims to virtually bring together natural science collections and related information held in natural history museums, botanical gardens, research centers and universities into a single Findable, Accessible, Interoperable and Reusable (FAIR) portal at European level. In DiSSCo, the Italian scientific community is represented by the Natural History Museum of Florence University, CNR (National Council of Research), ANMS (National Association of Scientific Museums).

The ITINERIS project, started in 2022, represent the first opportunity for a fruitful aggregation of the institutions holding natural science collections with the same aim: build a core of Italian Natural Science Collections. This is the first step of a path which involved colleagues from the Natural History Museum of Florence, and from three institutes of the CNR: Institute of Marine Science (ISMAR), Water Research Institute (IRSA), Institute of Bioscience and Bioresources (IBBR). The work carried out during these three years has made possible the formation of a cohesive team focused on a shared objective.

The outcomes of the ITINERIS-DiSSCo community are summarized in this book. Each contribution was presented in alignment with one of the meeting's four thematic areas:

- The natural science collections: history, value, new technologies and policies.
- The importance of RI DiSSCo in the study of functional biodiversity.
- The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms.
- Relationships with other Research Infrastructures (Cross-RIs initiatives).

The meeting concluded with a round table where representatives of ANMS, NBFC (National Biodiversity Future Center) and the national nodes of LifeWatch, eLTER (European Long-Term Ecosystem Research), EMBRC (European Marine Biological Resource Centre) were invited to discuss about the possible relationships between infrastructures and their future, and how to attract the new generations in the activity of the RIs.

Venice, Italy, July 31, 2025

The natural science collections: history, value, new technologies and policies

Natural Science Collections in Italy: between Scientific Interest and Social Value

Fausto Barbagli[1,2]

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2 *Natural History Museum of the University of Florence SMA, fausto.barbagli@unifi.it*

Over the past four centuries, the naturalistic significance attributed to specimens has evolved considerably, in parallel with scientific advancements and the emergence of new disciplines. From the Renaissance practice of collecting natural curiosities, the focus shifted to the systematic collection of species with the advent of modern taxonomy. Subsequently, with the emergence of biogeography, specimens from various origins were collected and, as a consequence of the spread of evolutionary theories, collecting began to focus on specimens that documented variability, leading to the formation of long monospecific series. This progressive transformation has resulted in a shift from small-scale collections—featuring one specimen per species—to extensive holdings comprising long series of specimens, shaping the structure of today's museum collections. In the 20th century, the growing interest in the history of science provided additional interpretative frameworks for these specimens, complemented by emerging connections with civil, local, and art history.

However, it was with the advent of the new millennium that further, and arguably more profound, transformations occurred within a relatively short time span, particularly in Europe. In Italy, the enactment of the new Code of Cultural Heritage in 2004 marked a turning point by formally recognizing scientific and natural heritage as part of the national cultural heritage. This legal inclusion extended protection to such collections and redefined the administrative and regulatory responsibilities concerning them. Notably, this recognition did not stem from a widespread awareness of the intrinsic value of scientific collections, but rather from a broader shift in perspective—from the aristocratic notion of "Fine Arts" to a more inclusive and democratic understanding of "Cultural Heritage". Moreover, in 2005, the Council of Europe Framework Convention on the Value of Cultural Heritage for Society was adopted in Faro, Portugal. This multilateral international treaty brought together some twenty European states in agreement on promoting free access to and broader participation in cultural heritage.

As a result, now natural history museums and scientific collections are no longer addressed exclusively to scholars and specialists in the natural sciences, but rather to society as a whole. It is therefore essential to critically examine the new political and cultural orientations, as well as the evolving institutional landscape, in order to ensure the effectiveness of initiatives undertaken by the infrastructures that manage or are otherwise engaged with scientific collections in Italy.

ITINERIS digitization led by UNIFI-SMA: a pilot experience to promote the mobilization of data from Italian NHCs holding institutions

Lorenzo Cecchi[1], Stefano Di Natale[1], Enrico Fracassi[2], Gianna Innocenti[2], Elisabetta Lori[2]

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2 *Natural History Museum of the University of Florence SMA-Zoological Section "La Specola" Florence (Italy).*

Modern Natural Sciences moved their first steps during the Italian Renaissance and the distribution of Natural History Collections (NHCs) in our country, which are estimated to include more than 30 Mln specimens, mirrors the variegate, rich and fragmented cultural background in which they have been established and grew during the last five centuries. The bulk of these collections is undoubtedly represented by biological specimens, an astonishing mass of objects and linked data that can provide an unparalleled observation window on the changes occurred to Italian and Earth biodiversity since the beginning of XVI century. The main obstacle preventing the accessibility to such a heritage is the lack of data mobilisation, from the physical to the digital medium, and/or the lack of proper data structuring and standardization, which is a crucial element for the image and data FAIRness. Digitisation, instead, through imaging and databasing leads to the creation of a wealth of data that, once shared on an open access platform, makes a significant contribution to both Biology itself and other related disciplines, such as Climatology, Ecology and the Geosciences.
From this perspective, the activity 6.4 "Italian Natural History Collections", leaded by the Museal System of of the University of Florence (UNIFI-SMA) within the ITINERIS Working Package 6 "Terrestrial Biosphere", offered an opportunity to both empower a technical networking activity among the museums, and to showcase the effectiveness of tools, standards and workflows to be then shared among them, through a impressive, pilot digitization activity. Due to project objectives and organisational/financial constraints, this effort was mainly focused on selected taxonomic groups, relied on internal staff and limited to collections held by UNIFI-SMA itself, but was also partially extended to some other collections/institutions and, also thanks to a training course addressed to all the Italian curators, the foundations were laid to improve their digitization skills and promote data mobilization from many other institutions an any type of natural specimen, including fossils, rocks and minerals.
The collection selection was made combining maximum scientific relevance, with a priority to terrestrial and freshwater taxa, which are more vulnerable to anthropogenic impacts, with minimum costs in terms of logistical solutions. Non-massive digitisation has been mainly carried on by mean of mobile and versatile photographic workstations made up by simple stands (Kaiser Reprokid KSR5360) with camera (Nikon Z50 and Nikon Z18-140 VR lens), external lights (Bresser BR-225-B) and color checker (Calibrite mini). A number of digitisation kits are provided on loan, through bilateral agreements, to institutions interested in participating in the project.
A standard digitisation workflow was set up based on pre-existing experiences and is basically organized in the following steps: encoding with persistent identifiers, imaging, databasing following the Darwin Core standard. It was later adapted to each specific collection according to the average specimen side, shape and preservation method. Entomological collections have been imaged by boxes and each specimen in them has been encoded by means of an AI tool to get their complete MIDS0/1 databasing with the lesser effort, in the shorter time. A similar post-processing of images has been used for ancient herbaria, where physical sticking of new QRcodes labels to the original sheets could not be used.
During 24 months of three persons full-day work, 385,626 biological specimens have been imaged and

databased at least at MIDS1 level. These include 23,349 bryophytes, 153 platyhelminthes, 15,133 mollusks, 1,537 annelids, 198 crustaceans, 145,464 insects, 5,745 fish, 2,545 amphibians, 1 reptile, 1,282 birds and 6,783 mammals from UNIFI-SMA collections, plus 183,536 insects from the entomological collection "Filippo Silvestri" held at the MUSA museal system in Portici (Naples Federico II University). Additional, thousands specimens are waiting to be fully databased from the Castelporziano presidential estate collections, from the herbarium of Natural History Museum in Verona and from the Scientific lab of Abruzzo, Lazio and Molise National Park in Pescasseroli.

In addition, a free digitization training course was organized to spread the awareness of digitization principles, standards and technical expedients, consisting of a single theoretical lesson, held remotely, and two days of face-to-face and practical activity repeated in five different cities (Padua, Turin, Florence, Naples and Palermo). More than 145 persons attended it and the outcomes of their final, practical tests produced additional 3.600 images and data at MIDS2 level.

Digital infrastructures and FAIR standards for the management and valorization of plant genetic resources: experiences from the documentation system of the CNR-IBBR germplasm bank

Eleonora Fornaro[1], Gabriele Bucci[2], Marina Tumolo[1], Domenico De Paola[1], Massimo Ianigro[3]

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As part of the ITINERIS project, we have developed a digital ecosystem for the management, documentation and dissemination of data on plant genetic resources stored in the germplasm bank at the Institute of Biosciences and Bioresources of the National Research Council (CNR-IBBR). These activities are part of an international initiatives that promote open access to scientific data (Open Science), as well as the adoption of FAIR (Findable, Accessible, Interoperable, Reusable) principles. Particular reference is made to natural science collections and the European DiSSCo (Distributed System of Scientific Collections) network.
The intervention consists of two main components: (1) the creation of a metadata catalogue that complies with international standards for semantic and technological interoperability and is publicly accessible at www.dissco- itineris.it, and (2) the development of an advanced software platform for the widespread management of germplasm bank accessions. This platform is conceived as a modular, containerised and scalable system.

Both the infrastructures are based on a microservice architecture in a Docker environment. The system employs a backend realised in Flask and MySQL, a frontend developed in HTML, JavaScript and Bootstrap, RESTful APIs for asynchronous operations, and an administrative UI based on phpMyAdmin. The reverse proxy Traefik enables centralised routing and security management. Moreover both of them are designed to enable the structured consultation of accession data in accordance with the DarwinCore standard.

The DiSSCo-ITINERIS site provides a comprehensive catalog of Italian naturalistic collections, encompassing 77 collections and 65 datasets, totaling over 119,000 digitized specimens. The Data Center interface offers advanced search and filtering tools, allowing users to perform text searches and apply filters by sample type, preservation method, geographical origin, taxonomy, and other key metadata. Each collection is cataloged with complete details, including identification codes, preservation methods, number of specimens, and publication on GBIF. The portal also offers a Search Datasets section for published occurrence datasets, listing all datasets with their respective counts and filters for origin, affiliated institution, dataset type, and thematic keywords. An integrated Download Center lists all available datasets and allows users to download data in various formats (DwC-A, JSON, XML) or access publication endpoints. RSS/XML and JSON feeds are also provided for automated access to the updated list of published datasets. This unified platform allows researchers to easily explore national natural history collections, view their metadata, and obtain raw datasets for in-depth analysis through a single intuitive web interface.

DiSSCo-ITINERIS uses international standards for sharing naturalistic data, including the Darwin Core (DwC) standard for biodiversity data. Occurrence datasets are published in the Darwin Core Archive (DwC-A) format, ensuring harmonization and easy integration with other global databases. Some collections, like agricultural genetic resource catalogues, follow the Multi-Crop Passport Data (MCPD) standard to describe details like

accessions, cultivars, and storage conditions. The MCPD schema is mapped to Darwin Core to enable publication through the GBIF ecpgr.org infrastructure, ensuring germplasm data is fully integrated with other biodiversity data. The portal offers data in JSON and XML formats, as well as zipped DwC-A, ensuring compatibility with different IT systems and workflows. This variety of open formats facilitates data reuse by other platforms and services.
The IT infrastructure developed for managing accessions consists of functional modules designed to meet modern genetic resource documentation requirements. The main interface allows direct interaction with multiple database entities, and data is presented dynamically. A system of validation and approval of modifications (ticketing) is provided, drawing inspiration from internal peer review practices. The system facilitates the attachment of multimedia and documentary files to accessions, with native support for images and generic formats. Formal validation checks are implemented to ensure the quality and security of uploaded digital objects. A Chart.js-based graphics rendering engine is integrated for statistical analysis and exploratory visualization of data. User authentication is facilitated through OTPs, and access to functions is regulated by a role control system. The solutions prioritize user experience and technical interoperability, enabling efficient use by operators with different levels of authorization and technical background.

In conclusion, the experience presented demonstrates how the adoption of open technologies, shared standards and modular architectures can transform scientific collections into high value-added digital assets for research, conservation and dissemination of biodiversity. The approach implemented at CNR-IBBR can be regarded as a replicable model for other naturalistic collections, in the wake of the evolution towards an increasingly transparent, interoperable and data-sharing -oriented science.

Naturalistic slide collection of Italian Ephemeroptera: the value over time

Simona Cislaghi[1,2,3]**, Marcello Cazzola**[1]**, Stefania Erba**[1]**, Carlo Belfiore**[1,4]**, Andrea Buffagni**[1,2]

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Natural Science Collections (NSCs) are usually the subject of the work of Natural History Museums, which have always been concerned with their proper archiving and conservation. In addition, within research institutions, many data are collected in relation to different projects, over extended periods of time (years and decades) and along a geographical gradient encompassing both altitude and longitude. The creation of NCSs of this sort is of great value, as they serve as a repository for information that extends beyond their initial purpose. To organize and make these data available, according to FAIR (Findable, Accessible, Interoperable, and Reusable) principles, many Research Infrastructures (RIs) were born. The CNR-IRSA Brugherio works on freshwater ecosystems and has collected tens of thousands of macrobenthic invertebrate specimens over the decades. The ITINERIS project has enabled the CNR-IRSA Brugherio to reorganise its existing collections, providing a fundamental guide to the standardisation of both physical and digital cataloguing, not only internationally between the different RIs, but also within the RI itself. In this context, the work of the CNR-IRSA Brugherio has focused on the collection of slides of Ephemeroptera, an Order of aquatic insects that typically live in flowing freshwater. The collection consists of about 300 slides and the first preparations date back to 1989. It is constantly updated and developed, as the Institute has embarked on a new phase of taxonomic revision of Italian Ephemeroptera, opening new perspectives. The study of the Order came to a standstill at the end of the 1990s, after a flourishing period of about 50 years in which three Italian researchers were the protagonists [1]. The most recent checklist [2] counts 106 species believed to be present in Italy today, of which about 27% are endemic. This list does not exclude controversial or unresolved cases, which could be clarified by continuous preparation, observation and therefore correct handling of specimens on slides. During the digitisation process, 58 slides representing 28 of the above 106 species have been deposited in GBIF [3]. The specimens digitised cover the entire national territory, with a predominance in northern Italy and five specimens crossing the border. The earliest slides were prepared from untreated animals that were dissected and not always complete in all parts, while the most recent slides include individuals that have undergone genetic analysis (COI barcode and other genetic markers). In fact, treatment with Proteinase K not only allows DNA extraction, but also enables the diaphanization of the specimen, whose exoskeleton is dissected and mounted on a microscope slide, complete with all its constituent parts. This procedure makes it possible to analyse the same individual both genetically and morphologically, with a view to the increasingly necessary integrative taxonomy [4]. The final intention is to create a reference collection for Italian Ephemeroptera, with at least one slide for each of the 106 species currently identified, and to keep it updated with the possible but plausible new Italian species that will be described in the coming years. In fact, comparative analyses of BINs (Barcode Index Numbers) between European countries on the BOLD platform show that Italy has many BINs that are not shared (i.e. exclusive) with other countries, implying the possibility of new species yet to be described [1]. The collection of slides, carried out by specialists of the Order, together with the COI sequences and a collection of high-definition images of both the slides themselves and the specimens, will (i) provide in-depth knowledge of the biodiversity of Italian Ephemeroptera and its evolution over time under climate change, (ii) serve as a reference for integrative taxonomic studies and (iii) constitute a part of nature's heritage to be passed on to future generations.

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ISMAR Collections, from the specimen to the dataset

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Introduction

This contribution, presented at the final DiSSCo UOs conference within the ITINERIS project, outlines the digitization and data-sharing of natural science collections curated by CNR-ISMAR in Venice, Naples, and Bologna, aiming to integrate them into global platforms like GBIF.

Material and Methods

The study focuses on 35.755 specimens that have been systematically digitized. The collections covered include: benthic invertebrates and macroalgae from biomonitoring and biodiversity surveys in the Venice Lagoon and Northern Adriatic; plankton samples from local marine environments; xylophagous organisms from aquatic environments across Europe; benthic foraminifera specimens from LTER sites in the Adriatic Sea and Linosa island.

For each collection, a thorough digitization process was carried out, including the collection of high- quality photographic documentation for 736 specimens through advanced imaging techniques such as macrophotography and focus stacking. A hands-on curation process was carried out at CNR-ISMAR, including cleaning, labeling, and preparing specimens for imaging. Photographs were taken using Olympus stereomicroscopes and high-resolution cameras, with post-processing techniques applied to enhance focus and image clarity. Imaging was performed under controlled LED lighting on neutral backgrounds to highlight morphological details and ensure consistency for digital cataloguing.

A dedicated effort was made to capture detailed metadata for each specimen, including taxonomic classification, collection site, environmental context, and condition. The metadata follow the MIDS standard to ensure the quality and depth of the level of digitalisation achieved.

The data pipeline includes specimen identification and curation, digital image acquisition, metadata generation, and the integration of all data into the GBIF platform. All digitized records were made publicly available on GBIF, contributing to the growing global repository of biodiversity data.

Results

All digitized collections were successfully integrated into GBIF, expanding the visibility and accessibility of underutilized institutional collections. The digitization of specimens using macrophotography and focus stacking yielded high-quality visual records, while metadata harmonization enabled effective linkage across taxonomic and geographic datasets. The datasets created are now discoverable and reusable through FAIR-compliant platforms.

Discussion and Conclusions

Throughout this process, significant challenges were faced, including the heterogeneity of the collections in terms of specimen types, preservation methods, and taxonomic groups. In particular, integrating legacy collections with contemporary digital practices required addressing inconsistencies in the original data and harmonizing outdated taxonomic nomenclature.

The FAIR principles guided the data management, ensuring that each dataset adheres to the highest standards of digital research and is readily accessible for further scientific study and environmental monitoring.

The digitization effort not only enhances the accessibility of historical and ecological data but also supports a long-term vision of biodiversity monitoring. The use of digital "twins" for specimens enables the preservation of valuable data that would otherwise be at risk of physical degradation. Furthermore, this project provides a robust example of how collections from research institutions, often not easily accessible or underutilized, can contribute to large-scale biodiversity monitoring initiatives, improving scientific collaboration and knowledge sharing at national and international levels.

The preservation and curation of natural science collections are vital activities for safeguarding documented biodiversity and supporting future research. Best practices—such as environmental monitoring, standard cataloguing, and digital integration—ensure that specimens are both preserved and scientifically enhanced.

The experience at CNR-ISMAR highlights how physical and digital curation can build a resilient scientific infrastructure, supporting biodiversity studies and open science in a changing world. Looking to the future, digitized collections can play a pivotal role in advancing taxonomy, ecology, and environmental science, facilitating access to high-quality data for researchers, educators, and policymakers alike. By embracing the principles of open science, we are fostering a culture of collaboration and knowledge sharing, ensuring that natural science collections can be preserved, studied, and applied for the benefit of both science and society.

Linosa Island: from priority benthic habitat to museum collection

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Introduction

The continental shelves of the Mediterranean Sea can be characterized by the occurrence of several habitats of crucial importance for marine biodiversity and conservation. In this context Linosa Island, part of the Pelagie Archipelago, encompasses a range of ecologically important benthic habitats, including Posidonia oceanica meadows, coralligenous assemblages, maërl beds, and benthic foraminiferal communities [1,2]. These habitats are designated as priority areas under the EU Habitats Directive due to their high biodiversity and ecological significance. Particularly benthic foraminifera serve as key bioindicators of environmental quality and play a critical role in reconstructing ecological baselines and monitoring habitat health [3]. Recent marine biodiversity surveys carried out around Linosa Island have led to the systematic collection of benthic specimens, including foraminifera, supporting both in situ conservation assessment and ex situ scientific preservation. Linosa benthic foraminifera collection is currently being digitized and integrated into national and European scientific repositories through DiSSCo-ITINERIS (Distributed System of Scientific Collections - Italian node). This infrastructure enables the transformation of biological specimens into digital, FAIR-compliant resources, enhancing their accessibility and scientific utility.

Material and methods

Linosa collection is composed of 13 micropaleontological slides collecting benthic foraminifera specimens from sediment samples of seafloor (depth ranging between 50 and 400 m). Sedimentological data were acquired by the National Research Council, Institute of Marine Sciences (CNR-ISMAR) of Naples during two oceanographic surveys, 'Linosa 2016' and 'BioGeoLin 2017', onboard the R/V Minerva UNO. About 50 cm^3 of sediments samples of the box-corer and Van Veen grab were collected with a tube of 8 cm in diameter from the interval 0-1 cm of the seafloor for the foraminiferal analyses and treated following the FOBIMO protocol [4], to facilitate distinguishing living from dead foraminiferal tests. Benthic foraminiferal specimens were picked from sediment fraction >125µ of each sample, and collected in microslides, using an optical stereomicroscope (model Zeiss SteREO Discovery V.8). The image dataset of benthic foraminiferal tests was acquired from living and dead foraminiferal specimens. Optical images were acquired with a 16× Ocular, S1.0× Objective Plan, and processed via the microscope imaging software Zen Lite. The collection is physically stored in the CNR ISMAR buildings of Naples (Italy).

Results

A total of 140 benthic foraminiferal species were identified from the 13 analyzed sediment samples. The relative abundances of foraminiferal taxa, sorted by test material, show differences among the 13 samples in the higher abundance of the epiphytic species with calcareous test. 2755 physical specimens were catalogued. The digital image dataset is composed of 20 selected taxa related to lithological facies and sediment texture of seafloor.

Discussion and Conclusions

The benthic foraminiferal assemblages of Linosa Collection are an important indicator of high biodiversity of the marine ecosystem. A significant aspect is the presence of alien species from subtropical/tropical waters such as *Amphistegina lobifera*, a large symbiont-bearing foraminifera, originating from the Indo-Pacific region, thriving in shallow waters below 20 m depth and proliferating at temperatures above 14°C, recognized as highly invasive in the Eastern and Central Mediterranean. *A. lobifera* arrival in the Mediterranean region was enabled by the opening of the Suez Canal [5] its establishment and spreading in this basin was related to climate change [6].

By linking georeferenced field data with museum-curated specimens and standardized metadata, DiSSCo-ITINERIS reinforces long-term biodiversity conservation strategies. The Linosa case highlights the essential role of integrated data infrastructures in bridging habitat-level conservation with taxonomic research, ultimately supporting informed decision-making, environmental policy, and adaptive responses to ecological change.

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The importance of RI DiSSCo in the study of functional biodiversity

The study of functional biodiversity: challenges and opportunities

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Functional biodiversity — defined as the diversity of organismal traits that influence ecosystem functioning - has emerged as a central theme in ecological research. By shifting the focus from taxonomic identity to organismal traits, this approach deepens our understanding of ecological processes, species interactions, community assembly, and responses to environmental change. However, fully realizing the potential of trait-based approaches remains hindered by conceptual and practical challenges. Among the latter ones, and beyond data availability and access, the heterogeneity of trait data often limits their reuse and synthesis. This heterogeneity is related to diverse measurement types and protocols, as well as to varying data management practices including inconsistent terminologies and data fragmentation across repositories.

Although the number of trait databases and collaborative networks (e.g., Plant Trait Database [TRY]1, Open Traits Network 2) is growing, the lack of harmonized and FAIR (Findable, Accessible, Interoperable, and Reusable) data continues to limit their large-scale integration and analysis.

In this context, national and international Research Infrastructures (RIs) play a pivotal role in overcoming these challenges by 1. promoting and supporting data mobilization and standardization; 2. developing or enhancing standards and terminologies for trait data harmonization; 3. providing FAIR-compliant data infrastructures and tools for data publication, access, and reuse. Furthermore, RIs foster interdisciplinary collaboration among ecologists, data scientists, and infrastructure developers, which is essential for advancing research on functional biodiversity.

In this contribution, I will present the key activities and developments implemented by LifeWatch Italy 3 to address practical challenges related to trait data management and unlock knowledge on functional biodiversity. I will also highlight how collaboration and shared strategies with other RIs, such as DiSSCo4, and other initiatives can reduce implementation efforts and create new opportunities for integrative, scalable, and policy-relevant ecological research.

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The digitization as an opportunity to share biodiversity data of natural science collections at the CNR-IRSA of Taranto

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Introduction

The DiSSCo Research Infrastructure (Distributed System of Scientific Collections), within the framework of the NRRP ITINERIS project, aims to preserve and valorise, through digital technologies, the natural science collections (NSCs). Its main goal is to accelerate their digitization, in terms of data and images, in order to become the fulcrum among data sharing portals (e.g. Global Biodiversity Information Facility "GBIF") for researchers across the world (https://www.dissco.eu/dissco/why-dissco/).

The CNR-IRSA of Taranto answered to the challenge launched by DiSCCo with the digitalisation and sharing of the huge biodiversity data stored with the scientific community of two macroalgal collections.

Materials and Methods

The digitization involved two herbaria: a younger herbarium coded as "TAR", set up in the 80s, and the historical Irma Pierpaoli herbarium "MBMP" born in the previous century.

The digitization process followed two steps: the acquisition of 1) high-resolution digital images and 2) metadata. Physical specimens, mounted on paper sheets (exsiccata), were photographed and scanned thanks to the new acquired equipment (i.e., a planetarium scanner, a digital camera, and a digital handheld microscope). For each collection, the acquisition of metadata was carried out in a dataset defined according to the "Darwin Core" terms for biodiversity data (https://dwc.tdwg.org/list/). When necessary, the nomenclature update was performed using the Algaebase. website (https://www.algaebase.org/).

Results

The main results of the digitization process showed that the herbarium TAR included 155 species of algae, comprising 76 species of red algae (Rhodophyta), 29 species of green algae (Chlorophyta) and 47 species of brown algae (Heterokontophyta), and 3 species of Tracheophyta, for a total of 353 digital specimens. Most of these species were collected in the Taranto seas, Mar Grande and Mar Piccolo. This collection is continuously implemented with new samples, so the digitization will proceed over time.

The herbarium MBMP preserves 400 sheets, including 36 Chlorophyta, 29 Heterokontophyta and 75 Rhodophyta species collected mainly in the Taranto seas and along the coasts of the Marche region for a total of 553 digital specimens.

All images were equipped with 2 labels, a color checker and a paper ruler, as shown in the picture below (Fig. 1).

Fig 1. Two examples of digitalized herbaria sheets: on the left a digital specimen of the TAR herbarium, on the right a digitalized one of the MBMP herbarium.

In order to share biodiversity data for open access and permanent storage, the online publication on GBIF portal was carried out. At the present time, 2 datasets (as a part of the entire collections) were uploaded to the GBIF portal. The first one, called "The Solieriaceae of the Herbarium TAR" and the second dataset called "The Rhodophyta of Taranto Seas", which belong to the MBMP.

Discussion and Conclusion

The MBMP herbarium represents the first description of macroalgal composition of the Taranto Seas, since samples were collected from the early twentieth of the last century (1921-1924 and during summer 1942). The TAR herbarium, conversely, is a repository of macroalgal species from long-term observations of the investigated areas (from the 80s to date). The analysis of datasets of the benthic assemblages highlighted the changes in macroalgal composition of the studied areas [1]. Both collections are the custodians of the first specimens of alien species found in the study areas. Furthermore, the MBMP herbaria provided a complete description of macroalgal vegetation of the Marche coasts [2].

Therefore, herbaria are very important research tools that could be considered a baseline for integrating data by recent research approaches for an exhaustive knowledge of the biological world and the study of temporal variations in coastal communities. The digitization and, particularly, the open sharing of data play a central role in achieving this goal and in obtaining a comprehensive understanding of the functioning of biological diversity.

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Preserving the “seed of resilience”: mobilising Plant Genetic Resources

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Introduction

Plant Genetic Resources (PGR) are the heritable diversity of crop species and their wild relatives. They form the biological basis for global food security, sustainable agriculture and the resilience of ecosystems (FAO 2010). Against the backdrop of accelerating climate change, habitat fragmentation and biodiversity erosion, it is becoming increasingly urgent to conserve, characterise and mobilise these resources. In the landscape of PGR conservation, the preservation of functional biodiversity – i.e. the diversity of morphological, physiological, phenological and biochemical traits that directly determine how organisms grow, reproduce, respond to environmental stresses and interact with their ecosystems (Violle et al. 2007) – plays an increasingly central role. Ex situ conservation, particularly through genebanks (seedbanks and field banks), provides safe and accessible repositories for seeds, vegetative propagules and other biological materials and acts as an insurance policy against genetic erosion and biodiversity loss in natural and managed ecosystems (Weise, Lohwasser, and Oppermann 2020). The genebank of the Institute of Biosciences and Bioresources (CNR-IBBR) in Bari, contains over 59,000 seed accessions belonging to 208 genera and 872 species. Over 13,000 samples have been collected through time, mainly across the Mediterranean basin, by exploration teams of CNR-IBBR, while others have been acquired from other Institutions through exchange activities. Within the DiSSCo-ITINERIS initiative, and particularly through the Activity 6.5: “Mining and mapping the functional biodiversity in in vivo and ex situ research collections”, the CNR-IBBR accessions have been indexed in a comprehensive digitisation and integration process covering both offline and online research collections/databases. This will integrate the CNR-IBBR genebank into a unique/federated European natural science collection, addressing one of the three foundational principles of PGR conservation and use proposed by Maxted et al. 2025, that is, the documentation and availability of the conserved resources for utilisation within the applicable legislative context.

Material and Methods

Data and metadata associated with seedbank accessions and in vivo collections have been digitised and systematically linked to their corresponding physical specimens, resulting in the creation of “Digital Extended Specimens” as defined by Hardisty et al. 2022. Existing online datasets have been standardised and harmonised following international interoperability frameworks, such as Darwin Core, to align with the FAIR principles (Wilkinson et al. 2016). Each specimen's taxonomic, genetic, geographical, ecological, and physiological information has been organised in an easily searchable platform supported by web-GIS functionalities. Cross-referencing to external molecular databases has been provided to facilitate genomic characterisation, useful for trait-genomic association studies, environmental niche modelling, and analyses of genotype–environment interactions. Taking advantage of the CNR membership in the DataCite consortium (https://datacite.org/), a permanent unique identifier will be minted for seedbank accessions and their associated digital objects.

Results

To date, the process for transferring accessions, collections, sequences and references associated with the accession data and making them available on the DiSSCo-ITINERIS hub is in preparation. 5259 high-resolution images for the characterisation of the accessions' morphological and phenological traits have been catalogued; this operation will proceed over time, because all the accessions stored periodically undergo to field propagation or multiplication and are characterised. The assignment of DOIs is managed by a specific CNR office and is still ongoing.

Conclusions

Digitising and harmonising CNR-IBBR collections with their data/metadata and integrating them within the DiSSCo-RI, will mobilise knowledge on PGR to support breeding, ecological restoration, and conservation strategies with unprecedented precision. It will unlock the potential of genebanks to serve as active buffers safeguarding the full spectrum of crop diversity and their wild relatives, including the functional diversity that plays a critical role in plant performance, such as biomass production, growth, reproductive output, and survival. Through DiSSCo-RI, stakeholders will be able to search and retrieve materials on a continental scale based on ecological descriptors, adaptive traits, and genetic profiles.

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Data on the Italian mayfly (Ephemeroptera): a basis for detecting subtle changes in river ecosystem function

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Introduction

Over the last 35 years, CNR-IRSA has collected benthic invertebrates in Italian rivers as part of a series of national and international projects. Among these organisms, the order Ephemeroptera has been studied in detail because of its importance in river environments, both in functional terms and for the usefulness of these insects as bio-indicators. Although the projects have had different specific aims over time, an attempt has been made, where possible, to extend the collections and maintain comparable sampling protocols, so that joint data analyses can be carried out later on a broader scale than in the individual projects. Over time, this has allowed large collections to be built up and much additional biological data to be collected and archived, often accompanied by a wealth of environmental and habitat information. However, much of this information has never been publicised, and often not even properly published, because it has been collected and organised as an afterthought to the main objectives of the projects concerned. For example, it is of considerable interest to study the variation in the size of organisms over time (e.g. monthly, over a year) for the main species found at a particular river station. The information that can be obtained from the measurement of organisms mainly concerns functional aspects of the benthic community and thus of the river that hosts it. This contribution provides some examples of physical collections that could be linked to biological RIs, e.g. DiSSCo (the Distributed System of Scientific Collections), also in the context of assessing the impacts of global change. Some examples of available case studies, where the analysis of the size of organisms is crucial and which could be shared in online databases, concern for example the definition of (i) biological cycles, a crucial aspect both for the coexistence of species and for the ecosystem as a whole [1], (ii) secondary production of macrobenthic organisms, also understood as a tool to assess the functional integrity of the watercourse [2], and (iii) coexistence between related species, regulated not only by different periods of presence but also by the shift - intra- and interspecific - of the realised ecological niche between different sizes of larvae coexisting in the environment [3]. The data associated with the collections can also be contributed to biological databases, such as the Global Biodiversity Information Facility (GBIF) [4], in order to reach a wider audience and be available for use by scientists worldwide after prior scientific validation. This last aspect is particularly important for Ephemeroptera. In fact, the taxonomy of the order, as far as most of the Italian species are concerned, is currently undergoing a major revision through an integrative taxonomic approach [5], which will probably lead, within a few years, to a comprehensive revision of the taxonomic reference framework, the list of species present in Italy and their distribution. The same ongoing revision processes may be of interest to DiSSCo, for example, to better coordinate activities with similar ones in other sectors or geographical areas, or to speed up the sharing of results obtained. Taxonomic revisions will make it possible to update the information collected over time, including that which is the subject of this contribution, by assigning it to the various taxa according to the new overall framework, thus restoring the value of the ecological and functional data. In many cases, organisms previously attributed to a single species will be distinguished as belonging to several species, making the characterisation of biological (e.g. life cycles, diapause periods) and ecological (e.g. optimal thermal regime, preferred microhabitats) traits more effective. The definition of these traits, until now mainly based on bibliographic sources derived on a large European scale [6], has inevitably suffered from a lack of accuracy and precision, as interspecific variability has often been added to intraspecific variability. Ongoing taxonomic revisions will therefore give new importance to the collections and data held - even those dating back decades - supporting the revision of important databases and bringing to light information that has never before been collected and/or presented in such detail.

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Dese collection: recording reproductive traits from the bibliography as functional biodiversity tool

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Introduction

The Dese Crustacean Collection (DC) includes crustaceans collected during studies on the biodiversity of the Northern Venice Lagoon (Fig. 1). It is a subset of a larger collection providing data as potential benchmarks for models of biodiversity change over time. In the framework of ITINERIS the crustacean samples underwent curation, cataloguing and digitization. An added value is the knowledge of species' biological traits, which can clarify causes and consequences of biodiversity changes [1]. Information on biological traits can be obtained from primary sources as field observations, phenological features from species of the collections, laboratory experiments and from secondary sources as online databases (e.g. BIOTIC http://www.marlin.ac.uk/biotic) or bibliographic resources [2]. To associate ecological and biological information to the species of the Dese collection, descriptive tables are being compiled with information taken from the bibliography following the BIOTIC (https://www.marlin.ac.uk/biotic/imgs/BioticGlossaries.pdf) and Clare et al [2] models.

Material and Methods

The reproductive traits were taken from a personal bibliographic archive, the result of a bibliographic search carried out over time for each species and regularly updated on Web of Science. To date, 429 papers covering all aspects of species have been recorded and 48 papers dealing with reproductive features have been selected. The papers are being summarized in tables reporting reproductive traits.

Fig. 1 study area

Results and Discussion

The collection is composed of 35 taxa of which 28 determined at species level. The bibliographic analysis provided information on reproductive traits for 15 species, while for the remaining 13 species no information was found. The 15 species involved are abundant species in DC collection and widely distributed in similar Mediterranean environments. An initial text analysis revealed three types of studies: 35 papers deal with population dynamics, 6 concern ecotoxicological studies providing information on some reproductive aspects, 7 describe laboratory experiments on the biological cycle. As a case study, the reproductive cycle of *Corophium orientale* Schellenberg, 1928, is summarized in a table. This is the most representative species of the study area preserved in the collection for which there is a single study carried out in a similar environment in Greece [3]. It is an oligo-polyhaline species endemic to the Mediterranean Sea.

Table. Reproductive traits of *Corophium orientale* [3].

Trait	Category	Description
Body size (mm)	Juveniles	0,85-2,75
	♀ mature	3,75-6,75 (larger in overwintering females, decreases in warm seasons)
	♀ gravid	3,95-9,2 (same seasonal pattern)
	♂	Maximum length shorter than females
Population density (individuals)	193-20.000	August, min. for the 2 generation population, max for 3 generation population
Recruitment	Continuous	April to October
	Not continuous	Late spring-early summer and early autumn
Breeding peaks	3	March, June, September
	2	Mid-spring, early autumn,
Brooding time (months)	2-3	Depending on T and S: the higher the temperature and salinity, the shorter the brooding time
Generation/year	3	Spring, summer and overwintering generations
	2	Late spring, early summer
Growth rate (μm/day)	37,5–39,5	Spring generation (T = 16-26°C)
	27,5	Summer generation (T = 24-28 °C)
	13,5–15,7	Overwintering generation (T = 1,8-14 °C)
Lifespan (months)	4-6	Spring generation
	5	Summer generation
	7-9	Overwintering generation

The table shows that *C. orientale* is a semi-annual species with 2/3 generations/year and adult size, growth rates and brooding time temperature dependent. The two populations analyzed live in the same habitat, but one produces 3 generations per year, the other 2. For this latter, it is hypothesized that shorebirds preyed on the large individuals before reproduction, causing a pause in reproduction and therefore in recruitment [3].

The proposed model is being applied to the species of the DC collection to provide a taxonomic and functional description of the collection. As a first approach, it was chosen to investigate the reproductive traits as one of the most important in studies investigating the effects of climate change. For instance, traits related to reproductive strategies and interspecific interactions are a useful tool for understanding the trend of biological invasions [1].

To find and gather biological traits information is time consuming because they are widely scattered in bibliographic sources. It would be advantageous to build thematic databases following the example of Polytraits (http://polytraits.lifewatchgreece.eu/) a database of biological traits of polychaete species of the world.

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The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms

The contribution to the Global Biodiversity Information Facility (GBIF) and other biodiversity data platforms

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Natural history collections have been, for a long time, the most important avenue to record and store biodiversity data. Species lists in tables and supplementary tables published in scientific papers have been a complementary source of information on biodiversity. The main advantage of museum collections is that the organisms can be studied by following researchers, whereas researchers have to trust species lists data from published papers, because only rarely they are accompanied by drawings, photos, or DNA-based data to support their taxonomic identification.

Such kind of data, regardless of whether it is from museums or from published papers, is highly valuable to assess past diversity. Yet, it is often difficult to access, especially if hosted in small natural history collections without dedicated staff and if the published papers belong to poorly known journals. In the recent decades, a wave of activities to make biodiversity data and metadata available online produced a series of successful platforms, especially iNaturalist [1] for data from any provider, mostly from photos and videos, and the Global Biodiversity Information Facility (GBIF) [2] for potentially validated data by scientists. iNaturalist can be assimilated to a modern form of spread and partially curated natural history collection, and GBIF as a convenient form to record species lists from scientific studies, more available than species lists published in scientific papers. The aim of DiSSCo is to deal with data from potentially hidden or poorly accessible natural history collections, making information becoming available. The objective is to have data from physical collections that are as easily available and visible as data on iNaturalist.

I will here deal with some examples from Italy of different types of biodiversity information that was not easily available but that was published online in different platforms, mostly in GBIF, and the role of DiSSCo in the activities of allowing data and metadata to become visible to a much broader audience.

I will then conclude with a discussion on how the future of DiSSCo in Italy is closely connected to the future of GBIF in Italy, especially through the Global Registry of Scientific Collections (GRSciColl) [3].

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Incorporating ecological studies into data platforms infrastructures to improve biodiversity information availability

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The digitization of Natural Science Collections is gaining growing importance in a context where the access to interoperable and smart water data spaces seems crucial for the definition of water resilience strategies and to tackle global change effects on biodiversity.

The Water Research Institute (CNR-IRSA – Brugherio) houses an extensive collection of freshwater benthic invertebrates containing specimens from diverse geographical regions collected from a wide range of river types. Such collections include samples gathered since the 1980s. Data collection was consistent with the aim of several research projects and tackled several topics such as the study of the links between riverine benthic invertebrate communities and habitat features, the assessment and intercalibration of Ecological Status, and effects of climate change on river habitats and biota. CNR- IRSA collections include samples that were mainly collected using a multihabitat proportional sampling technique, which is the Italian standard for the monitoring of wadable water bodies under the Water Framework Directive. With this protocol, invertebrates were quantitatively collected. However, in some cases, qualitative samplings were also collected to complement the quantitative ones or to collect specific taxa in selected habitats. A part of the collections also includes samples from non-wadable rivers, where macroinvertebrates are collected using artificial substrates.

Along with sampling of the invertebrate benthic community, several abiotic features at different spatial scales (e.g. water quality parameters, land uses) were also recorded, for a total of more than 50 single parameters including the characteristics where sample is collected (i.e. substrate type, flow type and water velocity, water depth). Local hydro-morphological characterization of each river reach was also performed following the CARAVAGGIO (Core Assessment of River hAbitat VAlue and hydro- morpholoGIcal cOndition) method. Collections hosted at CNR-IRSA include approximately more than 8000 sampling units, from more than 300 different river reaches, located in 14 different Italian regions and outside Italy (mainly Cyprus). The collections might contain several endemisms. The level of identification of organisms differs depending on the group and ranges from the family (mainly Trichoptera, Diptera, Coleoptera, Heteroptera, Annelids, Crustacea), to the genus (Molluscs, Plecoptera), to the species (mainly Ephemeroptera and Odonata plus selected taxa of other orders).

Within ITINERIS project, with the aim of promoting data and information accessibility and usage by a wider community and for a wider set of goals, a selection of these ecological collections has been elected for the digitization even if the level of identification of taxa included in the collection does not reach the species level. It was considered that the added value of such digitization is related to the fact that macroinvertebrate occurrences are linked with a unique set of environmental variables collected concurrently to macroinvertebrates samples. Sites for digitization were prioritized to cover specific geographical context, potentially highly susceptible to climate changes effects like temporary rivers, rivers hosting high numbers of endemic taxa (e.g. Sardinian rivers), alpine sites and reference sites (i.e. pristine sites not significantly altered by anthropogenic pressures). The process of digitization requires a vast amount of resources: as an example, the digitization of a part of the collection of Sardinian pristine sites resulted in the publication in GBIF of 642 digital specimens, each representing a single vial, containing one or more individuals of the same taxon, related to a specific sampling unit (e.g. microhabitat). Before digitization, each vial has been checked and properly stored to make it accessible. The future challenge will be to extend the digitization process to the other collections, also incorporating more detailed data, like species level data where possible.

Digitization of the entomological museum “Filippo Silvestri” at the MUSA in Portici (NA)

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ABSTRACT

As part of the ITINERIS project and in accordance with DiSSCo’s objectives, a digitization campaign was carried out on the "Filippo Silvestri" entomological collection at the Museum of Agricultural Sciences (MUSA), University of Naples Federico II. Led by the Natural History Museum of the University of Florence, this digitization initiative aimed to acquire images of entomological specimens using high-definition imaging systems and standardized protocols. The effort resulted in the digitization of 2,436 entomological boxes containing over 180,000 specimens, significantly enhancing the accessibility of the collection for research in taxonomy, ecology, and systematics. The data and images produced will be made openly available through the Global Biodiversity Information Facility (GBIF) open-access platform. This integration not only ensures global visibility and long-term preservation, but also aligns with European strategies for the digital transformation of cultural and scientific heritage and amplifies the scientific impact of the collection.

Introduction

In recent years, the digitization of natural history collections has become a strategic priority for museums and research institutions, aiming to enhance accessibility, ensure long-term preservation, and promote new opportunities for scientific inquiry. Entomological collections, in particular, represent a vast and largely untapped source of biodiversity data that is essential for studies in taxonomy, ecology, conservation, and climate change. As one of the representatives of the European infrastructure DiSSCo and within the framework of the ITINERIS project, the Natural History Museum of the University of Florence conducted a digitization campaign on the “Filippo Silvestri” entomological collection housed at the Museum of Agricultural Sciences (MUSA), University of Naples Federico II. The initiative was designed to apply high-resolution imaging techniques and standardized protocols to obtain the largest number of specimens’ images possible and make this collection of priority interest in the Italian NHCs panorama digitally accessible.

Material and methods

The two-week digitization campaign was carried out in January 2025 by three technicians ITINERIS-SMA at MUSA, Reggia di Portici (Naples), in one of the museum’s most significant sections of considerable historical and scientific value: the “Filippo Silvestri” entomological collection. The activity employed high-definition photographic systems and standardized acquisition protocols designed to maximize efficiency, ensure consistency and reproducibility, and support the long-term preservation of digital assets. A tested workflow was preceded by a phase of familiarizing with the collection and performing a reorganization based on existing catalogues in order to identify potential issues and better structure the subsequent steps. It also enabled technicians to accurately count the total number of entomological boxes and plan an effective schedule. Three photographic stations, each consisting of a Nikon Z50 camera equipped with an 18–140 mm Nikkor lens, a photo stand, and a pair of lighting softboxes, were set up close to the collection’s storage areas to streamline the imaging process. Subsequently, all boxes were physically labelled with a unique collection code (e.g. MUSA-SIL-B0001; MUSA-SIL-B2436). The image acquisition phase then began and took the largest portion of the overall process. Images of entire boxes were acquired at the highest possible resolution using validated digitization standards and renamed with the code associated with each box. Finally, during the post-production phase, each insect specimen was virtually assigned a unique identification code (e.g. MUSA-SIL-000001; MUSA-SIL-183536) through an image editing software.

Results and conclusions

The campaign resulted in the complete digitization of 2,436 entomological boxes, comprising 183,536 pinned insect specimens. Many of these specimens include rare taxa, type material, and reference samples that are essential for ongoing systematic and taxonomic research. The outcomes of this initiative represent a significant contribution to preventive conservation and sustainable access to entomological collections. The forthcoming integration of the digitized data into GBIF platform will ensure that this collection becomes part of global knowledge and scientific infrastructure, opening new avenues for research in systematics, environmental science, natural history, and museology, enabling not only researchers but also the public to access information that had long remained hidden in drawers. As a collateral benefit of the digitization process, conservation issues were addressed. Not least, this initiative has supported, and will continue to support, the curators in the management of the dry collection, by providing them an accurate overview of its full extent and any related issues.

Acknowledgments

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Enhancing the scientific collections data of CNR-ISMAR through the ITINERIS project

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Introduction

The Institute of Marine Science (CNR-ISMAR) hosts an extensive heritage of natural scientific collections spanning multiple research domains, botany, zoology, paleontology and geology, and addressing a multitude of topics ranging from habitat characterization to species distribution.
As often happens in these contexts, this results in extremely heterogeneous data stored in disparate data archives, which makes data acquisition increasingly time-consuming and challenging for researchers [1]. This work outlines CNR-ISMAR's experience in managing and collecting metadata from scientific collections until their publication, according to international standards and the FAIR principles.

Material and Methods

For all physical specimens of the collections involved in the ITINERIS project (see details in Di Russo et al. abstract), the respective digital specimens have been created. Applying international data standards (Darwin Core, ABCD), controlled vocabularies, and domain ontologies, we structured and harmonised the datasets. To settle the quality of the metadata process, we adopted the Minimum Information about a Digital Specimen [2]. Data were then linked to global biodiversity repositories including GBIF, BOLD and GenBank, creating new pathways for reuse and interdisciplinary research. The web-based tool FAIR-Checker [3] was used to evaluate the FAIRness of metadata presented in the digital resources.

Results

A total of 106 metadata terms - grouped into five categories (basic, taxonomy, morphology, genetic, and sampling) were identified for the biological aquatic natural collections of CNR-ISMAR. The IT structure for the storage of digital specimens and related data consists of a federation of systems that can interact and interoperate across ISMAR headquarters. The system is based on three NAS-QNAP (Network Attached Storage – Quality Network Appliance Provider) with QuTS hero (TS-h3087XU-RP). The NAS access is managed through myQNAPcloud, the mirroring of the archives through HBS 3 Hybrid Backup Sync. Each CNR-ISMAR branch (Venice, Bologna, and Naples) stores data locally with mirrored backups to ensure redundancy: ISMAR-VE hosts the complete version of the archive and receives mirrored data from Bologna and Naples, ISMAR-NA mirrors its local archive to Venice, ISMAR-BO stores its own data and mirrors the Venice archive. In this way, each local archive has a mirror delocalized copy. The archives have a consistent structure consisting of organised folder based on the collection field (botany, paleontology and zoology) and inside the specific collections. QNAP supports authentication by credentials, and the authorization system is based on multiple access levels depending on the folder permissions and on the user privileges (administrator, read and write, read only). QNAP allows users to store digital specimens and obtain a free or password-protected URL (Uniform Resource Locator) to be included in the metadata record (DwC, DC) useful to incorporate the picture into external platforms. CNR-ISMAR is registered as Publisher Institution on GBIF, and 3 of its branches (Venezia, Bologna and Napoli) are registered on GRSCiColl as locations where physical collections are hosted. To date, 7 dataset collections have been registered on GBIF, with 2,012 occurrences; the FAIR assessment of the dataset published was 79.17%. Lastly, the FAIR Implementation Profile (FIP) was developed to represent the strategies of the DiSSCo-ITINERIS community to optimise the reuse of existing FAIR-enabling resources and interoperation within and between domains.

Discussion and Conclusions

Integrating, sharing and reusing research data poses a significant challenge, especially in interdisciplinary collaborative projects [1]. This challenge is essential for a research infrastructure such as DiSSCo, which aims to facilitate efficient data discovery and integration of diverse data sources. The ITINERIS project has allowed the CNR-ISMAR to start a workflow for better managing and harmonising data from heterogeneous scientific research activities. The obtained data will contribute to detecting biodiversity changes and developing appropriate conservation measures; moreover, it will allow us to contribute to enhancing European and National initiatives, including the National Biodiversity Future Center (NBFC, https://www.nbfc.it/en) and the Biodiversity Gateway (https://www.biodiversitygateway.it/).

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CNR-DiSBA living collections: from Biomemory to GBIF and beyond

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The collections of living organisms maintained at the Department of BioAgroFood Sciences of the National Research Council of Italy (CNR-DiSBA) display unique characteristics compared to most collections in the DiSSCo research infrastructure, especially regarding preservation types, preservation methods, requirements, and consequently, maintenance costs. CNR-DiSBA research collections are aimed at supporting studies on the functional biodiversity of living populations in the wild, along with their evolutionary potential, interactions with pathogens, ecological performances, niche ecology, and the possible consequences of climate change.

In 2020, CNR-DiSBA launched the Biomemory departmental project aimed at inventorying the Natural Science Collection maintained across its nine institutes (CNR-IBBA, CNR-IBBR, CNR- IBE, CNR-IPSP, CNR-ISA, CNR-ISB, CNR-ISPA, CNR-ISPAAM, CNR-ISAFOM, totaling 27 sites spread throughout Italy. This project, which concluded in 2021, paved the way for the digitization, standardization, harmonization, and metadata enrichment of 56 collections of living organisms (plants, fungi, bacteria, animals, and viruses) that were conducted during the ITINERIS project, launched in late 2022. Since then, taxonomic, geographic, genetic, and preservation information from more than 55,000 living specimens have been included in 52 datasets: 35 occurrence datasets (passport data), 9 DNA sequence datasets, 3 SSR markers datasets, two trait score datasets, two climatic parameters datasets, and one literature dataset. Overall, 27% consists of cryopreserved collections, 17% field collections (orchards), 17% seed collections, 3.4% dried samples, 11.4% in vivo cultures, and 6.8% comprises cryo- stored material samples taken from georeferenced trees living in the wild, and others.

Globally, 1,862 different taxa from 331 families of 5 kingdoms have been recorded from the digitization activities. The acquisition of specimens in the collections varied from 1952 to 2023, with a collection timespan of 17.56 ± 3.75. The information associated with specimens varied across collections: for 49,296 specimens (89.5%), the country of origin is indicated, as well as the preservation type (71.8%), the life stage (74.3%), and the acquisition date (73.4%).

In contrast, the geographic coordinates of the collecting site are available only for 11,917 specimens (21.6%), as well as the associated references (10.8%), the associated images (5.8%), and the associated DNA sequences (1.07%). The collection of the latter information is currently ongoing.

Currently, 35 of the above CNR-DiSBA datasets have been metadata-enriched, endowed with DOI and registered on the GBIF platform (https://www.gbif.org/publisher/6563e0ba-fab7- 431c-b897-b6bf364f4f1e) through the use of the IPT package (https://ipt.ibbr.cnr.it/ipt/), totaling 49,669 distinct occurrences. For the time being, these datasets have been downloaded (as a whole or in part) and cited 53 times since early 2024. All this information is available to end-users and ready to be harvested from the DiSSCo servers and included in DiSSCo, which previously endorsed the CNR-IBBR as a publisher on GBIF.

Based on relevant information available on the Italian biodiversity from the above collections, Essential Biodiversity Variables (EBV) distributed across space and time for many organisms or groups of organisms will be assessed. Moreover, the availability of fine-scale climatic data from WorldClim/CHELSA climatic layers using downscaling tools (https://ibbr.cnr.it/climate- dt) will pave the way to both modelling the distribution of each species in the context of future climatic scenarios and mapping the Italian regions at risk of biodiversity erosion/depletion as a consequence of global change. Finally, the availability of a large amount of taxonomic, genetic, geographical, ecological, and physiological information on plant, animal, and microbial genetic resources will make it possible to mine and map the functional biodiversity of in vivo and ex-situ collections to better understand the specific mechanisms of adaptation to climate change.

Relationships with other Research Infrastructures (Cross-RIs initiatives) platforms

Being a European Research Infrastructure – critical aspects and national strategy

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Becoming a European Research Infrastructure with an established ERIC (European Research Infrastructure Consortium) is a long and complex process, but one that ensures a high degree of stability and a long-term strategic perspective. As of the ESFRI Roadmap 2021 [1], there are 63 Research Infrastructures (RIs), a number expected to grow with the upcoming 2026 Roadmap. Among the 11 Environmental RIs, three — including DiSSCo — are currently categorized as "projects", while the rest are established Landmark RIs, six of which operate under the ERIC legal framework. It is also important to consider RIs from other thematic areas that are closely related to and interact with Environmental RIs, such as AnaEE, EMPHASIS, IBISBA, EMBRC, and ELIXIR (from the Health and Food sectors), that makes the offer of environmental data and services large and variable.
Italy is the European country involved in the highest number of ERICs, officially participating in 24 and collaborating in an additional four. This brings significant visibility and research capacity but also raises concerns about long-term sustainability and the availability of resources. In this context, complementarity, coordination, and shared services are crucial for optimizing resource use and enhancing the efficiency and visibility of RI services for users.
Despite their heterogeneity and diversity in terms of goals, spatial scale, and organizational structures, Environmental RIs focused on terrestrial ecosystems have made efforts to develop shared tools and co-location strategies — both at the continental level (e.g., through EU projects such as ENVRI-PLUS and ENVRI-FAIR) and nationally, through initiatives like ITINERIS. These RIs exhibit different of level of maturity: some have operated as Landmark RIs under ERIC status for over a decade, while others are still in the preparatory phase and can benefit from the lessons learned by more established RIs to facilitate smoother development.
This contribution will present the experience of ICOS, the oldest RI in the environmental domain, focusing on its construction, management, and the pros and cons of key decisions taken — insights that may serve as valuable references for other RIs, including DiSSCo. Examples of potential collaboration, coordination, integration, and joint development among terrestrial ecosystem RIs will also be discussed, with particular emphasis on ongoing activities and those with the greatest potential impact.

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Towards Integration: Unlocking DiSSCo's Added Value for Marine and Environmental Research Infrastructures

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Reliable, harmonized, and interoperable data are essential across ESFRI environmental Research Infrastructures (RIs) to support cross-disciplinary research on biodiversity, ecosystem functioning, and environmental change. DiSSCo, the Distributed System of Scientific Collections, plays a pivotal role by mobilizing natural science collections and standardizing specimen-based data—providing a taxonomic backbone and reference baseline for other RIs. These collections serve as authoritative taxonomic references and foundational baselines that enhance reproducibility, traceability, and data integration across RIs, ultimately increasing data usability for researchers, environmental managers, and policy makers. This contribution explores the synergies between DiSSCo and aquatic environmental infrastructures, including DANUBIUS-RI, eLTER, and EMBRC. Despite operating in distinct domains—river-sea systems (DANUBIUS), terrestrial and freshwater ecosystems (eLTER), and marine biodiversity and biotechnology (EMBRC)—these infrastructures all benefit from strengthened linkage with DiSSCo's efforts in integrative taxonomy, specimen-based data, and data FAIRification. EMBRC, for example, combines molecular and classical approaches to taxonomy, producing genomic and meta-genomic data that complement LTER time series. DiSSCo supports these efforts by providing authoritative, specimen-based taxonomic knowledge, crucial for validating and enriching biodiversity observations. Similarly, DANUBIUS and eLTER aim to understand biodiversity patterns and ecosystem processes across gradients of stressors (e.g., pollution, climate change), where standardized reference collections and taxonomic baselines provided by DiSSCo can improve the traceability and reproducibility of research outcomes. This presentation highlights current contributions and future opportunities for interoperability among these and other RIs (e.g., EURO-ARGO, LifeWatch ERIC, ICOS), emphasizing DiSSCo's foundational role in bridging biodiversity knowledge with ecosystem research and policy, in alignment with FAIR and Open Science principles.

Combining Research Infrastructure data for a Greater Impact: The North Adriatic Foraminifera Collection (NAdFC) Case Study

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Introduction

The North Adriatic Foraminifera Collection (NAdFC), is a multi-year time series stored at the CNR-ISMAR in Bologna (Italy), based on benthic marine ecosystem biomonitoring conducted since 2016 at the North Adriatic Long Term Ecosystem Research (LTER) site "Delta del Po e Costa Romagnola" (DPCR). Integrating physical, chemical, and biological measurements with state-of-the-art methodologies (including recently metagenomics), the DPCR site represents a key observatory for the North Adriatic [1], a region shaped by natural drivers (e.g., currents, freshwater/sediments inputs) and increasing anthropic pressures (agriculture, fisheries, aquaculture, shipping, urbanization, and tourism). Within the ITINERIS project, the NAdFC is a valuable cross-infrastructure case study as its related ecological time series, focused on benthic foraminifera (BF), was provided by LTER activities and built in synergy with the Distributed System of Scientific Collections (DiSSCo). FAIRification, i.e. making these integrated data findable, accessible, interoperable and reusable, supports detection of biodiversity changes, identification of major drivers, and development of conservation measures. This contribution aims at highlights the value of such integrated digital infrastructures and FAIR collections for advancing biodiversity and ecosystem research and addressing ecological questions.

Materials and Methods

To date, the NAdFC consists of 46 micropaleontological slides containing BF specimens, among which 38 are from sediment samples collected at the S1-GB (Po Delta) and E1 (Rimini offshore) LTER-DPCR stations, while 8 samples derive from research cruises depth transects centred on S1-GB. Sediment samples were collected using a box corer during 2016, 2017, 2019 cruises, or employing a Van Veen grab during routine maintenance activities at the meteo-oceanographic stations (between 2016 and 2024). About 30 ml of sediment from the 0–1 cm interval was collected for BF analyses and treated following the FOBIMO protocol [2]. BF specimens were picked from the >63 µm fraction, identified and counted under an optical stereomicroscope and mounted on cardboard microslides. The image dataset was acquired using the Zeiss SteREO Discovery V.8 optical stereomicroscope (16x Ocular, 1x Objective Plan) and the imaging software Olympus EPview (v. 2023, 64 bit). Selected specimens were also digitized with an Environmental Scanning Electron Microscope Zeiss EVO LS 10 and the Esprit software (v. 1.9, 64 bit) at the Institute of Nanostructured Materials (ISMN).

Results

As part of DiSSCo activities, a subset of NAdFC samples (~6000 BF specimens), were recently digitized and taxonomically revised while the related occurrences dataset was harmonized according to international standards (DarwinCore) and published on the Global Biodiversity Information Facility (GBIF) portal [3]. In parallel, LTER activities provided harmonized environmental metadata linked to the NAdFC [4,5]. Correlation of the NAdFC multifaceted datasets revealed that in the LTER DPCR area BF assemblages are strongly influenced by sediment depositional events which lead to alterations in key environmental parameters for BF. A major driver affecting BF assemblages at S1-GB station, closer to the delta, is the Po riverine discharge, causing BF density and diversity decrease and increase in opportunistic taxa tolerant to organic-rich sediments and oxygen deficiency. Conversely, at Site E1, storm wave episodes drive significant increase in *Ammonia* and *Aubignyna* species and a marked decrease in fragile agglutinant taxa. Digitization, and taxonomic revision efforts, led also to the identification of *Virgulinella fragilis*, a BF Non-indigenous species (NIS) likely introduced in the DPCR site by shipping stowaway transport, and allowed discrimination of morphological features linked to oxygen fluctuations [6].

Discussion and Conclusions

By implementing the NAdFC dataset using international standards (DarwinCore), controlled vocabularies and ontologies, we achieved semantic consistency and adhered to FAIR data principles. The NAdFC digitized datasets facilitated taxonomic revisions, nomenclature updates, and the discovery of new overlooked species. Additionally, the integration of environmental metadata and ecological traits associated with specimen distribution allowed comparative analyses across both time and space, revealing main environmental/anthropic drivers influencing biotic shifts. Systematic digitization and semantic enhancement of research collections thus unlocked valuable insights for biodiversity conservation, ecological monitoring, and evaluation of human- driven environmental changes. This reshapes the landscape of research Institutes collections underscoring the relevance of standardized cataloguing, data preservation and integration with international platforms.

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The Ecosystems Virtual Museum. A bridge between DiSSCo and Lifewatch toward digital object sharing and valorization

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Digitization of Natural History Collections (NHCs) leads to the creation of a wealth of data that, when shared on an open access platform, makes a very significant contribution to both biological and earth sciences, and other related disciplines, such as Climatology and Ecology. In addition, FAIRness of digital objects makes them a powerful tool for outreach and dissemination activities, both enhancing the awareness of researchers about their physical location and accessibility, and providing versatile elements that can be easily arranged, showcased and narrated to the public, in parallel with one of the main missions of most NHCs holding institutions.

Even from this widened and inter-disciplinary perspective, adopting standard tools and languages is a crucial requirement. The establishment of the Italian Virtual Museum of Ecosystems (https://museoecosistemi.lifewatchitaly.eu/en/home), funded by PON Project IR 01_00028 - LifeWatchPLUS in 2021, thanks to the proactive activity of a compound Scientific committee, chronologically preceded, but partially overlapped, the ITINERIS time span, and represents an interesting case study of fruitful collaboration among representatives of two, different but tightly related, environmental RIs, Lifewatch and DiSSCo.

In particular, while working on the architectural backbone of bio- and geo-diversity data, which had to serve for didactic purposes, a digital archive was planned to collect images and data from NHCs objects, based on MetaFAD, a pre-existing Collection Management System (CMS) developed under the umbrella of Italian Central Catalogue and Documentation Institute (ICCD) by the Gruppo Meta company. This had been created to ensure the interoperability of NHCs information with the ICCD public archive that, in turn, adopted a widely overlapped ontology with the international standards used by GBIF and GeoCASE for bio- and geo-diversity data description (i.e., the Darwin Core and the European standards ABCD/EFG).

Practicing, together, with such a tool make all the participants either aware or more confident with those standards and laid the groundwork to then move the discussion from the Virtual Museum digital archive planning to some essential choices in the next ITINERIS activity, where MetaFAD would have been object of a training activity and further developed as a potential, shared CMS for Italian

NHCs, which have to comply with cataloguing requirements of both ICCD and the international platform for data sharing.

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Summary of the Round Table

"Prospects for the development of the RI DiSSCo Italy"

Venice, 18 June 2025

Organizer*: Scientific Committee Final Conference "UOs DiSSCO Itineris"*

Moderator: *Mario Sprovieri, Director of CNR-ISMAR*

Participants: *Diego Fontaneto (CNR-IRSA, GA DiSSCo Representative), Alberto Basset (University of Lecce, IR-LifeWatch), Fausto Barbagli (National Association of Scientific Museums), Irene Olivè (Stazione Zoologica A. Dohrn, IR-EMBRC), Giorgio Matteucci (CNR-IBE, IR-LTER), Luigi Bubacco (University of Padua, National Biodiversity Future Center).*

Objectives

At the end of the final conference of the DiSSCo ITINERIS UOs, the infrastructural, organizational and digital developments made possible by the PNRR in the IR-DiSSCo Italy, as part of the European initiative, were discussed. The main goals were presented, such as the digitization of nature collections, the networking of data and the strengthening of collaboration between research institutions and scientific museums. Following this summary, the panel aimed to explore the steps necessary to ensure sustainability, continuity and full operation of the infrastructure at the end of the PNRR funding. The discussion was dedicated to evaluating the long-term governance prospects and future funding models within the EU, as well as the possibility of cooperation and development synergies with other research infrastructures present at national level, also exploring the enhancement of new technologies to support the action.

Topics

The moderator opened the round table by reporting that the European Parliament had not accepted the Commission's recent proposal for the strategy in the use of the 200 billion euros to be dedicated to the research sector in the future FP10. It is therefore possible to offer reflections and input for an improvement of documents and future visions in the field of EU research.

At the opening of the discussion, a presentation by Diego Fontaneto, interim representative in the General Assembly DiSSCo EU, summarized the main infrastructural, organizational and digital developments made possible by the PNRR as part of the IR-DiSSCo Italia and as part of the European initiative.

Participants were then invited to answer questions on specific topics:

1) How can the respective RIs/scientific institutions contribute to interdisciplinary collaborations and impacts on environmental research, biodiversity, climate change and in the context of the programming of European Funds?

2) Do you have suggestions, ideas, also to propose in a national context that is important for the sustainability of these research infrastructures, with a governance model that has a logic? How can we also be attractive to the new generations?

Strategic priorities jointly recognized

1) There are strong interactions between biodiversity, ecosystem processes and people. Infrastructures must also bring all this together to make an impact not only on a local scale but aiming at a larger scale.

It is necessary to:

- include the "socio-sphere" through Citizen Science to enhance the offer of research infrastructures;
- create structured links for effective synergies between Ris;
- creating a museum network based on Citizen Science could accelerate the digitization process;
- enhance the capacity and potential of access to information, images, and everything that has been created by research infrastructures, creating services and utilities for the citizen.

2) The world of museums, previously aimed mainly at a specialized audience, must now address the whole of society. Serving research, but also serving society, with repercussions on all citizens.
3) The topic of digitization for museums is a fundamental element of accessibility to collections.
4) To do research in RIs, it is necessary to facilitate users' access to resources not only as physical access, but also as a data processing service or a data interpretation service.
5) The possibility of integrating complementary data creates active synergy with other research infrastructures and one aspect of the sustainability of the infrastructures concerns co-designing and co-developing as much as possible.
6) The roadmap for an effective enhancement of research infrastructures must be developed through the "Key Performance Indicators", as a method to take stock of the situation by looking to the future and the past and to be able to have topics at a negotiating table.
7) The production of communication services to encourage community engagement, as demonstrated by the "LifeWatch" project, is essential especially starting from the new generations: to overcome "eco-anxiety and to satisfy the desire to change the current situation.
8) A dedicated policy is needed for institutions that allocate personnel time dedicated to infrastructure. This time must be evaluated as a call for attractiveness for new professionals.

Critical concerns

1) A pragmatic reflection on the problem of fragmentation is needed in regards to the creation and maintenance of active networking between institutions.
2) In the post-PNRR period, it will be necessary to effectively manage the structural part, maintain a competitive approach and systematically attract resources in the long term.
3) There are still few opportunities for operational dialogue between museums and other institutions: it is necessary to act to trigger this constructive process.
4) A National scheme in addition to Trans-national Access also needs to be considered to enhance our attractiveness in doing research through research infrastructures with an emphasis on connection.
5) It is necessary to attract students and convince our researchers who are not directly involved of the strategic importance of research infrastructures.
6) A call for synergy is needed, especially aimed at avoiding any form of overlapping of actions to promote the complementarity of data as much as possible.
7) It is necessary to answer the questions of research, considering different aspects, from the speed of data sharing to the transversality and access to the latter, all the while ensuring a solid structure to be more competitive and not miss opportunities.

8) We need to find a moment of strong interaction to come back and talk frankly about the fact that there are overlaps between the RIs and that there are different maturities and a heterogeneity that needs significant harmonization in Europe for everyone.
9) It is necessary to activate a dialogue on semantics between research infrastructures of different environmental domains.
10) The issue of continuity of staff over time is a critical aspect, especially on how institutions, universities, assign personnel to infrastructures; it is an open problem at the CNR and probably also in other bodies that must be addressed to ensure performance, continuity and growth of skills to support IRs.
11) Direct rewards are needed on PRINs, for example on certain project initiatives that may not reach those who manage the research structure directly, but which still bring data, research and actions that are then shared.

Proposals and next steps

There are many elements for reflection that concern not only the entire NBFC community but also the broader network of research infrastructures discussed.

It is necessary to create additional opportunities for dialogue among those who work directly with research infrastructures as they possess clear firsthand insight into the challenges involved.

Is it necessary to activate a dialogue on semantics between Research infrastructures to identify what the objectives are? Why is Transnational Access structured in one way and not another? To address such questions, a true workshop in the full sense of the term is needed. This would bring together representatives of the research infrastructures present at the table along with others offering potential synergies (e.g. "Mirri", "BioArgo") to tackle **emerging challenges** and jointly formulate a meaningful proposal to present to the Ministry. This is a proposal that could be taken up again at the organizational level through the Biodiversity Gateway of the National Biodiversity Center.

New technologies facilitate the exchange of information and data, which in turn generate cascades of new knowledge within and among research infrastructures, for example through the scientific collections of DiSSCo or NBFC, now available and accessible. **It is also important to incorporate technological innovation tools that promote Citizen Science**, which can play a key role in fostering collaboration, especially within the museum sector.

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