Research data management practices and perspectives among Catalan archaeologists: a qualitative approach

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Abstract

Purpose – The aim of this paper is to study the data management practices and perspectives of archaeological researchers in the Spanish region of Catalonia. Data management is becoming increasingly challenging for archaeological research as the data grow in volume and complexity. As a result, it is also a crucial issue and a priority for the discipline.

Design/methodology/approach – The data have been collected through in-depth semi-structured interviews with Principal Investigators of archaeological research projects at Catalan research institutions (n = 14), analysed using a qualitative content analysis method with a mixed coding framework developed mostly with themes identified in the literature.

Findings – The findings show that current practices are based on a sensible DIY approach. The resulting systems work well for the projects' data needs but are far from the best practices. A general lack of data literacy is evident from the answers of the interviewees and the practices described. Finally, the role of intervention reports is considered crucial, not only for knowledge creation and communication but also as data backups.

Originality/value – Few studies have been conducted on archaeology researchers' data management practices, and even fewer have used interviews as a methodological approach. The focus of this analysis sheds light on the current situation of a clearly defined but insufficiently researched community of practice (archaeology researchers in Catalonia), and therefore assess its needs, challenges and future prospects.

Keywords Information literacy, Research methods, Information management, Data, Data collection, Archaeology, Research data management

Paper type Research article

Introduction

Research data management (RDM) involves all the procedures, management strategies and activities related to the research data lifecycle (Briney *et al.*, 2020), that is the management and curation of these data from the very moment of their creation (Higman *et al.*, 2019). According to the Guidelines on FAIR Data Management in Horizon 2020, "[g]ood research data management is not a goal in itself, but rather the key conduit leading to knowledge discovery and innovation, and to subsequent data and knowledge integration and reuse" (European Commission, Directorate-General for Research and Innovation, 2016). Indeed, effective RDM can have numerous benefits, such as facilitating data use, sharing and reuse by making it easier to deposit data in a repository (Faniel *et al.*, 2018; Higman *et al.*, 2019; Briney *et al.*, 2020).

Data are becoming increasingly important, and datification is transforming every aspect of our lives, including science (Cukier and Mayer-Schoenberger, 2013). With the proliferation of

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digital methods and, more recently, the increasing use of artificial intelligence, research is becoming more data-driven every day (Tenopir *et al.*, 2011). This situation highlights the importance of managing these data effectively, as reflected in the new mandates of funding bodies and journals (Higman *et al.*, 2019). However, studies show that RDM quality is still low and far from being a priority for researchers (Ashiq *et al.*, 2020).

Archaeology is no exception. Digital technologies are now used extensively in archaeological research, and as a result data are becoming increasingly digital, large and complex, which is having a huge impact on the discipline (Faniel *et al.*, 2018; Hacıgüzeller *et al.*, 2021). One of these consequences is that data management has become more difficult and time consuming for researchers. Despite the growing importance of data within the discipline, however, there are still very few studies on researchers' data management practices. There is thus an urgent need to evaluate current RDM practices in archaeology, as it is the only way to identify the biggest challenges the discipline is facing today.

Literature review

RDM is a rapidly growing field (Birkbeck *et al.*, 2022) and studies on how scientists manage their research data are increasing in number (Ashiq *et al.*, 2020). Specifically, research analysing the RDM practices of academics and their perspectives on the subject has increased significantly over the last decade.

Most of this research uses surveys or interviews as primary data collection methods and normally seeks to understand RDM practices and needs in order to improve institutional services (Bishop *et al.*, 2020), assess existing ones (Aydinoglu *et al.*, 2017; Ismail *et al.*, 2022) or develop new strategies or infrastructures (Weller and Monroe-Gulick, 2014; Senft *et al.*, 2022). Some studies, however, are primarily concerned with characterising the state of the question and studying RDM practices in specific countries or even at specific research institutions (Abduldayan *et al.*, 2021). Some focus on a single discipline or academic field (e.g. Senft *et al.*, 2022 for agriculture; Syn and Kim, 2022; Krahe *et al.*, 2020 for health sciences; and Gualandi *et al.*, 2022 for humanities), while others are more general and include researchers in different fields.

The practices analysed in these studies vary widely. This inconsistency has been criticised by authors who identify a need to establish standards in order to achieve comparable results (Goben and Griffin, 2019). In general, from the author's observations during the review, the subjects studied in the literature can be categorized into five groups, that will be described in more detail later: data characteristics, data collection and analysis practices, data management practices, data storage practices and data management and storing perspectives.

However, there have been very few studies focusing on RDM in archaeology. Data collection is crucial in this field because of the largely destructive nature of archaeological methods (Frank *et al.*, 2015), which, along with the characteristics of the data, makes RDM in archaeology extremely complex (Huvila, 2019b; Taylor and May, 2024). Moreover, the introduction of digital technologies to the research process over the last few decades has contributed to an increase in the volume of data generated (Faniel *et al.*, 2018).

Despite its crucial nature, most archaeologists have a very limited understanding of RDM (Cook *et al.*, 2018; Garstki, 2022; Kansa and Kansa, 2021). In this regard, Huvila *et al.* (2019) highlight the lack of interaction between knowledge management and archaeology as disciplines. Only a few researchers have analysed the RDM practices of archaeologists, as most studies have been focused on promoting open data sharing. Among the few, Frank *et al.* (2015) analysed and compared the RDM practices and perspectives of archaeologists and zoologists, based on a set of interviews focusing mainly on the first steps of the data lifecycle. On the other hand, the project "The Secret Life of Data" (SLO-data) sought to improve archaeological RDM by analysing how these practices impact future reuse. This project was funded by the National Endowment for the Humanities (EUA) and promoted by the Alexandria Archive Institute. It studied the whole data lifecycle, with a focus on data reuse, of archaeological data drawn from

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three geographical areas (Africa, Europe and South America). The outputs of this project included a paper by Faniel *et al.* (2018) that analysed data creation and management practices in two archaeological excavation projects, combining interviews with ethnographic observation. This study was later complemented with another publication (Faniel *et al.*, 2020) that proposed some recommendations to improve current practices. Finally, the results of the SLO-data project were compiled in a closing paper (Austin *et al.*, 2024) containing proposals for the creation of internal guidelines and protocols to standardise RDM processes.

Research objectives

In light of the evident need for more in-depth research on archaeological RDM, the aim of this paper is to describe the current situation of data management in the Catalan archaeological research community. Its main objective is to identify and analyse the data management practices of principal investigators on Catalan archaeological projects (hereinafter, PIs) and the rationale behind them. To achieve this main objective, a number of secondary objectives have been established.

In relation to practices, this study aims to identify the specific type of data archaeologists work with, how these data are created, managed (organisation of the data, documentation practices, application of standards, etc.) and stored (short- and long-term). In relation to the rationales behind these practices, the aim is to identify researchers' opinions on data preservation, data ownership and data management in the future. Finally, this research also aims to determine whether there are any unique characteristics of archaeological research that influence RDM practices and perspectives.

Methodology

The study design was developed in accordance with the COREQ criteria for reporting qualitative research (Tong *et al.*, 2007).

Research team and reflexivity

The author of the study designed the interview guidelines, conducted the interviews and carried out the subsequent analysis and reporting as part of their PhD research. Due to their background in archaeology, they knew some of the participants personally.

The basic information on the research and the interviewer, such as the research objectives and methodology, were shared with the participants prior to the start of the interview. When asked by the participants, the interviewer also shared her assumptions and interests in the research topic, always stating that they were personal, subjective opinions.

Study design

For this study, interviews were considered preferable to surveys for the following reasons:

(1) The small size of the population of Catalan PIs ($n = 138$) would make it difficult to obtain a response rate high enough for the results to be statistically significant.

(2) During the pilot test of the survey, concerns arose in relation to the risk of respondents misunderstanding the key terms and main topics addressed due to a lack of knowledge about RDM.

(3) Interviews are a more effective way of extracting researchers' perspectives, experiences and opinions.

Participant selection

The study context is Catalonia, as this region has a robust archaeological community of practice. PIs were chosen as participants due to their influence on shaping research and

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knowledge-sharing strategies. An awareness of the practices and attitudes of research team leaders seems especially useful for developing an understanding of the current situation.

A study on archaeological research projects in Catalonia between 2014 and 2022 (Batlle-Baró and Abadal, 2023) identified a population of 138 PIs. With the initial intention of applying a purposive sampling technique, a sample of 40 PIs was selected, attempting to ensure a proportional representation of all chronological subdisciplines and institutions within the subset. Of these 40 PIs, 20 were contacted by email, beginning with a first-contact email presenting the project and asking them to participate; following their acceptance, a date for the interview would be set. Out of these 20 researchers, 16 agreed to take part in the interviews. The others did not answer to the initial email or the subsequent reminder.

Interview setting

The data were collected in online video calls using Microsoft Team. All interviews were individual, and were conducted between August 2022 and February 2023.

While it was not possible to fully apply the planned purposive sampling, the participants included in the final sample used to analyse the practices and perspectives of Catalan archaeologists cover various institutions and chronological periods, although some were overrepresented. Because the population studied were PIs, researchers with years of experience were also overrepresented. Moreover, most of the participants were male. Further details of the participants' characteristics are shown in Table 1.

Data collection

An interview guide was designed in accordance with the guidelines proposed by Whiting (2008), and approved by the university's ethics review board. The script was developed after conducting a literature review, taking the main themes identified in the papers analysed as a starting point, as recommended by Krauss *et al.* (2009). The questionnaire was pilot-tested with a PI prior to starting the interviewing phase; this interview was not included in the research.

The interview questionnaire was structured in four parts:

(1) Demographic questions about the project, the team and the researcher

(2) Data creation and management habits within the team

Table 1. Categories and themes found in papers on research data management

Code	Gender	Years of experience (in 2023)	Institution type
PI1	F	16	University
PI2	F	30	University
PI3	M	18	University
PI4	M	10	Research center
PI5	M	21	University
PI6	M	29	University
PI7	M	35	University
PI8	M	10	University
PI9	M	28	Other
PI10	M	26	Research center
PI11	M	21	Research center
PI12	M	21	Research center
PI13	F	15	Research center
PI14	M	20	Research center

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(3) Data sharing habits and perspectives of the researcher

(4) Data reuse habits and perspectives of the researcher

At the beginning of each interview, the participants were given details about the interview flow, the project and the research. They were also informed the interview would be recorded and how that recording would be processed. They were then asked to give their informed consent before continuing with the interview.

Only one interview per PI was conducted, and no repeat interviews were carried out. The interviews were video recorded, but only the audio was subsequently used. Some field notes were taken during the interviewing process, but these were not used for the subsequent analysis. The average interview time was around 75 min.

The video recordings of the interviews were transcribed verbatim using the Sonix AI software platform (www.sonix.ai). The transcripts were revised by the author, but they were not returned to the participants for comments due to time and practical limitations.

Interviews were conducted originally in Catalan (12 interviews) and Spanish (2 interviews). The quotes used in this paper to illustrate the results and discussion have therefore been translated to English by the author.

Although 40 interviews were originally planned, saturation was reached after 14 (Guest *et al.*, 2006). This number was considered sufficient based on a review of studies that had applied similar methods (Bishop *et al.*, 2020; Gualandi *et al.*, 2022).

Data analysis

After the data acquisition phase, the transcripts were analysed using a qualitative content analysis technique (Schreier, 2012). The content of the interviews was coded by the author using the software tool Atlas TI. For this paper specifically, the second part of the interviews related to data management practices and perspectives was analysed. A mixed coding frame was used, including both deductive and inductive codes. The main themes were drawn from the literature reviewed on RDM, while a few other themes were added in order to code specific practices related to unique aspects of archaeological research. All the themes used can be consulted in Table 2.

In order to minimise the bias that could result from the participation of a single coder, every step of the method was carried out twice, with at least a week in between rounds (Schreier, 2012).

Limitations

The population chosen to study is quite homogeneous. For future research, it would be interesting to widen the population to include younger researchers, who might have different experiences with and perspectives on research data management.

Findings

Researchers' practices

Data characteristics. Researchers were asked what type of data they were producing. Although processes and tools differed, most were creating the same range of data types. According to most interviewees, these types included textual data, tabular data, raster images, vector images and 3D models. Most also included artefacts, materials and samples.

Data creation and analysis. The main data collection/creation methods mentioned during the interviews were photography, photogrammetry, 3D scanning, manual drawing, total stations, artefact visual observation and description, analysis (C14, chemical analysis, DNA, etc.), excavation journals, context sheets, databases or data tables, vectorizing tools (CAD), documental studies and reuse of other people's data.

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Table 2. Participants' basic demographic data

Category	Topic
Characteristics of the Data	Definition of data
	Types and formats of data
	Volume of data
Data Collection and Analysis Practices	Methods or tools for data collection
	Frequency of data production
	Methods or tools for data analysis
Data Management Practices	Person responsible for data management
	Naming systems and protocols
	Creation of metadata, documentation or use of standards
	Costs and funding for data management
	Data management plans
Data Storage Practices	Data loss
	Data storage media
	Backups (frequency, methods, media)
	Data protection and privacy
	Long-term data preservation (duration, medium, size)
Data Management and Storage Perspectives	Challenges, problems and needs
	Responsibility for data and its curation
	Knowledge of data management
	Expertise or skills in data management
	Data management services and infrastructure
	Criteria or priorities for data storage
	Data ownership

Many of these data creation tools and methods are now digital. However, in the field, most projects used a combination of mostly analogue and some digital tools. As a result, the data have to undergo a digitization process. For example, contextual information is mostly recorded on paper (PI2, PI3, PI5, PI4, PI6, PI7, PI8, PI9, PI10, PI14), and subsequently digitized. Graphic information, on the other hand, is usually recorded digitally (PI3, PI4, PI5, PI6, PI9, PI10), as is volumetric data, with photogrammetry (PI2, PI4, PI7, PI14, PI6) or laser scanning (PI14). Some teams use the resulting models to create graphical information, mostly profiles and plans (PI7, PI9).

Despite this uneven implementation of digital methods, the aim is generally to achieve full digitization of field recording. However, digital tools are not always well adapted to the specific needs and challenges of archaeological fieldwork. Problems such as low connectivity, power availability or physical impediments and logistics were mentioned when explaining the limited use of digital solutions (PI5, PI8, PI14).

A similar situation was identified in discussions of the software used to acquire, process and analyse the data. Although there was no specific question about software, interviewees mentioned different programs used. For tabular data, Filemaker (PI1, PI2, PI8) and Excel (PI1, PI2, PI5, PI7, PI10) were mentioned, while researchers referred to Coreldraw (PI3, PI8), Photoshop (PI3) or Illustrator (PI10) for graphic information editing. All this software is proprietary, which a couple of researchers mentioned as a problem, due either to its price and licensing (PI1, PI8), or to the constraints it imposes when sharing data (PI1).

Data management tasks. The interviewees were asked whether there was a dedicated person on the team who was responsible for data management. In most cases, these tasks were performed and centralised by the PI (PI4, PI8, PI9, PI10), although sometimes they might delegate specific tasks to other team members. Some teams had a person who would be assigned the task of data management due to their digital knowledge or skills. This can be a problem, because not all team members have a secure and stable position, and therefore their dedication to the project is not always assured. Another common strategy was to make each

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researcher responsible for managing the data they created (PI11), especially when there are multiple sites and the directors take care of managing the data derived from their site's excavation (PI4, PI7). Finally, only two interviewees mentioned a dedicated technician, in both cases offered by the institution. This institutional support had a beneficial impact to the data management practices of the groups.

Most of the researchers interviewed had a system for organising files, although compliance with existing protocols or systems within the team was not always assured (PI14). Some reported unsuccessful plans to develop a bigger, more standardised structure.

Such structures and internal data management protocols were rarely planned ahead but normally developed as the team identified new needs (PI3, PI4, PI9, PI10, PI12). On some projects that had been continuing over a long period of time, these ways of working and managing the data were inherited from previous generations of researchers (PI5, PI8). In any case, structures, systems and protocols were all in a constant state of transformation depending on the project needs (PI8, PI9, PI14), and some were considering the introduction of changes in the near future (PI5, PI6, PI13). As PI9 explained, "as the data comes in or as things get done, that's when we start creating all of this . . . this whole system."

None of the researchers had developed data management plans (DMPs) for the projects because the funding calls that these were part of did not ask for one. Some had prepared DMPs for other projects (PI4) or were aware they would need to write one in the future (PI7, PI13, PI12).

Data documentation emerged as a theme in different interviews, but only one PI reported documenting their data as a regular practice (PI12). Some researchers claimed that archaeological data were explicit enough and there was no need to document them (PI1, PI13). Several interviewees were optimistic about the capacity of future reusers, both within and outside their team, to understand their data (PI12, PI13, PI14). However, other researchers were more aware of the problems that the lack of documentation and standardisation could cause in the future. On this point, one researcher noted that archaeological data "have no kind of format and are not standardised with one another" (PI9). Other researchers agreed with this, although the importance of the problem depended on their individual perception (PI13, PI14). Most became aware of the problems caused by the lack of standards when trying to reuse either legacy data (PI3, PI4, PI5, PI8) or modern data (PI4, PI6, PI8, PI9, PI12). As PI4 exposed,

> [s]ince right now there isn't a standardisation of how data is collected in archaeology, the same thing happens with modern data. Just because it's newer it doesn't mean . . . Because it's true that there's no standard. So, the problem of integrating data always . . . It's a problem because . . . because all of them are collected in slightly different [ways]. (PI4)

In most cases, researchers explained that they had solved the issue by contacting the data creators to ask for more contextual information (PI9, PI12). When this was not possible because the data creator was no longer available (PI8), the researchers resorted to other strategies to deal with the imperfection of the data (PI4, PI9), as they were used to working with imperfect data (PI13).

To avoid these problems, some interviewees mentioned the need to create standards or common records (PI1, PI2, PI6, PI9, PI13). A couple of researchers were aware of failed initiatives to try to build common, standardised data collection systems (PI1, PI2), but as PI9 put it, "there is a very big problem, which is that the standardisation of recording systems has never, ever been considered [. . .] at the national level, at the level of Catalonia." On a related point, one of the PIs explained the work that had been developed by their institution, which had a dedicated technician in charge of improving data standardisation (PI12).

Data storage. Different data storage media were mentioned by the researchers interviewed. The preferred data storage method was the cloud (PI1, PI2, PI3, PI5, PI7, PI8, PI13), whether the service offered by their institution (PI2) or personal services (PI1, PI7, PI8). Researchers liked the fact that it ensures instant, online backup (PI2, PI5), and that it allows the files to be accessed by different people (PI1, PI3) and from different places (PI5). The possibility of

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sharing files easily with colleagues was also mentioned as a perk of this system (PI8). However, its dependence on an Internet connection (which is not always available in the field) was identified as a drawback (PI1, PI8), as was the fear of hacking (PI13).

Personal computers were also a common option for storing data, usually on team members' laptops. The logistics of fieldwork favours the use of these devices (PI1), as does the high level of collaboration on archaeological projects (PI6, PI13). External hard drives constituted another widely used storage option (PI5, PI8, PI11), mostly for storing backups (PI3, PI6, PI10). Other options were institutional servers (PI4, PI14, PI12), institutional workstations (PI1, PI6) and physical archives at the institution in cases of analogue data collection (PI5, PI10, PI14). These archives were often seen as a secure backup option due to a distrust in digital storage. Finally, none of the researchers interviewed used data repositories to store their data. However, three teams were taking actions to deposit their data in their institutions' data repositories (PI10, PI12, PI14).

Although researchers were well aware of the importance of backing up their data, only a few reported that they adhered to a system of regular periodic backups (PI4, PI13, PI14). As one researcher put it, "[i]t's not something you would say is well-structured, but we do keep creating them as we go" (PI9). In some cases, mostly on the bigger teams, PIs considered that backing up data was the responsibility of the individual researchers, and trusted their team members to perform regular backups (PI11, PI13, PI14).

Some researchers conceived of the compulsory excavation reports that archaeologists must submit to the Catalan government after an intervention (Batlle Baró, 2021) as backups. However, as there are no established guidelines on what to submit, the quantity and quality of the data included in the reports varied depending on the team (PI6). For example, one researcher described sending the report together with "the CorelDRAW database with the plans" and "the FileMaker database with the inventories, with the contexts", considering that this way "at least we have a backup copy" (PI8). Another researcher (PI2) explained that on one occasion they lost a whole year's worth of data but they were able to recover part of them by extracting the information from their own report.

On the question of preservation, most researchers did not recognise any difference between short- and long-term storage, and they tended to store and preserve all the data (PI2, PI9). This is because archaeological research is normally a slow and cumulative process that continues beyond the project's life, that generally lasts, for publicly-funded projects in Spain and Catalonia, 4 years (PI4, PI7, PI12, PI13, PI14). Normally, "when the project ends, the research doesn't end" (PI11); instead, it continues, as "projects follow an administrative path or period, but, in contrast, the archaeological sites have a life of their own" (PI7). As a result, rather than losing value or becoming obsolete over time, archaeological data "are necessary in order to continue working afterwards [. . .]. They will continue to be part of our background and our essential working foundation to keep moving forward" (PI1).

On a related note, researchers were also asked whether they thought their data would still exist in 10 or 20 years. In response, although some expressed pessimism (PI2, PI4, PI13), most were optimistic or had no doubts that their data would still be useable (PI3, PI7, PI10, PI11, PI12, PI14). Again, the fact that certain data and reports were stored by the government gave researchers confidence in the preservation and longevity of their data (PI6, PI8, PI10), because "if it's in a public institution, the public institution is strong and will support it. Or not. We don't know" (PI13). Although none had done it at the time of the interviews, a few researchers expressed an intention to deposit their data in a repository for long-term preservation (PI6, PI10, PI12, PI14), in most cases because their institutions were developing this service.

On the subject of long-term preservation, the main concern appeared to be data and format obsolescence and how to prevent it. Many of the researchers interviewed had experienced the dawn of the digitalization of archaeology, and because of technological advances they had experienced a range of changes to standard formats, storage media and software (PI2, PI5, PI12, PI13, PI14). For this reason, they had personal experiences with data loss or data

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migration linked to obsolescence. Researchers tried to avoid this problem by carefully migrating files (PI3, PI9, PI11) and seeking out stable formats (PI2, PI3, PI4).

Researchers' perspectives

Data literacy. When first asked about data, some researchers were confused by the term and its meaning in archaeological research (PI5, PI14). Other researchers had a slightly negative view of archaeological data, which they described as "very raw, very primary, very tough" (PI3), "dull" (PI2) or "absolutely boring" (PI1). This contrasted with the narratives and interpretations that archaeologists construct out of those data, which they considered to be "much more fun" (PI1) and "interesting" (PI2). This distinction between data and information/interpretation was highlighted by several researchers (PI2, PI3, PI6, PI8, PI9). Interpretations are the result of the work of the researcher(s), an output of their intellectual activity with the data, combined with previous knowledge (PI9). Only a few researchers mentioned other characteristics of archaeological data. PI12 and PI13 highlighted their unrepeatability, while PI13 also mentioned the fact that they are incomplete, and PI4 considered them subjective.

Although there were no specific interview questions related to the researchers' knowledge and RDM literacy, some commented on their lack of skills or experience. In most cases, researchers alleged a lack of digital literacy (PI5, PI8) related to their age (PI3, PI11, PI14). In this respect, only a few interviewees, all of whom were working at research centres, reported receiving training or information on this subject from their institution (PI4, PI13, PI14).

Perspectives on data management processes. The main challenges that researchers associated with RDM were related to the volume of the data, which made them difficult to manage (PI2, PI3, PI8). Challenges were also identified in relation to new technologies that entail the creation of more data, such as photogrammetric 3D models, whose construction requires hundreds of photographs (PI1, PI7).

Another common concern was data loss. Some researchers had experienced it (PI2, PI13, PI14), and the fear of it informed their practices and perspectives (PI3). This can sometimes lead to data redundancy, when backup copies are not effectively managed (PI6, PI7) or there is no version control system (PI8, PI10, PI11). As a result, PI3 explains,

> with the growing number of systems for obtaining new data and the growing number of backups, clearly, this has led us to a current chaos of platforms, physical locations, and backup copies. We have everything, but it's spread across many places and in very different ways. (PI3)

Human error in the creation, processing, analysis or management of the data can also be an issue. In this respect, data digitization is especially problematic, because "data entry is really boring" (PI5) and this repetitive task can lead to errors (PI8). To minimise the mistakes, teams try centralising these tasks or reviewing the results (PI8, PI10).

Perspectives on rights and responsibilities. When asked who they thought was the owner of the archaeological data generated by the project, researchers offered different answers. Most understood that the ownership of the data was public (PI6), either society's (PI14), the regional government's (PI5) or the funding body's (PI6, PI10, PI13). As PI6 explained,

> The data, of course, are public. Any excavation, in one way or another, has been funded either directly with public money or through a company that received public authorisation to carry it out. Therefore, the data are obviously public. (PI6)

PI8 made a distinction between raw data, which would be publicly owned, and interpretations, which would be the researchers' intellectual property. Similarly, PI11 suggested that it would depend on the data, and PI12 proposed a separation between unpublished data (owned by the research institution) and published data (owned by the public).

On this question, some researchers expressed concerns and doubts related to intellectual property, mostly because of a lack of knowledge, information or clarity on the subject (PI6, PI8, PI9, PI10, PI11, PI13).

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Researchers were also questioned about the responsibility for data and data preservation. Many believed this fell within the government's responsibilities (PI4, PI7, PI9, PI10), although some thought it was not equipped for the task (PI5, PI9). Others identified different responsible parties depending on the data (PI10), or advocated for a shared responsibility between researchers and the government (PI14) or the government and the institutions (PI4, PI11). PI12 suggested that it should be the institution responsible for the research data it generated, while PI3 and PI9 were uncertain about this.

Discussion

The findings drawn from the interviews reveal a situation quite similar to the general state of RDM in other disciplines, especially in the humanities. However, they also expose some aspects unique to archaeological research due to the specific characteristics of the methodology used and the data generated in this discipline.

Archaeological data

As noted above, the definition of the term "data" was problematic in some cases. This difficulty associated with defining data is quite common in the humanities, as the findings by Gualandi *et al.* (2022) show. Taking their research as a reference, the interviewees in the present study took quite a restrictive view of the concept; from their responses it can be extrapolated that "data" would include primary sources (historical documents, artefacts) but not interpretations (Gualandi *et al.*, 2022).

The findings highlight the heterogeneity of archaeological data and the methods used to collect, create and analyse them. This heterogeneity is well-established in the literature (Hacıgüzeller *et al.*, 2021; Taylor and May, 2024) and has prompted some authors to describe archaeology as a "total science" (Huvila, 2019b). As happens in other disciplines, such as agriculture (Senft *et al.*, 2022), the wide variety of data types and formats make data management more difficult.

Other characteristics of archaeological data mentioned included their unrepeatability, which was referred to by only two PIs. Archaeological methodologies such as excavation are destructive and the data often constitute the only lasting evidence of what has been destroyed (Henninger, 2018; Huvila, 2019b). Although researchers are aware of this, it does not seem to be an important consideration when managing data. Similarly, although the subjective nature of archaeological data is well known (Roosevelt *et al.*, 2015), researchers seemed to treat them as objective records (especially in contrast to more subjective interpretations).

Data collection and analysis

The findings confirm the importance of digital data collection methods. This importance has already been studied in the humanities (Gualandi *et al.*, 2022) and discussed in detail in relation to archaeology (Huggett, 2012). However, it is interesting to note that there are still many teams that combine digital and analogue methods in the field.

Data management

Based on the findings, it can be concluded that researchers tend to manage their own data, corroborating what has been found in other studies (Whitmire *et al.*, 2015; Chigwada *et al.*, 2017). This results in the use of a wide range of data management and storage systems, which vary depending on the needs, options, abilities and experiences of each research team.

The systems used are generally a combination of databases and single files in different formats. These systems are dynamic and usually adapted to the evolving needs of the team, and in some cases, they are legacy systems. These findings are similar to observations made about American archaeologists by Kansa and Kansa (2013), who suggest that these practices impose a constraint on data popularisation and preservation.

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Teams normally manage their own data, as is common in many disciplines (Krahe *et al.*, 2020; Whitmire *et al.*, 2015 for the humanities), and only one institution offered a dedicated RDM technician to support its researchers. PIs are the ones in charge of data management, as also observed by Bishop *et al.* (2020). However, in some cases they may allow team members to manage their own data (Syn and Kim, 2022). When there is someone assigned specifically to this task, it is normally a young non-tenured researcher who has no professional stability within the research institution. This means that there is a lack of continuity in data management, which can lead to errors and other problems (Kansa and Kansa, 2021).

The findings highlight a lack of adherence to best practices in data documentation habits. This situation is similar to those described in other studies that have found that most researchers do not enrich their data with metadata (Ismail *et al.*, 2022; Liu and Ding, 2016; Piracha and Ameen, 2018). The high percentage of researchers who do not document their data found in these studies is similar to that recorded by Gualandi *et al.* (2022) for researchers in the humanities. Many of the interviewees consider that their data are self-explanatory and do not need documentation, a belief also observed by Ismail *et al.* (2022).

This idea that there is no need to explicitly state how certain parts of the process have been developed (e.g. data creation methods) is reflected in the silences identified by Huvila *et al.* (2022) in Swedish archaeological reports, most of which lacked descriptions of the activities carried out and the methods used in the excavation or research process, information that is considered to be tacit knowledge. Faniel *et al.* (2013) have demonstrated that this contextual information is crucial to allow future reanalysis of the data. It could be argued that excavation journals serve the role of recording and documenting the research process, particularly excavations and the interpretation of their findings (Mickel, 2015), similar to the role that laboratory journals have in other disciplines. However, the interviews show that journalling is not a common practice anymore, probably because of the digitalization of the field recording process. Moreover, the lack of standardisation, structuring and systematisation of these products hinders their usefulness for documentation (Henninger, 2018).

The findings show that although researchers are aware of the need for standardisation, there are either no common standards or they are not applied. This is not surprising given the well-known reluctance of archaeologists to adapt to standards (Kansa, 2007).

Data storage

Most data are stored in the cloud or on physical storage media (personal computers, hard drives). This is in line with practices observed in studies of other researchers (Aydinoglu *et al.*, 2017; Chigwada, 2021; Syn and Kim, 2022).

The prevalence of the usage of cloud services is quite high compared with recent studies (Chigwada, 2021; Sheffield and Burton, 2022). This may be due to the increase in the use of these storage methods in recent years, which can be identified by comparing this study with older studies (Weller and Monroe-Gulick, 2014; Whitmire *et al.*, 2015). However, the preference for cloud services may be best explained by the advantages that make this storage medium especially well-suited to the mobility and extensive collaboration that characterises archaeological research (Batist, 2023). The use of personal storage solutions (personal computers, hard drives) is also significant, exceeding the use of institutional or external options. This may reflect a trend in line with observations made in other studies (Krahe *et al.*, 2020; Ismail *et al.*, 2022).

None of the researchers were using an institutional repository to store their data, in keeping with studies of researchers in other disciplines (Chigwada, 2021; Ismail *et al.*, 2022; Senft *et al.*, 2022; Whitmire *et al.*, 2015). However, the recent development of such services by Catalan research institutes was reflected in reports by some researchers that their teams plan to use them in the near future.

The findings show that researchers are aware of the need to back up their data, although most teams lacked a well-designed system of regular periodic backups, which can sometimes

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lead to data redundancy and version control problems. This reflects a lack of concern about data security and integrity that has been found to be common among researchers (Bishop *et al.*, 2020; Jusoh *et al.*, 2019), although it seems to be even more pronounced in the case of the Catalan archaeology researchers interviewed for this study (Abduldayan *et al.*, 2021; Hikson *et al.*, 2016).

Researchers expressed a preference for storing systems that can act as backups themselves, such as cloud services (Hickson *et al.*, 2016). The preferred media for backup copies are similar to those identified in other studies (Jusoh *et al.*, 2019; Piracha and Ameen, 2018). Generally, most researchers tend to use more than one medium to store and back up their data, which has been found to be quite a common practice (Whitmire *et al.*, 2015).

The findings suggest that the PIs make no distinction between short- and long-term data preservation. The main reason for this is that archaeological data are cumulative and therefore legacy data are preserved and analysed together with new data. This phenomenon seems to be quite unique to archaeology, as it is not mentioned in any other study on RDM. Although it is not the same situation, it is similar to the finding by Ismail *et al.* (2022) that researchers rarely deleted their data even in the long term.

Consequently, researchers tend to manage and store their data for long-term preservation, in the ways described above. This poses challenges related to format obsolescence, which was found to be a major concern among researchers, as also identified by Kennan and Markauskaite (2015).

Researchers' perspectives

Perceptions related to long-term data preservation have been found to be closely associated with intervention reports. The importance of these documents in data management was a theme that emerged from the analysis of the interviews although this topic was not anticipated when designing the research. Because they are quite unique to archaeology, it is difficult to find parallels for these outputs in other disciplines. However, their role has been explored in various studies on archaeological documental practices (Börjesson, 2015; Evans, 2015; Huvila, 2008; Huvila *et al.*, 2022).

Excavation reports normally include a descriptive/explanatory section with contextual information related mostly to the fieldwork. The results are presented in an objective way and a preliminary interpretative proposal is included (Börjesson, 2017). This text encompasses a large volume of unstructured information, thus hindering its reusability (Börjesson, 2015; Huvila *et al.*, 2022). The explanations are normally accompanied by illustrations, photographs, plans and profiles, material inventories and studies and context sheets. Some teams also include other data in different storage media: databases, 3D models, field journals, analysis results, geospatial data, etc.

In Catalonia, it is compulsory to submit this report to the Catalan government (Batlle Baró, 2021). This obligation means that such reports are a standard output for all fieldwork related archaeological research, although they are not a standardised product. Some basic instructions for the content of the reports standardise them to some extent (Catalunya, 2002), as is the case in other countries (Huvila, 2008), but following these instructions is not a legal requirement. In any case, these reports are usually the first output of the fieldwork and the document that other archaeologists consult when they need information about a site or excavation (Huvila *et al.*, 2022). This highlights the crucial role they play in the knowledge construction process in archaeological research, and explains why their importance also extends to data management.

Due to their view that data ownership and data preservation are primarily the responsibility of the public institutions rather than their own, similar to the understanding identified by Frank *et al.* (2015), researchers tend to confuse depositing and maintaining reports with storing and preserving the research data derived from fieldwork, even when the data are not effectively submitted with these reports. As a result, some researchers think of reports as a data backup and as a way of ensuring long-term data preservation.

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The above considerations, together with the practices described in the "Findings" section, reflect a low level of familiarity with RDM and a lack of awareness of best practices. Although PIs demonstrated extensive knowledge of and concerns about certain specific issues (standardisation, obsolescence), the lack of backup protocols, data documentation, standards and DMPs suggest a reality that falls far short of what could be considered best practices (Briney *et al.*, 2020; Corti *et al.*, 2014). Researchers manage their data sensibly but with a do-it-yourself approach adapted to their needs and possibilities. Although they experience few problems with these systems, most lack knowledge of and training in this area. The low data literacy levels among researchers has been highlighted in various studies (Chigwada, 2021; Mancilla *et al.*, 2019), including studies of archaeologists (Kansa and Kansa, 2021). Many of the researchers interviewed associated this with their age, but the need for RDM training is evident, as has been noted in other studies (Cook *et al.*, 2018; Garstki, 2022; Rivers-Cofield *et al.*, 2024). The positive influence of institutional training and support is clear from the findings, as researchers whose institution had a dedicated technician or had been actively implementing their data policy were more familiar with the key concepts and had an overall better understanding of RDM, although this did not always translate into better practices.

Conclusions

The findings of this research suggest that knowledge of RDM and best practices is limited among PIs on archaeological projects in Catalonia. Nevertheless, the researchers interviewed do manage their data and have developed systems based on personal experience and common sense that yield acceptable results and meet their needs.

Data are created using different methods, both digital and analogue, and processed and analysed with a variety of software platforms and tools. PIs play an important role in data management, especially on smaller teams, while on bigger projects this responsibility tends to fall on individual researchers. The data are stored mostly in the cloud and on personal storage media (computers and external hard drives) and are backed up, although not always on a regular basis. Organisation systems are developed ad hoc, adapted to the needs of the project and sometimes added to existing in-team traditions. In general, researchers' data creation, management and storage practices align with those observed in similar studies.

However, the specific characteristics of archaeological data and research processes result in certain unique aspects of data management in this field. Firstly, the distinction between short- and long-term preservation is meaningless, as archaeological data is continuous and cumulative, rarely losing value over time. Secondly, the heterogeneity of formats and tools for data capture and analysis complicates RDM. This complexity is compounded by the lack of standards and documentation habits, which researchers often consider unnecessary, negatively impacting data management, sharing and reuse. And thirdly, it is important to consider the role of archaeological reports as research outputs. These reports are variable in quality and depth—some include large volumes of data, while others contain only minimal information. Despite this diversity, archaeological reports play a key role in communicating research results. Moreover, because they are submitted to the government, which is legally required to preserve them, the documents and associated files are often considered a final backup copy that ensures the preservation of (some of) the data and the interpretations thereof.

The ownership of and responsibility for data and its preservation were viewed by the researchers as public matters that fall within the purview of the government. Only in specific cases, particularly regarding more research-oriented data, did interviewees consider it viable for the government and researchers or research institutions to share this responsibility. It therefore seems necessary to clarify who is in fact responsible for data management and preservation, especially in light of researchers' rights, obligations and intellectual property.

Overall, the findings highlight an urgent need to improve and increase RDM training to raise archaeological researchers' data literacy levels, as well as a need to formalize guidelines and policies in order to clarify aspects such as standards of use, report content, intellectual

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rights and responsibility for data preservation. Given that data management is a crucial component of any research project, it is necessary to promote training and raise awareness among archaeologists, with the aim of improving their practices and the quality of the data they create, as well as to ensure data preservation and future reuse.

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