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Patrice Pruvost

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BENEFITS FOR THE MANAGEMENT AND PRESERVATION OF FLUID COLLECTIONS USING QR CODES

P. PRUVOST

*Laboratoire Biologie des Organismes et Ecosystèmes Aquatiques (BOREA, UMR 8067),
Muséum national d'Histoire naturelle, CNRS, Sorbonnes Universités, IRD, UCN, UA; CP 26,
43 rue Cuvier, 75005 Paris, France
patrice.pruvost@mnhn.fr*

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In a pilot study carried out in the Ichthyology Collection (IC) of the Muséum national d'Histoire naturelle (MNHN) in Paris, we investigated the potential of quick-response (QR) codes for the improvement of collection management and conservation care of fluid collections. We analyzed the existing management procedures and work flows, including data work flows and current database architecture. During this process, we recognized potential improvements in the processes for managing the fish collection and other fluid collections from the field to the museum.

Our main conclusion was that collection management and databasing work flows could be improved by generating unique and stable identifiers through a tracking number management database (TraCol). We use the term “tracking collection number” to refer to any type of number that can be associated with a natural history object to identify it. This tracking collection number ID can correspond to or incorporate any number associated with the object during fieldwork (field number), in the laboratory (laboratory number), or at the time of integration into a collection (accession number). The database allows immediate management of metadata associated with the tracking collection number as soon as it is created, which can occur even before the specimens are collected. Thus, for each tracking collection number ID created, we can associate the name of the person who generated the number, his or her institution name, and the context of intended use.

By associating an object with a printed label including a digitized tracking collection number ID, the ID and its metadata can be directly linked to the object. This makes it possible to quickly identify collection objects and to track their status and location in the work flow as well as enabling remote data web access and download. The TraCol database can be regularly updated and then provide new information on location or on the conservation actions that have been taken on the collection objects. Incorporating the tracking collection number ID into a scannable QR code printed on the label can provide direct access to the dedicated tracking number management website, including a specific web page for each tracking number.

Our pilot study demonstrates that the adoption and future development of such a database and associated website should allow for the direct access, via a QR code, to the information needed for real-time monitoring of the MNHN fluid collection.

CONTEXT

Natural history collections are built up over time as they accumulate objects for a broad diversity of scientific purposes to document the natural world. Managing a natural history specimen as a collection object requires tracking information that distinguishes it from all other similar objects. The term “object” is inclusive and comprises natural specimens, living

or preserved, taken from natural or artificial sources and preserved for scientific research or museological use. Early naturalists such as Georges Buffon, Alfred Russel Wallace, and Alexander von Humboldt recognized the importance of associating information with these objects, including the following:

- The provenance of the object (place, date, and collector)
- A description of the object (species identification, number, and size of individuals)

These vital pieces of information are often referred to as the primary data. The primary data should be recorded as handwritten markings directly on the object or by means of associated labels and identifiers that characterize specimens as units that can be differentiated, recognized, and managed independently of each other. Such marks, labels, or identifiers can be highly variable in type, quality, and accuracy, especially in institutions with rich historical collections. Regardless, the loss or dissociation of these individual primary data marks turns the objects into unspecified items without context.

The process of building and managing natural history collections has changed little over time and includes four main steps:

- Collection of the object
- Description of the object and its provenance (e.g., in field notes or data sheets)
- Preservation and transportation
- Accession, cataloging, and integration into the collection

Documentation of museum specimens starts in the field when collectors record their observations and should continue when specimens and associated information are transferred to the laboratory for research, prior to museum deposition. When specimens are deposited in a museum, collection managers and curators then must record the associated data for each object. The minimum data required by a museum collection should include the location and date of the collect, the collector's name, a description of the object (size and the preservation techniques used), and at least a preliminary taxon name of the specimen. In addition, images are increasingly associated with specimens (see Fig. 1).

When specimens are deposited, accessioned, and cataloged in museum collections, their data are typically captured in a specific collection database. However, there may be delays between field collection and cataloging that may last sometimes for years after the initial fieldwork. During this time, specimens and their associated primary data may be lost or mismanaged.

Common risks leading to loss of specimens and their data prior to museum deposition are the following:

- Difficulties encountered during fieldwork that affect labeling, documenting, and packing specimens, particularly for large collections
- Import and export delays, including delays caused by regulatory requirements for transport or animal health
- Loss of specimens or their associated information during research use prior to museum deposition

The data loss from these delays not only hampers the eventual integration of specimens into collections but also reduces the value of the specimens for future research.

Additional delays and data loss can occur in the museum during the sorting of incoming accessions. The integration of specimens into a collection inevitably depends on the iden-

MUSEUM
NATIONAL D'HISTOIRE NATURELLE

MNHN / Ichthyology (IC) / 2003-1592

Sphaerooides marmoratus (Lowe, 1839)

SPECIMEN
Alcool: MNHN-IC-2003-1592
Prélevement manuelle: Boarque n°BFS-0020 Photo par S. Iglesias

TAXONOMY
Phylum: Chordata
Class: Actinopterygii
Order: Tetraodontiformes
Family: Tetraodontidae
Genus: *Sphaerooides*
Species: *Sphaerooides marmoratus*
Name: *Sphaerooides marmoratus* (Lowe, 1839)

ORIGIN
Country label: azores (.)
Country ISO (code): Portugal (PT)
Locality: horta
Spécimens données par: S. Iglesias
Collector's name: Iglesias
Ocean: atlantique
Island group: des azores
Collection date: 2003-9-20
Geographic coordinates: 38° 31' 58.8" N, 28° 37' 58.8" O

DETERMINATION
iglesias 2003 *Sphaerooides marmoratus* (Lowe, 1839)

Figure 1. MNHN website information for specimen (accession number MNHN-IC-2003-1592) from the IC in the MNHN (<https://science.mnhn.fr/institution/mnhn/collection/ic/item/2003-1592>).

tification and type of the objects, and their identification or sample type affects their final deposition within the collection. For example, fish larvae, ethanol vouchers, or DNA samples may have different management and storage requirements and are potentially handled and numbered differently during the accessioning and cataloging processes. Consequently, the recording of data and the assignment of a catalog number is closely correlated with collection-specific procedures or work flows that may proceed on different time lines in different collections. Complicating matters even further, the same individual specimen and its derivative parts may be assigned multiple different identifiers during collecting, processing, and research use, and all these must also be tracked and associated with the original specimen and its data.

It is therefore crucial to improve our ability to identify, document, and accession bulk samples or groups of organisms associated with the same collection event, for example, specimens collected by marine trawls or in bulk traps. All objects in bulk samples share the same origin, collection date, and locality and thus need to be understood as a coherent whole.

TRACOL, A TRACKING COLLECTION NUMBER MANAGEMENT DATABASE

The creation of a centralized tracking collection number management database (TraCol) enables inventory and digital tracking of a collection object and all its associated data and identifiers (e.g., field number, laboratory number, or collection number). This database can be used to capture existing data and assign a unique tracking number or tracking collection number ID with associated metadata. The metadata associated with the tracking number can expand over time as new information is entered and documented in TraCol.

TraCol provides the opportunity to generate a URL-based label for each tracking number ID with a QR code, which can link the label to a website page where these data can be stored and accessed. Thus, once a label, including a tracking number ID, is attached

to an object, the metadata associated with this ID in TraCol become associated with the object. As new data concerning all the subsequent management and preservation activities conducted on the specimen are generated, these data are easily incorporated and tracked via the TraCol database. Ultimately, the development of a website associate to this database should allow the use of a QR code system to access a web page specific to each tracking number ID from everywhere in the world.

The concepts related to the development of the TraCol database were described and tested as part of a graduate research project (Zilbermann 2014). The work was inspired by two studies incorporating QR codes into the collections. The first one was conducted at the Natural History Museum in London, where a new method was developed to digitize specimens (Blagoderov et al. 2012). This method includes a digitization protocol and software (Metadata Creator) to enable retrieval of metadata. Another study on large-scale scanning was done at the Australian National Insect Collection with SatScan imaging and the addition of two-dimensional codes (Mantle et al. 2012). The metadata entered during the digitization process follows the Darwin Core Standard (<http://rs.tdwg.org/dwc/doc/list>). As in the previous study, the emphasis was on finding a method to improve the digitization of collections while associating metadata to manage the tracking of specimens.

TRACKING COLLECTION NUMBER ID

In order to track individual specimens, we attach a label to them so that they can be identified. More and more frequently, these labels contain a unique number that can be incorporated into a tracking collection number ID. There is currently no standard that defines a tracking collection number ID. Our investigations of different natural history collections and research collections suggest that identifiers tend to be composed of two parts: a fixed alphanumeric code, that is, a symbolic code (i.e., CE-, PP, PMM, MNHN-IC-2020, MNHN-IC-ICOS), and a numerical sequence incremented from one to one. In some cases, a third part is assigned to differentiate subsamples. In the TraCol database, the symbolic code +, the numerical sequence, is denoted as the tracking collection number ID.

TraCol allows the user to request that the database generate tracking collection numbers, following the criteria below to guarantee their uniqueness:

- A unique alphanumeric symbolic code assigned for a series of objects defined according to the user's criteria
- A unique sequence numbers assigned with ranges reserved under each collection-specific code

The user can then add metadata to the requested series of tracking collection numbers. These metadata describe the significance of the specific code and the intended use of the number series.

Choice of Unique Alphanumeric Symbolic Codes

The first step in using the TraCol database is to record and describe the symbolic codes chosen by the user for digitization. A symbolic code is an alphanumeric code that identifies the collections in which objects of the same kind are grouped and managed together. For example, MNHN-IC groups all fish specimens curated and administered in the ichthyological collection. The choice of a symbolic code must be specific and unique and may consider additional criteria, including the following:

- Naming rules imposed by a museum or the leader of a scientific expedition

Table 1. Symbolic code table example.

Symbolic code	Use	Created by	Created date	Valid date	Valid
MNHN-IC-2019	MNHN Fish Collection Inventory Number Series: 2019	Person X	1 Jan. 2019	1 Jan. 2019–31 Dec. 2019	Yes
PMM_13	Mangrove inventory program in Mayotte	Person Y	1 Jan. 2013	31 Dec. 2014	Yes
CE	Fish study collection	Person Y	1 Jul. 2014	31 Dec. 2021	Yes

- Descriptors such as taxon groups (IC = ichthyology, RA = reptile and amphibian) or provenance (e.g., the Duke of Orleans Collection or Baudin's Expedition)
- Collection type: dry or fluid specimens, samples or whole specimens
- Specific treatments, preparations, or uses associated with a collection or a collector (e.g., otolith or DNA collections)

The database should be flexible enough for users to create their own symbolic codes and to record who contextualized the desired symbolic code in the database. The symbolic code table includes the following fields: Symbolic_code, Use, Created_name, Created_date, Validity_date and Validity (Table 1). TraCol prevents duplication of codes and ensures proper management of codes by database management staff. When a symbolic code already exists in the database, the user is invited to validate this choice or to define a different acronym.

To create a new symbolic code in TraCol, the user is asked to enter the value and to explain the context in which the code is used and the name of the person who is requesting the code. Input of a new symbolic code or selection of an existing one should require approval of a collection or database administrator who has a good understanding of historic or previously used codes within the institution that may not yet have been entered into the database.

Creation of Unique Sequence of Tracking Collection Numbers

The second step in the use of TraCol is the creation of a series of individual tracking collection number IDs and the metadata related to their use. TraCol allows users to request a range of tracking numbers that are automatically generated by the system. This allows a series of numbers to be reserved for a specific use to prevent the same numbers from being used multiple times by different staff or for different purposes. Again, the requesting user specifies the intended use for the series of tracking collection numbers (Table 2). Such requests should require approval of the collection or data manager responsible for each symbolic code.

Table 2. Inventory number table example.

Symbolic code	Serial beginning	Serial end	Request name	Request date	Use
MNHN-IC-2019-	0001	1500	Person X	1 Jan. 2019	Acquisition of MD50 cruise specimens
CE-	600	3000	Person Y	1 Dec. 2012	Acquisition of REVOLTA cruise specimens from Antarctica

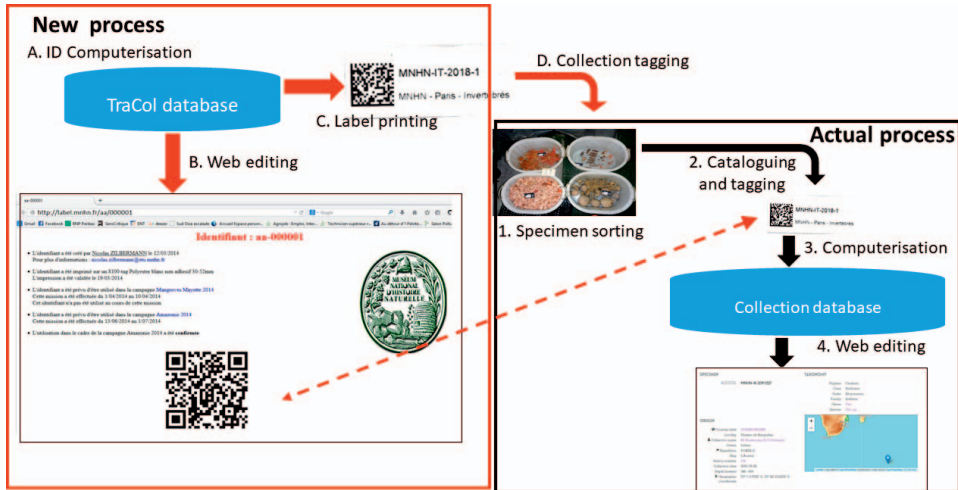


Figure 2. TraCol work flow for collection management. The black arrows in the box at right show the current process of steps 1–4. Step 1: Sorting and inventory of the collection. Step 2: Cataloging and numbering. Step 3: Computerization. Step 4: Publication on the web. The red arrows in the box at left show the new steps A–D to be added during the assignment of a tracking collection number ID and QR code. (A) Digitization of tracking numbers. (B) Online data capture in the TraCol database. (C) Printing of tracking collection number ID labels. (D) Specimen labeling.

The final tracking collection numbers will consist of the previously minted alphanumeric symbolic code prefix (step 1) combined with a sequential number (step 2), and these tracking collection numbers must be unique: “Tracking Collection Number” = “Symbolic Code Prefix” AND “Sequential Number” (Example: “MNHN-IC-2019-“ and “0001” = “MNHN-IC-2019-0001”).

Label Printing, QR Codes, and the TraCol Web Portal

The TraCol database automatically generates a new URL and associated QR code for each new tracking collection number ID. The QR codes can then be printed on durable labels and read by an appropriate scanner to access the online record. The tracking collection numbers generated through TraCol can be printed on any type of media that can accommodate a QR code. Labels can be assigned and preprinted for use before specimens are collected.

The advantage of QR codes is that they can link to a large amount of information that can be accessed on the internet through QR code readers with mobile devices such as computers or smartphones. The metadata associated with each URL provide, at a minimum, information on the person who created or edited the label, an explanation of the meaning of the specific code, and the context of use of this label and of the object associated with it. As new information becomes available, for example, regarding curation or use, these data can be easily added and made accessible.

Thus, the tracking collection number label becomes a unique identifier whose metadata are accessible both from data written on the label and from its QR code online. The following information will be clearly accessible and identifiable on the website:

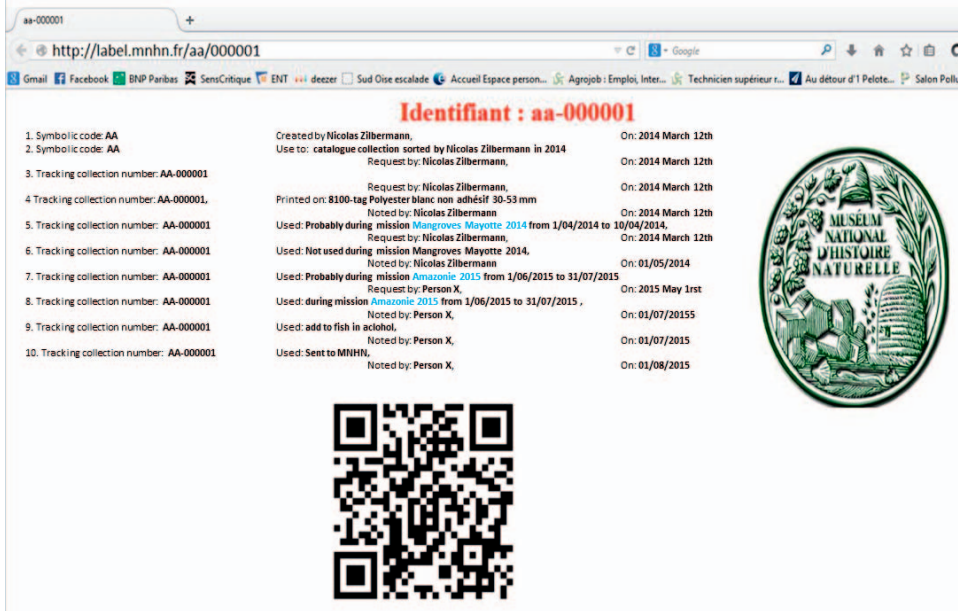


Figure 3. Mock-up of an example TraCol tracking collection number web page to be developed.

- The symbolic code corresponding to a particular type of collection and the institution or collection and the curator responsible for managing the tracking collection number
- The series of numbers to which a label belongs, requested by a particular person on a specific date, and the name of the person who reserved the series of tracking collection numbers ID, including the date of the request
- The inventory numbers assigned for a particular use (e.g., collection or shipment) at the request of a specific person on a particular date and the intended use of the generated tracking collection number ID

TRACKING OF COLLECTION OBJECTS

Once a tracking collection number ID label has been associated with a specimen, TraCol makes it easy to add new data concerning the object's conservation and use. These new data will then be immediately available from the QR code link from the label and object to the website. These additional data fields can be customized based on the needs of the collection (Fig. 2).

TraCol makes it possible to quickly digitize data related to a series of objects. Users will be able to easily fill in all the conservation and management tasks completed for a specific number series. It is thus possible to determine the work flow of each tracking collection number ID of a group of specimens by scanning the QR codes. The label may also specify the disposition of the specimens. For example, a series of codes may document the following:

- Specimens collected as part of a scientific expedition or other research studies
- Specimens from a sampling station in the process of taxonomic identification

- Specimens undergoing specific curation and preservation processes

In addition, TraCol is designed to digitally capture additional information on preservation and research of specimens (e.g., contact with specific chemicals or narcotics, prolonged chilling on ice, or UV exposure influencing DNA quality), including the nature of the preserving method or fluid, the date of preservation, and the operator. This information can be very useful for collection management and to determine the suitability of each specimen for specific use, for example, confirming that alcohol rather than formaldehyde was used to fix samples requested for a DNA study (Fig. 3).

Finally, this system makes it possible to supplement the data capture and digitization work flows by initiating metadata capture online prior to field collection or museum acquisition.

CONCLUSION

The development and use of an online tracking collection number management database such as TraCol offers several advantages. It enables inventory and metadata capture for all types of numbering systems used to manage collections. It provides information on the names and institutions of the users of these numbers and explains the context of how each unique number is used, and provides online access to this information on a website. TraCol enables printing scannable labels containing a QR code to provide a direct link to a web page containing metadata. These QR codes and their associated metadata can be accessed online worldwide using mobile devices.

Because TraCol separates the recording of the metadata associated with inventory numbers from the creation and use of these numbers, the data associated with each tracking number can thus be available prior to use. The association of a preassigned, digitized tracking collection number label with an object allows all the information in the number to be automatically associated with the object at the time of collection. This decoupling enables early data capture (e.g., during fieldwork or research use) and enhances the ability to track specimens and data from field collection through research to facilitate deposition, accession, and curation in a museum collection.

Assigning digital tracking collection numbers on or before disposition in a museum reverses the traditional data acquisition work flows: with TraCol, specimen digitization occurs as the first rather than the final step in collection management. This procedural change enables better tracking of an object through all stages of collection, curation, and use. Early assignment of a digital accession identifier not only enhances the documentation but also supports specimen conservation because TraCol can accommodate additional contextual information, such as condition or preservation history, that is rarely included in traditional collection databases.

Permalinks and QR codes are essential components that can increase the ease of use for collection management and enable online access to specimen data across collections and institutions. The widespread use of QR codes in recent years is an encouraging factor for the further development and adoption of this kind of tracking number management database in the future.

RESUMÉ

Au cours d'une étude pilote dans la collection d'ichtyologie du Muséum national d'Histoire naturelle à Paris, nous avons étudié le potentiel des codes à réponse rapide (QR) pour l'amélioration de la gestion et de la conservation des collections de fluides. Nous avons analysé les procédures existantes, y compris les flux de données et

l'architecture actuelle de la base de données. Nous avons ainsi identifié des améliorations potentielles dans les processus de gestion de la collection de poissons et d'autres collections de fluides, du terrain au musée. Nous proposons ainsi de développer une base de données (TraCol), pour gérer les numéros de terrain et de collection, capable de générer des étiquettes avec des QR-Code à associer aux spécimens de collection lié à un site web.

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