D2.3 Final Report on Community Needs

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Project co-ordinator name, Title and Organisation:	**Prof. Franco Niccolucci, PIN Scrl - Polo Universitario "Città di Prato"**
Tel:	**+39 0574 602578**
E-mail:	**franco.niccolucci@pin.unifi.it**
Project website address:	**www.ariadne-infrastructure.eu**

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About this document

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Partner in charge of the deliverable:	Salzburg Research
Author:	Guntram Geser (SRFG)
Contributing partners:	Special thanks are due to: Flavia Massara (ICCU) for the collaborative work on the archaeological repositories survey All colleagues of project partners, associated partners and projects who disseminated and contributed to the archaeological repository survey. *Related to the VRE use cases workshop:* Edeltraud Aspöck (ÖAW, ACDH-CH) Massimiliano Assante (CNR-ISTI) Phil Buckland (Umeå University) Jan Hasil (ARUP-CAS) Carlo Meghini (CNR-ISTI) David Novák (ARUP-CAS) Rachel Opitz (University of Glasgow) Eugenia Tabakaki (FORTH-IMBB) Maria Theodoridou (FORTH-ICS) Douglas Tudhope (USW)
Quality review:	Holly Wright (UoY-ADS)

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1 Executive Summary

This report of ARIADNEplus Work Package 2 (WP2) "Extending and supporting the ARIADNE community" presents the results of major activities carried out to understand and support community needs:

- A study on the impact of COVID-19 on archaeology and cultural heritage,
- An overview of the results of the user community needs survey (reported in October 2019) and subsequent activities following the recommendations of the survey,
- Selected results of a survey on practices and needs of archaeological repositories regarding FAIR data, data policies, how to improve data access, and other pertinent questions,
- Results of Virtual Research Environments (VREs) workshops organised to support the development of VREs that are relevant and fit for purpose for archaeological researchers.

The report is titled "Final report on community needs", as given in the Description of Work of the project, however the project work will continue for fourteen months, and additional activities focused on identifying and supporting community needs will be carried out.

In addition to the two VRE use case workshops another two are already planned. There is also demand for user needs and requirements work concerning the use of specific technology-based ARIADNEplus services and other services (e.g. training and professional development). Furthermore, needs and requirements will also be investigated for potential users of services beyond researchers and professionals in archaeology and cultural heritage, for example, citizens actively engaged in archaeological activities ("citizen science").

The many results of the activities covered in this report are summarised and recommendations given in the respective chapters. Here we highlight a single result: The COVID-19 crisis arguably will increase the effect of the work of ARIADNEplus for proper data management and sharing, digital repositories, and data discovery, access and use for archaeological research.

Research funders, councils and associations take the sharing of knowledge and data demonstrated during the COVID-19 pandemic as an example of Open Science which they now want to see adopted in all fields of research. More researchers in other fields also recognised that digital repositories, data search and access services, and virtual research environments are important for their work, including archaeologists. For example, in the ARIADNEplus repository survey of the 27 repositories that could collect and analyse access to their data 24 said that during the COVID-19 pandemic overall there was an increase in use from 5% to over 100%.

There is no guarantee that effects of the COVID-19 crisis will persist, meanwhile ARIADNEplus will continue to promote and possibly increase what the project can offer the archaeological research and data management community for adopting Open Science and FAIR data principles.

2 Study on the impact of COVID-19 on archaeology and cultural heritage

2.1 Introduction and overview

This chapter presents the results of an ARIADNEplus study on the impacts of the COVID-19 crisis on the sectors of archaeology and cultural heritage. The study was carried out to understand the consequences for these sectors and how ARIADNEplus could contribute to recovery, beneficial changes in practices, and future resilience. In line with the focus of ARIADNEplus on using digital technologies for archaeology and cultural heritage. This is also the main theme of the study results.

The study describes impacts on academic as well as contract archaeology and cultural heritage institutions and professionals. The cultural heritage sector has overall suffered more from the impact of the COVID-19 crisis but benefitted significantly from using available online platforms to stay connected with audiences and offer cultural content and experiences.

Concerning archaeology, the study addresses suggested changes in research methods, how work on collection databases continued during the crisis, and the role of repositories for data access and reuse. Furthermore, it includes a spotlight on how the COVID-19 crisis raised awareness of the FAIR data agenda. The study suggests that the overall message to be drawn from the impacts of the COVID-19 crisis is "no return to business as usual", instead progress in Open Science practices should be promoted.

The final section summarises the study results and gives recommendations for activities ARIADNEplus might support, what the project can offer, perceived beneficial changes in archaeological research and cultural heritage communication.

2.2 Academic archaeology

The COVID-19 crisis has a strong impact on archaeological research activities. In 2020 and 2021 fieldwork campaigns of university-based and other projects were canceled or curtailed, shutdown of institutes and travel restrictions meant that researchers had difficulty accessing laboratories, reference collections and archival materials.

Fieldwork campaigns and field schools with students and volunteers following COVID-19 regulations for travel, accommodation and work protocols (e.g., physical distancing, no shared use of equipment, etc.) were hardly possible, and therefore cancelled by the organisers responsible for the participants' health and safety. The same happened with Public Archaeology activities at archaeological sites.

Where field schools were cancelled alternative activities with students included work on previously generated data and presentation of results. For example, at Leiden University an existing exhibition on Carribean archaeology was turned into a website presenting results from many excavations in the region (Leiden University 2021). In Public Archaeology, organisations and projects provided resources for online teaching and learning, activities such as webinars and online reading groups, online desk research and back garden digs, and other ways to stay active until a return to other participation and volunteering is possible (e.g., Band 2020; Fox 2020; Redfern 2020).

With the field seasons in 2020, and in many cases also 2021, cancelled, archaeologists had more time to analyse the data of past seasons and prepare publications. Where ground-truthing assumptions with fieldwork data was not possible, an approach was the digitising and repurposing of existing legacy

data, e.g. to confirm assumptions based on remote-sensing imagery (Fitton & Wynne-Jones 2021). Archaeologists also explored new tools for improving the digital documentation workflow and related skills to be best prepared for future field seasons (e.g., Budka 2020).

Academic archaeologists active on missions in developing countries longing to get back to site may have to wait some time until this will be feasible. It will take some time until some countries will see much of their populations vaccinated, and measures against COVID-19, which make work difficult will remain in place. Meanwhile they could reconsider their relations with local communities and researchers as projects are often perceived as not being conducted on equal terms (e.g., Budka 2021; Chirikure 2020a/b; Ogundiran 2020).

In a keynote lecture at the 2020 conference of the European Association of Archaeologists, Cornelius Holtorf stressed the importance of a more inclusive archaeology for promoting trust, collaboration and solidarity between communities (Holtorf 2020; see also Holtorf & Bolin 2020). Other researchers were more outspoken about necessary changes in this regard, e.g., Olson (2020) in a reply to observations on research in archaeology and social anthropology by Jobson (2020) and Rosenzweig (2020).

Archaeological excavations are costly, and it is seems likely that in the coming years less funding will be available. While some of the already planned work will be resumed, archaeologists may have a hard time securing funding for new projects. The knock-on effect of the COVID-19 crisis will be felt for a long time, particularly by graduate students and early-career archaeologists due to the disruptions of field and laboratory work, and reduced employment chances (Bloch 2020; Di Fiore 2020; Neves 2020; Velez 2021). A large survey with most participants from the USA showed that female archaeological researchers and students are most affected (Hoggarth et al. 2021).

Another concern is increased looting at archaeological sites and illicit trafficking of cultural heritage objects as the COVID-19 crisis has adversely affected the surveillance of archaeological sites (UNESCO 2020c). If more control cannot be put in place this development will very likely continue. There are projects that monitor websites on which objects are offered, e.g., the ATHAR Project[1], but looting must be prevented.

2.3 Preventive archaeology

Preventive archaeology concerns measures such as investigation and improvement of conditions at sites and rescue excavations due to development projects carried out by businesses of contract archaeologists or public institutions (e.g., preventive archaeology units of museums).

Contract archaeologists carry out mainly excavations as for most European countries pre-development evaluation by them as to whether archaeological remains are present is not allowed. The share of commercial service providers in developer-funded excavations varies, e.g., in 2015 in the Czech Republic 15-20% were conducted by 15 licensed private organisations (Mařík 2016: 49), in France around 30% by 19 accredited private firms (Randoin 2016: 62). Thus, in these and some other countries most excavations are carried out by public institutions, for example in France by ARIADNEplus partner INRAP, Institut National de Recherches Archéologiques Préventives. In Norway, almost all such work is being done by museums.

In contrast, in the Netherlands and the UK over 90% of preventive fieldwork is carried out by contract archaeologists, for example 2015 in the UK by 70 members of the Chartered Institute for Archaeologists, of which 46 carried out excavations (Perring 2016: 96-97); however, the larger members such as Oxford Archaeology and Wessex Archaeology are charitable trusts.

[1] Athar Project, http://atharproject.org/media/

Based on results of a survey of the European Archaeological Council (2020) in August 2020 among their members it seems that many preventive fieldwork projects could continue and undertake at least some of the necessary rescue work, following the COVID-19 rules for such work. In rural areas there were fewer problems, while in cities it was more difficult.

Still, some archaeological companies had to furlough staff and terminate temporary contracts. The situation for smaller companies and self-employed archaeologists has become insecure. However, it appears that the impacts of COVID-19 are less severe than those of the economic crisis which began in 2007 and lasted for several years (Aitchison 2009; Cleary et al. 2014; Schlanger & Aitchison 2010).

Publications on the situation in the United Kingdom and United States provide more detail on how archaeological companies adapted their work to cope with the COVID-19 crisis (Aitchison et al. 2020; Douglass & Herr 2020; Head & Aitchison 2020; Lennox 2020; RESCUE 2020). For INRAP in France ARIADNEplus colleagues give an overview on impacts of COVID-19 on activities and mitigation measures taken (Salas Rossenbach et al. 2021; see also Garcia 2020).

Observers of the preventive archaeology sector cautioned that public authorities might relax regulations to allow development work to proceed without previous proper documentation and rescue of archaeological remains. This warning is not unfounded as there are many cases in which infrastructure development was indeed given priority. One COVID-19 example in Europe is the future site of the Parliament of Wallonia in Namur, Belgium, where the local authorities aimed to cut short necessary rescue work but backpedalled in face of strong community opposition (Vandevelde & Pasquini 2020).

It is expected that in some countries, new public and private infrastructure development will help in the recovery from the COVID-19 impact, which could generate more work for contract archaeologists. The survey report of the European Archaeological Council (2020) states that members often mentioned *"the potential increase in infrastructure development and investments (which usually accompanies governmental action to combat economic crisis), leading to increased demand for archaeological work, rise in contracts and employment in the sector"*.

2.4 Cultural heritage museums

The COVID-19 crisis affected all museums, monuments and other heritage sites worldwide. Due to the public health protection measures, restrictions on mobility and a drastic decrease of tourism they have seen their attendance plummet and much income lost. However, to stay connected with their audiences, many cultural heritage institutions increased the digital communication, online access to and experiences of, cultural heritage.

Surveys on museums and other cultural heritage institutions

Several organisations conducted surveys on the impact of the COVID-19 crisis on cultural heritage institutions. Most of the surveys concern museums, including large surveys by major organisations during the first global lockdown and follow-up surveys: UNESCO (2020b, 2021a), International Council of Museums (ICOM 2020a, 2020b, 2021), and Network of European Museums Organisations (NEMO 2020, 2021).

In several countries heritage organisations carried out surveys, in Europe for example the Finnish Heritage Agency (2021) and the Observatorio de Museos de España (2020), in Colombia the Museo Nacional de Columbia & Ministerio de la Cultura (2020), in New Zealand the Museums Aotaroa (2020). In the United States the American Alliance of Museums has run surveys in June and October 2020 and April 2021 (AAM 2020a/b and 2021).

In addition to their museum surveys, UNESCO carried out a survey on World Heritage sites (UNESCO 2021b). Results are also available of a survey on Cultural Routes of the Council of Europe (EPA Secretariat & European Institute of Cultural Routes 2020), and on religious sites reported by Future for Religious Heritage (2020a/b).

The COVID-19 impacts on museums have been studied extensively, but we could not find a survey or other major report on archaeological museums specifically. There are also many articles by cultural heritage professionals on the impacts (e.g., the articles in Cobley et al. 2020; Informal Learning Review 2020; Historic England 2020), but publications about archaeological museums are rare. One interesting paper discusses three scenarios for museums and other public-facing archaeology to consider when planning their future (Gould 2020).

Most likely the impacts of the COVID-19 crisis on archaeological museums have been the same as on other museums. The main impacts reported by the available surveys are a large drop in the number of visitors and loss of income, hence financial disruption, and difficulty getting back to normal operation.

In some countries the losses have been partially compensated by the government, while institutions in others even faced cuts in regular subsidies. In the first ICOM survey in April–May 2020 with 1,600 respondents 12.9% feared they would have to close forever, another 19.2% said they were uncertain whether they will be able to continue (ICOM 2020a). In the third ICOM survey one year later with around 840 respondents the percentages were 4.6% and 12.5%, respectively (ICOM 2021).

Concerning museum staff and freelance professionals, ICOM (2021) reports that in their surveys the percentage of participants stating that employees have been laid off has risen steadily from 5.8% in May 2020 to 9.6% a year later.

The situation for freelance professionals remains critical: in Spring 2020 15% of survey participants stated they had been laid off (i.e., contracts terminated and not renewed), a year later it was 5% less. At that time 43.7% of museum respondents still expected that they would have to suspend freelance/temporary contracts. Conservators and restaurators have been particularly affected by the COVID-19 crisis, as reported by surveys on their situation in 2020 (ACRE 2020; CAC & CAPC 2020; Mantyniemi 2020).

Concerning what they can offer their visitors, in the ICOM survey in April–May 2021 48.9% of the museums expected that in future they will have to reduce exhibitions and 48.1% will have to reduce public programs; reduced opening hours was expected by 40.2%.

The shift to online cultural heritage communication and experiences

The main positive effect of the COVID-19 crisis was that it brought about an increased focus within cultural heritage institutions on digital communication, online access to and experiences of cultural heritage. All surveys on cultural heritage institutions mentioned above included a part on this.

Briefly summarised the surveys found that most online offers of closed museums, monuments and sites were those not requiring high funds and staff expertise, such as posting messages and using hashtags on social media platforms (e.g., Twitter, Instagram, Facebook)[2] and highlighting some already digitised collection content or objects. Online experiences which required more time, resources and skills to produce increased the least, for example online educational programmes, virtual museum visits (e.g., 360-degree museum tours), virtual reality exhibitions and 3D object exploration.

The ICOM survey in April–May 2020, with responses from around 1,600 museums and museum professionals in 107 countries (46.3% from Europe), gives an impression of museums' digital activities

[2] Here two studies are available on how archaeological museums Italy and Spain used social media, both focused on Twitter (Rivero et al. 2020; García-Ceballos et al. 2021).

after the first global lockdown (ICOM 2020a). The survey question on their digital services included some basic categories, avoiding advanced formats and content such as virtual reality or 3D models which, however, could be subsumed under the category online exhibition or online collection.

The survey found that museum social media activities increased by 47%, quizzes/contests by 19%, live events 19%, collection online activities 18%, online exhibitions 16%, newsletters 13%, and podcasts 10%. Thus, there was quite an increase in digital activities, but apart from using social media channels the majority of respondents said these remained the same or there was no activity. For example, concerning online exhibitions 49% of respondents said there was no activity, 22% same as before, and 11% that such exhibitions were started after the lockdown (for online collection activities see *Section 2.7*).

For many institutions it was not easy to bounce forward by offering more digital services. Asked whether the museum had dedicated staff for digital activities, around 18% of respondents said no, 56% had such staff, but it was not their main domain of activity, and 26% said they work on digital activities full-time. Thus, at some institutions, staff with limited or no previous experience worked on digital communication, most using social media platforms.

Advanced digital content and experiences seen wanting

In media articles about online communication and experiences offered by cultural heritage institutions there was a tendency to highlight virtual tours and exhibitions, often with a focus on 3D models and other advanced content. Also, compilations of online offerings for audiences in lockdown included mostly such content and experiences.[3]

There are good reasons to highlight such content and experiences, and these are also one of the focus areas of ARIADNEplus services (i.e., the ARIADNEplus Visual Media Services). Among the goals here are enabling adoption beyond well-resourced institutions and promoting innovative uses for archaeological and cultural heritage purposes. Demand for this exists.

Samaroudi et al. (2020) during April to July 2020 conducted a very detailed survey of the digital offerings of 83 heritage institutions in the UK and in the USA. They found that virtual visits in the form of 360° tours and views of exhibitions, VR/AR experiences or online audio tours were the least common types of digital engagement, with only 3% of those offered by institutions in the UK and 2% in the USA.

3D models of cultural objects were offered as part of digital content collections and guided explorations. At 1% this was the least frequently offered type of content. A study by the Europeana 3D Content Task Force (2020) showed that this is still a developing field and more support for cultural heritage institutions is necessary to make available functional 3D content that can be explored by users.

Academic articles which discuss digital heritage content and applications in the context of the COVID-19 crisis are often critical of the experiences offered. The researchers find that these mostly replicate in a shallow way the experience *in situ*, instead of using digital technologies to provide novel, alternative and engaging experiences of cultural heritage (e.g., Burke et al. 2020; Hoffman 2020; Lopez Rodriguez 2020; Orlandi 2020). Although easily possible online, applications often present objects without rich description and historical context (Kahn 2020). Designed for audiences familiar with museum communication and exhibitions, the applications tend to create cultural "ghettos" (of those already interested) while excluding others from cultural participation, as argued by Lopez Rodriguez

[3] For example, European Commission, DG CONNECT: CulturalHeritage@home, https://digital-strategy.ec.europa.eu/en/news/cultural-heritage-home; Museum Computer Network: The Ultimate Guide to Virtual Museum Resources, E-Learning, and Online Collections (14 March 2020), https://mcn.edu/a-guide-to-virtual-museum-resources/

(2020). In general, the communication is often one-way, from the institution to the audience, lacking an active dialogue about the content and experiences offered. Furthermore, the online offer is typically designed for single-user experiences, lacking tools for visitors to interact and share their views and ideas (Vayanou et al. 2020).

Hoffman (2020), addressing most of the shortcomings mentioned, concludes that these *"cannot be argued to be a result of rapid response to pandemic conditions, but rather is a product of museums' long history of poorly articulating what 'digitization' means and viewing online potentiality through the lens of our physical world. While the casual viewer will chance upon enjoyment of the various online exhibitions and tours during the pandemic, it seems clear that for the most part online museum exhibitions betray an outmoded understanding of the digital with only a few transcendent examples."*

In conclusion, in addition to providing cultural heritage institutions high-quality services for novel content and experiences (e.g., the ARIADNEplus Virtual Media Services), guidance and good practices are also needed regarding meaningful and engaging content and user interaction for study, education and enjoyment.

2.5 Impacts on ARIADNEplus

Compared to the impacts of the COVID-19 crisis on the archaeology and cultural heritage sectors overall the impacts on ARIADNEplus have been low or could be minimised by mitigation actions.

That there was no dramatic impact is due to the fact that ARIADNEplus mostly focuses on the use of digital technologies, and a strong existing core partnership also helped the project to overcome challenges. The main activity for which an online replacement was not possible is the Transnational Access (TNA) programme, which allows researchers visiting one of the project's competence centres. Consequently, the TNA programme had to be suspended. Other training offers such as tutorials at domain conferences could be moved online, in the form of webinars and the ARIADNEplus Training Hub[4] (see *Section 3.2.6*).

ARIADNEplus sessions at major conferences, co-organised events and project workshops all took place online, arguably with more participants than in-person meetings. For example, one very successful online event which ARIADNEplus co-organised was "3D Digital Cultural Heritage for Resilience, Recovery and Sustainability" (27 May 2020), in collaboration with the European Commission (DG CONNECT) and Inception s.r.l. The conference was streamed live on YouTube, with an audience participation count of 280-300 steady viewers and many who watched the recording thereafter.

All planned in-person meetings and other joint activities of partners are still digital, possible thanks to Web platforms and communication channels. The ARIADNEplus community adapted very well to this change, carrying on their work from home and in recent months from their research centres.

During the lockdowns, most data providers could continue working on their repositories and collections, using already implemented remote access or solutions quickly set up to carry out work on data and metadata online (see *Section 2.7*).

Most importantly, the COVID-19 crisis increased the recognition within the archaeology and wider heritage sector of the importance of proper data management, repositories of open/FAIR data, and discovery and access services. Thus, the crisis will probably increase the effect of the results of ARIADNEplus and its "sister project" SEADDA[5] in this regard.

[4] ARIADNEplus Training Hub, https://training.ariadne-infrastructure.eu

[5] SEADDA - Saving European Archaeology from the Digital Dark Age (COST Action), https://www.seadda.eu

2.6 Changes in research methods

While the COVID-19 pandemic affects archaeology worldwide, the situation resembles the impact of the "Arab Spring" which disrupted archaeological fieldwork in countries in North Africa and the Middle East (see e.g., Casana 2013; Near Eastern Archaeology, 78.3/2015; Abdulrahman 2017). At that time archaeologists suggested focussing more on analysing already excavated but not studied material, and digitising and bringing online archival collections of investigations conducted in these regions for decades (e.g., di Lernia 2015; Mitchell 2019).

These are still valid suggestions, and regarding digitised and born-digital documents, available natural language processing (NLP) and data mining techniques offer much potential to exploit existing digital archaeological repositories (e.g. the NLP services of ARIADNEplus).

Scerri et al. (2020) argue that the field-based sciences must transform in response to COVID-19, building capacity for advanced remote collaboration based on digital research archives and platforms. Referring to the highly influential Marwick et al. (2017) paper on Open Science in Archaeology, they emphasise that "*longstanding arguments by those in favour of Open Science must be more broadly accepted in a COVID-19 world. Ensuring the future of field-based science requires greater investment in communication, shared analyses, open data repositories and international perspectives. In particular, accessible new digital archives will form an important part of peer-review and assessment, thus improving the documentary quality and reproducibility of scientific results.*"

Scerri et al. (2020) also outline virtual research environments that are built on top of digital archives at different scales (i.e., sites and landscape level), and provide analysis and collaboration tools through which local research groups are supported by subject experts helping analyse remote-sensing data and finds virtually. Jarus (2021) mentions than such an approach was applied in 2020 in archaeological work near the city of Erbil in the Kurdistan region of Iraq as project members could not get there. He thought that it *"may become more common in 2021 and the years ahead. This method not only limits travel problems but also reduces or eliminates accommodation and airfare expenses"*.

Providing Cloud-based virtual research environments for archaeologists is one of the goals of ARIADNEplus (see *Chapter 5*).

2.7 Work on online collection databases

In a survey on how UK research libraries adapted to the COVID-19 crisis, 61% of the 336 respondents indicated that COVID-19 had acted as a catalyst for change as it had *"encouraged or embedded pre-existing ways of working, at a faster pace"*. This concerned the rollout of systems for working remotely and the prioritisation of projects enabling the access to digital collections as well as the provision of online teaching content (Greenhall 2020: 11-12). Among the many results of this survey is that many written responses highlighted the importance of training and other support activities to promote digital scholarship and enable utilising the full potential of digital collections (Greenhall 2020: 29). In the coming years the digitisation of special collections and archives of academic libraries will gain in importance (Cox 2020).

Concerning museum online collection activities, in the first ICOM survey April–May 2020 around 33% of museums indicated that they did not provide such a service, 44% indicated there was no change in the level of activity, while 18% indicated an increase, and 4% had started activities. In comparison, in the third ICOM survey a year later 32% said the level of online collection activities was as before (12% less), 20% reported an increase (plus 4%), and 8% had started activities (plus 3%) (ICOM 2021: 16). Hence it appears that due to the COVID-19 crisis online collections gained in importance at many museums. Another question is whether the implemented collection management systems allow staff to work with them remotely from home.

A survey by the Collections Trust in the first weeks of the nationwide lockdown in the UK asked museums if staff and volunteers could access their collections database remotely to carry on working from home. Of the 265 respondents 113 (43%) said they could not. This problem was shared across museums of all types and sizes. Among the reasons were IT infrastructure not set up to support remote computers, a limited number of software licenses, only partially computerised collections data, staff lacking equipment or good internet connection. The article about the survey results concludes that this *"suggests a sector struggling with basic issues of digital resilience – and perhaps not just when it comes to collections data"* (Simpson 2020).

Among the ARIADNEplus data providers most could continue working on their collections. This was thanks to already implemented remote access to repository databases or solutions quickly set up to carry out work on data and metadata online.

Chris Nicholson, Director of ARIADNEplus partner Digital Antiquity, who manage The Digital Archaeological Record (tDAR) repository, notes: *"Because we have digital information stored in a service like tDAR (and there are many others), and the tools to access them, we can continue to work and provide a platform for others to do the same. The same cannot be said for many other archaeologists/historic preservationists"* (Nicholson 2020). He urges that archaeologists *"need to continue efforts in 1) converting our physical documents (those reports sitting on shelves gathering dust) to digital formats, 2) creating online platforms to access these items, and 3) planning for future work interruptions, whether they be from pandemics or other reasons. Making information and data accessible, either intra- or inter-office, truly is as important as ever."*

In Turkey associated partner British Institute at Ankara (BIAA) did just that, preparing data and metadata for implementing a digital repository. Atalan Çayırezmez of BIAA describes how the repository team worked online using a digital platform to share documents and work on metadata. *"Given that the BIAA has existed for more than 70 years, files and folders generated over the course of this time needed to be organised on the digital platform in order to increase efficiency and performance. The availability of the platform has been a great benefit, and has allowed us to work online with interns and volunteers during the pandemic"* (Çayırezmez 2020: 10). Work on the repository concerned preparing assessment reports for the various collections, and learning about and applying the metadata and vocabulary standards ARIADNEplus suggests for datasets of collections.

BIAA's digital repository team also translated into Turkish the PARTHENOS "Guidelines to FAIRify data management and make data reusable". ARIADNEplus and SEADDA promote this FAIR data guide which was developed by the PARTHENOS humanities and social sciences research infrastructures project. Translated successively in different languages and available for download from the Zenodo repository, since December 2018 there were 2,666 unique downloads of this FAIR data guide (per 15 October 2021), 279 of the Turkish version made available in July 2020.[6]

2.8 Repositories for data access and reuse

The Figshare 2020 "The State of Open Data" survey in August 2020 published a snapshot of results based on responses of 3,436 researchers on how the COVID-19 crisis was impacting their ability to carry out research and their views on reusing available data (Baynes & Hahnel 2020). Among those saying that their research has been "extremely" or "very" impacted, laboratory scientists were most affected (e.g., in chemistry 47%), while researchers in humanities and social sciences much less (20%).

Due to the inability of many researchers to gain access to their lab or to carry out fieldwork there was an increased interest in reusing data (Baynes & Hahnel 2020: 24): 64% of respondents intended reusing

[6] PARTHENOS Guidelines to FAIRify data management and make data reusable. Zenodo, https://doi.org/10.5281/zenodo.2668479; numbers given above are for unique downloads.

their own data during lockdown and 65% planned to use it over the next 12-18 months; 58% said they had previously reused their own data. Reuse of data shared by other researchers was intended by 50% of respondents during a state of lockdown and 51% over the next 12-18 months; 44% reported that they had previously reused other's data.

Actual reuse of data is difficult to identify and measure, but some digital repositories experienced increased access to and download of documents and data (Pool 2020). This happened also at archaeological repositories. In the ARIADNEplus repository survey in 2021 of the 27 repositories that could collect and analyse access to their data, 24 said that during the COVID-19 pandemic overall there was an increase, reporting increases from 5% to over 100% (see *Section 4.4.4*).

2.9 The pandemic and the FAIR data agenda

Observers of the sharing of COVID-19 related data from laboratories, clinics, public health organisations and others saw it as a change of research culture to a paradigm of Open Science and Open/FAIR data (Hook & Porter 2020). The OECD stressed that this was the right thing to do and that *"open science policies can remove obstacles to the free flow of research data and ideas, and thus accelerate the pace of research critical to combating the disease"* (OECD 2020).

In a position paper on COVID-19 and FAIR data CODATA, GO FAIR, Research Data Alliance and World Data System emphasised that the COVID-19 crisis made clear "*the fact that we need to meet both the immediate needs and long-term objectives of global science and accelerate the implementation of a FAIR ecosystem"* (CODATA et al. 2020).

Other observers felt that from the sharing of research data on COVID-19 some lessons can be learned by policy makers and researchers in other disciplines on why FAIR data are important and how it can be promoted, for example, *"The research data community has an important opportunity to use this hard won knowledge on the impact of FAIR in a pandemic, and accordingly shape the future of how we share data and research outputs"* (Khodiyar 2021).

However, many researchers are not yet ready to apply the FAIR data principles. The international Figshare "The State of Open Data" surveys found that in 2018 only 15% of the respondents claimed being familiar with FAIR, increasing to 18% and 24% in 2019 and 2020 respectively. There was also an increase in the proportion of respondents who had heard of FAIR but did not consider themselves familiar with the principles, 25% in 2018, 28% in 2019 and 31% in 2020 (Figshare 2018, 2019, 2020; Khodiyar 2021).

While there may have been an increased awareness among COVID-19 researchers of the open/FAIR data agenda, it is less likely there will be a broad impact in other research domains (Bobrow 2020). In archaeology some impact may have occurred indirectly, when archaeologists, not able to work in the field or laboratory, instead turned to digital archives to find data relevant for work on pause, prepare publications or design a new project. They may have recognised how important it is to have open access digital archives and information shared by other researchers, archaeologists as well as researchers of other fields from which they need reports and data.

2.10 No return to business as usual

The overall message to research organisations and researchers drawn from the impacts of the COVID-19 crisis is "no return to business as usual", instead progress in Open Science practices should be promoted.

On 30 March 2020, UNESCO hosted an online meeting of representatives of ministries in charge of science from 122 countries to exchange views on the role of international cooperation in science and

increased investment in the context of COVID-19. Open Science, for which UNESCO has been working on an International Recommendation since November 2019[7], was a major topic of the meeting. UNESCO Director-General Audrey Azoulay declared, *"The COVID-19 pandemic raises our awareness of the importance of science, both in research and international cooperation. The present crisis also demonstrates the urgency of stepping up information sharing through open science. The time has come for us to commit all together"* (UNESCO 2020a).

The benefits of Open Science practices, like open sharing of research data and publications, have been exemplified in research on COVID-19. Representatives of research funders, associations, repositories and other stakeholders now want to see the practices adopted in all fields of research (e.g., Barbour & Borchert 2020; COAR 2020; CODATA et al. 2020; European Commission[8]; International Science Council 2020; OECD 2020; SPARC Europe 2020).

In archaeology the request to follow open research practices is not entirely new, it has been voiced by researchers for several years (e.g., Beck & Neylon 2012; Beck 2013; Costa et al. 2012; Kansa 2012; Lake 2012; Marwick et al. 2017; Wilson & Edwards 2015). Particularly the *Open Science in Archaeology* paper by Marwick et al. (2017), published by a large group of recognised archaeological researchers, has greatly added to the awareness of the Open Science agenda in the field.

The overall vision of Open Science is making the research process and its results as transparent and accessible as possible to increase societal benefits which can be derived from scientific and technological knowledge. It is highly relevant for archaeology where excavation of sites – by academic or contract archaeologists – destroys the primary evidence, hence the data generated to document it, reports and publications should be easily accessible to other researchers and the interested public. Archaeological work to preserve, research and communicate archaeological heritage is generally carried out in the public interest and therefore requires a strong commitment to transparency and openness.

Open Archaeology, including open sharing of research resources (methods, tools, data), novel forms of research collaboration, and a deeper involvement of citizens, can greatly extend the societal relevance and reach of archaeological knowledge. However, many archaeologists are not yet well prepared for Open Science practices. As the matter is complex, strong leadership regarding policies/ mandates, supportive institutional measures (e.g., capacity building, training of researchers), and state-of-the-art digital repositories are necessary.

In coming years archaeologists will face many challenges and the community could benefit from adopting Open Science practices in its efforts to overcome them. Rather than trying to go back to business as usual, creativity and openness to new ways of working are needed.

2.11 Summary of results and suggested actions

This study has been carried out to understand the consequences of impact of the COVID-19 crisis on the sectors of archaeology and cultural heritage, and how ARIADNEplus could contribute to recovery, beneficial changes in practices, and future resilience.

The COVID-19 crisis has had profound impacts on archaeological research and cultural heritage communication. In comparison, impacts on ARIADNEplus have been low or could be minimised by mitigation actions. That there was no dramatic impact on ARIADNEplus is due to the fact that the project mostly focuses on the use of digital technologies and a strong existing core partnership.

[7] UNESCO: Open Science, https://en.unesco.org/science-sustainable-future/open-science

[8] European Commission: Open Science, https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/our-digital-future/open-science_en

Impact on archaeology

In academic archaeology, site-based fieldwork and public archaeology, as well as laboratory work has been affected. Planned fieldwork campaigns and field schools with students and volunteers in 2020 and 2021 had to be cancelled. In coming years less funding for archaeological projects may be available.

The impact on preventive archaeology carried out by companies and public organisations appears to be lower, at least compared to the economic crisis some years ago which forced many contract archaeology businesses to close. However, some companies had to furlough staff and terminate temporary contracts; the situation for smaller companies and self-employed archaeologists has become insecure.

In academic archaeology the knock-on effect of the COVID-19 crisis will be felt for a long time, particularly by graduate students and early-career archaeologists due to the disruptions of field and laboratory work and reduced employment chances. Established archaeologists had more time to analyse data from past field seasons, prepare publications, and applications for new research and public archaeology projects.

Also, an increase in access to available data in digital repositories has been observed, and it seems likely that the COVID-19 crisis made archaeologists more aware of the importance of publicly shared data, data repositories and discovery and access services.

In addition to looking for reuseable new and legacy data, archaeologists also explored tools for improving digital documentation and online platforms for collaborative research, including support of small local teams, where fieldwork was possible.

Conclusions and suggested actions

The main conclusions for ARIADNEplus are:

- The COVID-19 crisis arguably increases the effect of the work of ARIADNEplus for proper data management and sharing, digital repositories, and data discovery, access and use for archaeological research.
- Therefore, more may be achieved by promoting and possibly increasing what the project can offer.

Suggested actions:

- *Capacity building:* Increase promotion of resources for capacity building in data management and sharing, for example guidelines (e.g., the PARTHENOS FAIRify Guide), training resources (e.g. the ARIADNEplus Training Hub), training webinars in collaboration with SEADDA, and practical tools (e.g. the online Data Management Plan tool).
- *Data Portal:* Over the coming months more datasets will be included in the new Data Portal, which with additional features has become an effective research tool. Demonstrate the new capabilities when new national and thematic datasets are being released.
- *Special services:* Demonstrate the use of already available special services, for example, the Cloud-based Natural Language Processing service which supports extraction of information from archaeological documents such as fieldwork reports. Archaeologists who, due to the COVID-19 crisis, could not carry out fieldwork to collect new data showed interest in exploiting already existing documentation.
- *Virtual Research Environments (VREs):* Archaeologists also used online platforms to carry out research tasks, for example virtual support by subject experts of a local group of archaeologists. ARIADNEplus aims to provide VREs for different tasks and data types. When

VREs become available their advantages could be demonstrated in experimental case studies prior to the larger ARIADNEplus Pilots.

Impact on cultural heritage

The impact of the COVID-19 crisis on cultural heritage institutions such as museums, monuments and other heritage sites and routes has been tremendous. Due to a drastic decrease in tourism and local attendance they have seen their in-person engagement plummet and a lot of income has been lost. The situation for many institutions and their staff has become insecure and even more so for freelance professionals.

The main positive effect highlighted by all impact surveys is that the COVID-19 crisis has brought about an increased focus of cultural heritage institutions on digital communication, online content and experiences of cultural heritage.

What increased most was use of social media platforms whereas offering online experiences which required more time, resources, and skills to develop them was less common. Where well-resourced institutions had already invested in online educational programmes, virtual museum visits, online exhibitions, and 3D models of heritage objects these were of course re-activated and promoted.

Media articles on what cultural heritage institutions offered often highlight virtual tours and exhibitions, 3D models and other advanced content. Academic articles which discuss the online content and applications see shortcomings in several respects, shallow replication of the experience *in situ*, lack of rich description and historical context, one way-communication instead of a dialogue with audiences, among others.

Conclusions and suggested actions

The main conclusions for ARIADNEplus are:

- The project focus is not on improving the online communication, content and experiences offered by cultural heritage institutions.
- However, some services developed for researchers could be relevant also for other purposes such as heritage presentation and learning about archaeological sites and objects.
- Therefore, enabling use of such services, particularly beyond well-resourced institutions, should be considered.

Suggested actions:

- *Cultural heritage / archaeological online collections:* Collections are being used for heritage research as well as other purposes. Investigate with museum partners how different ARIADNE-plus services could improve heritage presentation, education, and other uses of collections.
- *Novel content and applications*: The ARIADNEplus Visual Media Services (VMS) are relevant for institutions interested in using 3D models for the presentation of heritage objects and sites. It is already planned to demonstrate the VMS to institutions and explore existing demand and specific requirements. In addition to high-quality services, guidance and good practices may also be needed regarding meaningful and engaging content and user interaction for study, education, and enjoyment.

3 Survey on ARIADNE user community needs

3.1 Introduction, survey topics and participation

In the third quarter of 2019 ARIADNEplus conducted an online survey of community needs regarding data sharing, access and (re)use, new services, and related training needs (ARIADNEplus 2019). The reported survey results are based on 484 fully or sufficiently questionnaires. Questionnaires were received from all 27 ARIADNEplus partner countries and a few other countries. 93% of the respondents are professionally based in a European country; 46% said the organisation they work for is a member of the ARIADNEplus consortium.

The organisational background of most respondents is a university or public research organisation (53%), museum (19%), governmental institution (15%) or a private company or research institute (8%). Regarding professional activities, 53% are archaeological researchers (field work), 9% laboratory-based researcher, 13% managers of an institutional repository or other data access services, 7% managers of project databases, 7% directors of an archaeological institute or research centre/laboratory, 12% other (various academic, technical and data management activities). Results of the survey were compared, where possible, to those of the ARIADNE survey in 2013 (ARIADNE 2014).

The analysis of the results focused on the match between the perceived user needs and the planned ARIADNEplus technical and other services, and suggestions were provided for activities likely to enable an optimal match. This chapter summarises the main results and recommendations of the survey and subsequent activities and results.

3.2 Survey results and recommendations

We summarise the results of the survey on the following topics:

- Data publication practices
- Barriers to data deposition & sharing
- Reuse of data
- Data search & access services
- Special services for researchers and data managers
- Training needs

Each section includes the recommendations of the survey report for ARIADNEplus activities to address perceived community needs. The final section of this chapter describes how the project followed the recommendations and results were already achieved.

3.2.1 Data publication practices

In the ARIADNE/plus surveys we used the concept of “data publication” to emphasise the common understanding that publication means that the data indeed is publicly available. Researchers often share data directly with colleagues but do not make them publicly available (e.g., in a repository). This means valuable data remains within small circles of peers and is not available to other researchers and the wider public. Moving more data from closed-circle or not shared to “open data” requires overcoming strong barriers, which are addressed in the next section.

Survey results

In the 2019 survey, around 65% of respondents said they published some to all their project data through an accessible repository, in 2013 around 50% said they did so. The results suggest that from 2013 to 2019 in the ARIADNE/plus communities of respondents the sharing of data through accessible repositories increased significantly by up to 15%. The percentage of 65% in 2019 is over 30% more than reported by other surveys with respondents from different disciplines, e.g., Tenopir et al. (2015) 30%, Figshare (2018) 33%.

Many survey respondents share data as supplementary material to publications and reports, 81% of 449 respondents in 2019 (82% of 520 respondents in 2013). In 2019, 13% said they do so in all or most, 25% in many, and 42% at least in a few projects. In other surveys the percentages were smaller, Tenopir et al. (2015) 19.4%, Figshare (2017) 34%.

The explanation for the much higher percentages in the ARIADNE/plus surveys could be that many of the respondents are obliged to provide fieldwork reports to a national heritage authority and do this with supplementary material added.

The survey participants were also asked if they agreed with the statement: *"In the last 5 years the readiness of archaeologists to share data through publicly accessible repositories or databases increased"?* – 83.2% of 376 respondents agreed. However, several respondents perceived a higher awareness among archaeologists that data should be made available, but little increase in readiness to do so. Others felt that the increase is taking place only slowly. More must be done to foster data sharing.

Suggestions for ARIADNEplus

While the ARIADNEplus survey shows good results for sharing reports and data through institutional repositories (e.g., repositories of heritage authorities or research centres), many archaeologists in European and other countries do not have available yet a state-of-the-art digital repository for archiving and sharing their data.

This issue is being addressed by the COST Action Saving European Archaeology from the Digital Dark Age (SEADDA). SEADDA and ARIADNEplus share the goal of making archaeological data FAIR (Findable, Accessible, Interoperable and Reusable), especially by supporting knowledge exchange and collaboration within data repositories and e-infrastructure.

The core requirement for moving research data into accessible repositories is decisive open data mandates by research funders, coupled with funding of the basic costs of domain repositories and researcher data deposition costs (e.g., as part of research grants).

Suggestions to increase further the sharing of archaeological data through appropriate repositories are:

- Continue the good collaboration between ARIADNEplus and SEADDA on capacity building for new repositories and use of the ARIADNEplus digital infrastructure.
- Support strict open data policies of funding bodies and institutions – providers of data repositories and e-infrastructures should give full support to such mandates.

3.2.2 Barriers to data deposition & sharing

Core functions of the ARIADNEplus digital infrastructure are to aggregate data from archaeological repositories and provide search and access services. Therefore, the ARIADNEplus initiative depends on repositories richly filled with accessible data shared by researchers. It cannot ignore obstacles which

hinder researchers in sharing their data in an open manner. Rather the initiative must support researchers in data sharing and help ensure that they receive appropriate credit for doing so.

Survey results

In the ARIADNE/plus surveys 2013 and 2019, participants were given a list of potential barriers for researchers to deposit their data in digital repositories and share it with others. The barriers which respondents perceived as most critical were the same, albeit with some differences regarding the percentages of "very" or "rather" important combined:

- *A lack of professional recognition and reward:* was considered as most critical by 75.5% of respondents in 2019, while 72% in 2013.
- *The work effort for providing the data and metadata in the required formats:* was an important barrier for 74% of respondents in 2019, while in 2013 more respondents worried about the work effort for metadata and data (80%).
- *Intellectual property rights issues:* was a concern for 75% of respondents in 2019, while significantly less in 2013 with 65%.
- Two barriers were perceived as somewhat less important with about the same percentages: *Lack of appropriate repositories* with 67% in 2019, while 66% in 2013; *the cost for depositing data in a repository* with 59% in both years.

Regarding professional recognition and reward for data sharing, in the Figshare survey (2018) the majority of respondents felt that they did not get sufficient credit for data sharing, 58%, compared to 9% who felt they do; 33% were not sure. Fecher et al. (2015) in a large survey with respondents from different disciplines found that *"if I were cited in publications using my data"* would motivate 79.3% of 1,420 respondents to make data available (9.5% said it would not, and 11.2% were undecided).

Suggestions for ARIADNEplus

Understanding obstacles to data sharing and helping to remove them is essential for research data infrastructures such as ARIADNEplus, as well as the underlying digital repositories. Advocates of open data argue that such data will often be (re)used and cited, bringing recognition and rewards to data publishers (incl. data repositories). The scenario is that data citations indicate and acknowledge providers of valuable data, promote further data sharing and (re)use, and enable the impact of open data to be tracked and measured. Most importantly, it would drive the emergence of an academic credit system that appropriately rewards open data sharing.

- Research infrastructure components, protocols and metrics for data citations are in development. ARIADNEplus should investigate how services of the research infrastructure could help identify and track (re)use of data based on data citations (e.g., article-data links) and other indicators.
- As a general requirement for identifying data (re)use, the project could promote and support standardisation of data citation in the archaeological sector, i.e., how data should be cited in publications to ease the identification and tracking of data (re)use.

3.2.3 Reuse of data

Sharing data is important but without (re)use the benefits associated with open data sharing would not materialise. There are many good arguments for making data available, for instance, that reported research results can be scrutinised and duplicative data collection prevented. Particularly strong however is the argument that reuse of data, for example to investigate new research questions, allows

exploitation of previous investment. Preserved data that is being reused gains in value, otherwise it might be perceived only as a cost factor.

"Return on investment" expected by research funders explains much of the increasing pressure on researchers to share their data from publicly funded research for reuse. It is also very important for repositories to document not only downloads but actual reuse. Metadata with rich context information is essential for reusing data, as is a license that clearly states what users are allowed to do with the data.

Survey results

Results of the ARIADNEplus 2019 survey confirm that archaeological researchers often (re)use available data and allow some insights into what and how that data will be (re)used. The survey participants were asked, *"Did you / your research group in the last 2 years use any data which other researchers made available through a publicly accessible digital repository or databases?".* – An astonishing number of 220 respondents said they did and briefly described the data types and/or the sources.

In comments 34 respondents also gave reasons why they did not (re)use other's data. Most said relevant data was not available or posed some problems, difficulty to access or use, missing licensing information, lack of support, among others. Some also said that they did not need data from other researchers.

The 220 respondents were asked "*What was the main purpose of the data reuse?"*, and three pre-defined purposes and the option "Other" offered. Building a database for the research community was a purpose for 31%, comparison to own results for 55%, and use together with own research data for 63% (multiple answers were possible). Few mentioned other purposes for the data (re)use, for example, to use it as test data (e.g., "test algorithms and approaches") or as a conceptual resource (e.g., "typology terms", "data structure").

Suggestions for ARIADNEplus

- ARIADNEplus should promote and support data reuse so that the investment in the collection of archaeological data can be exploited further for research, education, and other purposes. Ways to enable easy reuse of data with the ARIADNEplus infrastructure should be investigated.
- Different purposes and forms of data reuse should be considered to better understand actual practices of data reuse in archaeology so that these can be supported effectively.

3.2.4 Data search & access services

ARIADNEplus will incorporate data from a wider range of archaeological research domains than ARIADNE, including environmental archaeology, maritime and underwater archaeology, biological and inorganic materials studies, radiocarbon, dendrochronology, and other dating methodologies, among others. Furthermore, the project aims to integrate more datasets at item level to provide advanced semantic data search to find data items based on semantically defined relations.

The ARIADNEplus 2019 survey investigated three closely related questions on data search and access: current online availability of the different types of archaeological data, and how helpful it would be to discover and access the data via the ARIADNEplus portal, at both the collection level and item level.

Survey results

***Online accessibility of data types**:*

Survey respondents were asked to rate the current availability of the different types of data ARIADNEplus aims to mobilise and integrate into the dataset catalogue and portal. The data types were rated as follows:

- Good availability: archaeological sites and monuments data (usually provided by heritage authorities), national GIS data and maps (from mapping agencies), and satellite or airborne remote sensing data (in Europe offered freely by the European Space Agency).
- Less good availability: data and documentation of fieldwork (excavation, field survey/prospection, fieldwork reports), and databases and catalogs of various artefacts (e.g., museum collections).
- Poor availability: dating data (e.g., dendrochronology, radiocarbon) and scientific data/analysis of biological and inorganic remains. Also, the availability of environmental archaeology and maritime & underwater archaeology data was perceived as poor.

***ARIADNEplus portal for data discovery & access**:*

One particularly important objective of the survey was to identify if respondents perceive support by the ARIADNEplus portal to discover and access more helpful for some data types than for others. A comparison of the online accessibility rating of the data types and the helpfulness of portal support for discovering and accessing datasets or collections of such data showed:

- Surprisingly, the appreciation of support was lower for data types for which the accessibility was evaluated as insufficient.
- Respondents were most appreciative of portal support for discovery and access of sites and monuments databases or inventories, national GIS data & maps, and satellite or airborne remote sensing data (e.g., LiDAR), although the online accessibility of these data types was rated much better than that of other data types.
- the rationale for ARIADNEplus should not be to prioritise support for data types which are already much more accessible than others; the fact that the more accessible types are being provided by national mapping and heritage authorities indicated ARIADNEplus should prioritise other data types.

Suggestions for ARIADNEplus

The survey results tentatively suggest the following prioritisation of data types for mobilisation and integration in the ARIADNEplus portal:

- Data types with high or medium appreciation of portal support, and currently medium or low online accessibility – sequence according to the appreciation of support and level of accessibility: Excavation data (e.g., excavation archive); Artefact/finds databases or image collections; Radio-carbon, dendrochronology and other dating data; Environmental archaeology datasets; Unpublished fieldwork reports; Field survey/prospection data.
- Next would come the following data types with lower appreciation of respondents of portal support: Maritime and underwater archaeology data; Scientific data/analysis of inorganic remains; Scientific data/analysis of biological remains; Inscriptions, coins, or other special databases.

  But it must be noted that the lower appreciation is very likely due to fewer survey participants being specifically interested in these data types (e.g., maritime and underwater archaeologists).

The survey participants also rated which data types they would find helpful for their research if able to search items within datasets integrated from multiple sources (item-level access). The results

confirmed the evaluation above, except that artefact/finds databases or image collections were ranked highest.

3.2.5 Special services for researchers and data managers

A wide range of enhanced and new services for researchers and data managers is foreseen to be provided on the D4Science platform for virtual research environments. Therefore, an important goal of the ARIADNEplus community needs survey was to find out which ones the respondents perceive as particularly helpful for their research or data management. The services in question are for end-users, "back-office" services, those which end-users do not use directly were not included in the survey.

Survey results

The survey question presented a list of 16 services each concisely described from the perspective of what users could do with it. The list included four services already provides, ten advanced and new services considered, and two potential future services (i.e., not considered in the work plan of the current project).

A very encouraging survey result is that respondents greatly appreciated services which are already available (and which they may have already used): Register a dataset in a portal that allows the searching of data from many providers; Discover & access archaeological data stored in repositories in different European & other countries; Spatially and/or chronologically defined search options.

Services for searching and visualising geo-spatial/GIS datasets were the highest ranked among the new services and are part of the plan of services ARIADNEplus will implement. Respondents were also particularly interested in using Linked Data to interlink their own and other datasets. Applying Linked Data standards and technologies is the general approach in ARIADNEplus for data integration and some of the search services. Project datasets in Linked Data formats will also be made available to external developers for interlinking datasets (e.g., via an API).

Furthermore, respondents were interested to use services for working with visual content (e.g., 3D models, LiDAR imagery), considerably more than using services for textual content. Visual content services were already offered by ARIADNE but not integrated on a service platform, for which ARIADNEplus will employ the D4Science platform.

Lowest on the list is a service for mapping databases to the CIDOC-CRM extended for archaeological research data. This result did not come as a surprise because the service is specifically for data managers (databases, repositories) and these made up only 20% of the survey respondents.

Suggestions for ARIADNEplus

The main suggestions that can be derived from the survey results are:

- Devote special attention to the new services for search and visualisation of geo-spatial/GIS datasets.
- Prioritise the use of Linked Data for interlinking datasets, particularly at item level.
- Continue to enhance existing and develop new visual content services of interest.
- Evaluate further which services for textual content are of interest to users, including services not yet considered.
- Promote use of the CIDOC-CRM by making clear its capability to integrate research data conceptually, especially regarding the ontology extensions developed in the ARIADNE project for archaeology (e.g., excavations, standing structures, epigraphy).

3.2.6 Training needs

ARIADNEplus training for researchers and data managers of archaeological projects was planned in the Transnational Access (TNA) programme as well as at domain conferences in the form of tutorials and short courses, e.g., on how to use ARIADNEplus services for research and data management. In matters pertaining to archaeological repositories ARIADNEplus coordinates activities with the SEADDA project. SEADDA aims to foster the development of archaeological data repositories in countries where the research community lacks an appropriate repository.

Survey results

The ARIADNEplus survey investigated current training needs of archaeologists regarding data management and processing. In a survey question eight activities were suggested, with the option to add comments, e.g., suggest other topics, which no respondent did.

The respondents who answered the question approved the different areas of training as very helpful or helpful between 86.6–94.5%. Therefore, the thematic areas were later adopted for structuring the training resources included in the ARIADNEplus Training Hub.[9]

The survey results for training needs can be summarised as follows:

- *On top: the FAIR data principles:* Training in the application of the FAIR data principles in archaeology was appreciated most, and ARIADNEplus is committed to promote the principles in the archaeological sector.
- *Other interesting topics:* Next on respondents' wish-list for training came depositing project datasets in a digital repository, managing datasets of a large archaeological project, and data science skills.
- *Less appreciated:* Significantly less appreciation was expressed for training in how to create and implement a data management plan (DMP), manage a digital repository, produce metadata and use domain vocabularies to describe archaeological datasets.

That there were many more researchers than data managers among the survey respondents had a considerable impact on the results. Responses to the survey question on barriers to data deposition and sharing show that researchers worried about the work effort for providing data and metadata in the required formats, a perceived barrier for 74% of respondents. This explains why training on DMPs, metadata and vocabularies is appreciated less than other training topics.

Suggestions for ARIADNEplus

- *Application of FAIR data principles:* Support FAIR data policies and good practices of researchers and data managers through guidelines, workshops, and training (e.g., online webinars to reach many researchers). Training offers should be as practical as possible, distinct from the broad wave of general information on the FAIR principles; focus on what matters for archaeological researchers and data managers specifically.
- *Data science skills:* ARIADNEplus has limited capacity to raise the level of data science skills of archaeological researchers, i.e., use of advanced data processing and analysis methods. This should be done by dedicated courses within universities and data science centres. However, a focus on data science skills is possible, related to the ARIADNEplus Cloud-based Virtual Research Environments (VREs).

[9] ARIADNEplus Training Hub, https://training.ariadne-infrastructure.eu

- *Research Data Management (RDM):* Continue making researchers aware of available guides to good practice, e.g., the guides offered online by Archaeology Data Service and Digital Antiquity for different types of research data.
- *Data Management Plans (DMP):* To define and implement a DMP and related activities (metadata, vocabularies) adds work, and researchers are unsure they will benefit from this additional work. Case studies making clear the benefits could promote more interest in data management planning for archaeological projects.

3.3 Summary of ARIADNE plus activities

This section summarises how the project took account of the recommendations of the survey report for activities aimed to meet perceived community needs.

Data publication practices

Archaeological researchers often share data directly with colleagues but do not make them available through accessible repositories. Among the reasons for this behaviour is a lack of suitable domain repositories for their data in many countries. This issue is being addressed by the SEADDA project with which ARIADNEplus collaborates closely to foster the development and use of state-of-the-art data repository and e-infrastructure services. The related recommendations of the community-needs survey have been being followed by:

- Support of Open/FAIR data policies, e.g., through the ARIADNEplus Training Hub and work-shops (see *Section 3.2.6*).
- Promoting further the development of archaeological data repositories and investigate their needs and requirements, e.g., the Repository Survey (*Chapter 4*).

Barriers to data deposition & sharing

Data repositories and e-infrastructures like ARIADNE aim to remove barriers of researchers to enable (re-)use of the data they have collected or generated. Most of the data stems from publicly funded projects. Therefore, the main way to remove researchers' reservations is that research funders request data deposition in accessible repositories. A supporting factor is that data users must acknowledge the sharers (and repositories) through data citations, which raise their reputation in the research community. The related recommendations on data citations of the community needs survey have been followed by:

- Promoting the FAIR data principles, which require citable and well-described datasets; established data citation standards are recommended by partner repositories.
- Investigation of how services of research infrastructures could help identify and track (re)use of data based on data citations (e.g., article–data links): a specific task works with OpenAIRE to enable linking of cited ARIADNEplus datasets to publications (Task 4.5).

Reuse of data

Reuse of data increases the value of the investment by researchers and repositories in making datasets accessible. Therefore, it is important to promote, support and track the use of shared data for various purposes, e.g. build or extend a community database, carry out new research, training in digital scholarship, etc. The related recommendations of the community-needs survey have been followed by:

- Investigating further different practices of data reuse in archaeology so that these can be supported effectively; ARIADNEplus also collaborates with a SEADDA working group on the topic of data reuse.
- Highlighting benefits and requirements of data reuse in project presentations; it is also planned to focus conference sessions in the last project year on this topic.
- Ways to support easy reuse of data with ARIADNEplus services are being explored; for example, download in appropriate formats of portal data search results (e.g., distribution maps for artefacts) or transfer to ARIADNEplus virtual research environments which provide data processing and analysis tools; for Linked Open Data service developers an Application Programming Interface (API) for building on the ARIADNEplus LOD will be provided.

Data search & access services

This part of the survey investigated three closely related questions: the perception of participants of the online availability of different types of archaeological data, and if capability to discover and access via the ARIADNEplus portal would be more helpful for some data types than for others, considering both collection-level and item-level access (i.e., items within collections).

The analysis of the results showed that respondents appreciated portal support more for data types for which the online availability was evaluated as much better than for others. Therefore, the survey report suggested not to prioritise these data types but those with high or medium appreciation of portal support, and currently medium or low online accessibility.

The report presented a tentative prioritisation of data types to mobilise and integrate in the Data Portal based on this approach. It also noted that discussion of the approach should consider that the lower appreciation of some data types was very likely due to fewer survey participants being specifically interested in such data:

- The subsequent conclusion for the data mobilisation was that preference for some data types over others should be considered when prioritisation becomes necessary, i.e., limited resources to integrate all data from interested providers.
- Concerning collection-level versus item-level search & access: datasets that can be integrated at item-level are preferred as ARIADNEplus aims to integrate more such datasets than the original ARIADNE project.

Special services for researchers and data managers

The survey yielded very useful results regarding the different services the project aims to provide on the Data Portal or as part of virtual research environments on the Cloud-based D4Science platform. Firstly, the ranking of the services showed that respondents greatly appreciated services which were already available from the first ARIADNE project, but could be improved even further. Secondly, the ranking showed preferences for some of the foreseen enhanced and new services. The related recommendations of the community needs survey have been followed for example by:

- Devoting special attention to enhancements of the Map-based search and visualisation of results on the Data Portal and the development of new services for geo-spatial/GIS datasets. The Map-based search of the Data Portal is already enhanced with many new features (e.g., different layer types, polygon-shaped areas of interest, and other features).
- Supporting the use of Linked Open Data (LOD) to interlink datasets, which is ARIADNEplus' general approach for data integration. A LOD tool is being developed to annotate data resources with terms from different vocabularies and link to related resources using these terms. LOD service

developers will be enabled to use the ARIADNEplus LOD via an Application Programming Interface (API).

- Many new features of the Visual Media Services (VMS) are being developed; for example, the ones for 3D models of artefacts or monuments include provision for users to add interactive links from a 3D model to related content such as stories, images and other media. The Cloud-based VMS will be available for researchers as well as curators and educators of cultural heritage institutions. The COVID-19 crisis raised demand for meaningful and engaging online content of the institutions for their audiences (see *Section 2.4*).

Training needs

The COVID-19 crisis has forced ARIADNEplus to suspend its started Transnational Access (TNA) programme in 2020 after just two of the 13 TNA candidates could benefit from visiting one of the project's competence centres. The possibility of a call for TNA visits and summer schools in 2022 is being evaluated. Other training offers for researchers and data managers, e.g., tutorials at domain conferences, have been moved online. The recommendations of the community-needs survey for training activities have been followed by:

- Providing training tailored to researchers and data managers in archaeology and cultural heritage, with a focus on digital skills and practices. Application of the FAIR data principles, in the survey the top-rated training need, is of course a key topic of the training content and activities.
- The ARIADNEplus Training Hub, covering the topics of interest evaluated in the survey, provides over 60 carefully selected Web-accessible training resources from both partners and other providers, in formats such as online courses, training modules with videos, downloadable tools and tutorials, and more.
- For the elaboration of Data Management Plans an online tool tailored for projects of archaeological researchers has been developed.
- The ARIADNEplus partnership, including associated partners and projects, provided training in-person (when possible) and as online webinars and workshops for perceived needs. For example, the #Connecting Archaeology webinars of CARARE (Connecting Archaeology and Architecture in Europe, Ireland) or SEADDA workshops for data curators in collaboration with the Digital Preservation Coalition (DPC). Data science skills will become an important topic related to the ARIADNEplus Cloud-based virtual research environments (see *Chapter 5*).

4 Survey on repository practices and needs

An ARIADNEplus online survey on practices and needs of digital archaeological repositories has been carried out in a collaboration of the community needs task of Work Package 2 (Task 2.2) and the FAIR data policies task of WP3 (Task 3.5). This chapter presents selected results of the survey that are particularly relevant for understanding and supporting needs and requirements of repositories regarding FAIR data, data policies, how to improve data access, and other pertinent questions. The report on the full results of the survey is currently being prepared and a journal publication on the most interesting results is considered.

4.1 Survey approach, context and participation

4.1.1 Survey approach and context

The questionnaire-based online survey invited digital archaeological repositories that are operative or in development, broadly defined as *"any systems that store and provide access to results from archaeological work in digital formats"*. Concerning repositories currently being set up the announcement explained that in this case *"the answers will concern the envisaged future operation of the repository"*.

Invited were repositories that participate in the COST Action SEADDA[10], many other repositories already known or identified during the survey preparation, and others mobilised by dissemination activities. The online survey was open for responses from 17 June to 19 September 2021.

In this context the roles of SEADDA and ARIADNEplus for the implementation of repositories appropriate for archaeological data curation and sharing must be highlighted. SEADDA involves ARIADNEplus partners and institutions from several other countries, with representation from nearly all European countries and participation also from other countries (Argentina, Canada, Israel, Japan, Turkey, United States). The SEADDA network supports institutions concerning various requirements of archaeological data repositories, which must take account of heritage regulations as well as curate and make accessible varied and complex data. The goal is to promote the development of more appropriate data archiving solutions in Europe and beyond so that archaeologists can safely deposit and make FAIR data available to the research community and other users.

SEADDA and ARIADNEplus have complementary objectives: SEADDA fosters the development of archaeological data repositories in countries where the research community lacks an appropriate repository, while the ARIADNEplus platform enables finding and accessing data that is being shared through existing and new repositories, with search and access across the participating repositories. ARIADNEplus can help developers of new repositories plan participation in the data infrastructure and portal at an early stage, so that thereafter records of FAIR data can be easily aggregated and integrated in the common pool of the ARIADNE initiative.

[10] SEADDA - Saving European Archaeology from the Digital Dark Age, https://www.seadda.eu

4.1.2 Overview of participation

Number and distribution of the repositories

The survey gathered information about 60 repositories, 43 operative and 17 currently being set up. *Table 1* gives an overview of the countries and the number of repositories for which filled questionnaires have been received. The responses provide information on one or more repositories located in most European countries as well as repositories in other countries.

Table 1: Number of repositories per country present in the survey. N=60

Countries	***Repositories***		***Countries***	***Repositories***
European countries			Netherlands	1
Austria	3		Poland	3
Belgium	2		Portugal	4
Bosnia & Herzegovina	2		Romania	2
Bulgaria	2		Serbia	1
Croatia	2		Slovakia	2
Cyprus	1		Slovenia	1
Czechia	1		Spain	2
Denmark	1		Sweden	2
Estonia	1		Switzerland	2
Finland	1		United Kingdom	2
France	1		**Other countries**	
Germany	3		Argentina	1
Greece	3		Canada	1
Hungary	1		Israel	2
Italy	3		Japan	1
Latvia	1		Turkey	1
Lithuania	2		United States	1
Malta	1			**60**

Repository organisations

Table 2 presents the distribution of types of organisations at which the repository is or, in case the repository is in preparation, will be based. Most of the organisations are research centres or institutes (20), universities (13) or heritage agencies/authorities (16). The latter are governmental institutions (e.g., ministries of culture) or operating under them (e.g., heritage councils). Three organisations are heritage management institutes, i.e., organisations to which heritage authorities delegate operative tasks of heritage management. The sample of repositories also includes 5 based at museums, 2 at archival institutions, and 1 “other”, which is a national archaeological association.

Table 2: The repository is (will be) based at (the selected type of organisation). N=60	
Research centre or institute	20
University	13
Heritage agency/authority	16
Heritage management institute	3
Museum	5
Archival institution	2
Other [an archaeological society]	1

Main responsibilities/tasks of respondents

Table 3 presents the distribution of the repository-related responsibilities/tasks across the survey respondents. In the survey questionnaire a limited set of responsibilities was included as answer options, those most likely of survey respondents, with the additional option to specify responsibilities or tasks. Most respondents are responsible for more than one task, often including project management, collections development, and digital archiving/curation. 20 of the respondents are directors or deputy-directors of repositories, of which five are also digital archivists/curators. Less present are respondents responsible for IT systems management or user access services and support.

Table 3: What are your main tasks/responsibilities? (multiple answers possible). N=60	
Director or Deputy-Director	20
Digital archivist/curator	26
IT systems management	16
Project management	33
Collections development	26
User access services and support	15

All respondents selected at least one responsibility from the list. The free text field was used by some respondents to explain their main role or activity, for example: "*Head repository manager*", "*Head of the data provider group* or *"I manage the IT team that maintains IT services for the repository, but we also do a lot of other things"*.

4.2 Surveying repository FAIRness and access

4.2.1 The FAIR principles

Over the last few years, the FAIR data principles, published in 2016, have been adopted by research funders, institutes and researchers to promote the access to research data through data repositories and infrastructures. The FAIR data principles require "*that all research objects should be Findable, Accessible, Interoperable and Reusable (FAIR) both for machines and for people"* (Wilkinson et al. 2016).

The FAIR principles address important attributes of research data, for example, globally unique and persistent identifiers, rich metadata, use of domain vocabularies, registration in a searchable resource, and release with a clear data usage license. The 15 principles are listed below:

The FAIR guiding principles

To be Findable:

F1. (meta)data are assigned a globally unique and persistent identifier

F2. data are described with rich metadata (defined by R1 below)

F3. metadata clearly and explicitly include the identifier of the data it describes

F4. (meta)data are registered or indexed in a searchable resource

To be Accessible:

A1. (meta)data are retrievable by their identifier using a standardized communications protocol

A1.1. the protocol is free, open and universally implementable

A1.2. the protocol allows for an authentication and authorization procedure, where necessary

A2. metadata are accessible, even when the data are no longer available

To be Interoperable:

I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation

I2. (meta)data uses vocabularies that follow FAIR principles

I3. (meta)data include qualified references to other (meta)data

To be reusable:

R1. (meta)data are richly described with a plurality of accurate and relevant attributes

R1.1. (meta)data are released with a clear and accessible data usage license

R1.2. (meta)data are associated with data provenance

R1.3. (meta)data meet domain relevant community standards

Source: Wilkinson et al. 2016.

We cannot give here in-depth commentary of the meaning of each principle. This can be found in the original FAIR data paper and subsequent publications (e.g., Boeckhout et al. 2018; Expert Group on FAIR Data 2018; Mons et al. 2017). Our approach to questions concerning the application of the FAIR principles by repositories is explained in *Section 4.2.4*.

4.2.2 Current application

While there is a FAIR "boom" in the international research data management community no wide knowledge of researchers and repositories in how to apply the principles in practice can be assumed.

In the international Figshare "The State of Open Data" surveys the percentage of researchers who claimed being familiar with FAIR increased from 15% in 2018 to 20% in 2020. Other respondents had heard of FAIR, but did not consider themselves familiar with the principles, or had never heard of the principles (Figshare 2018, 2019, 2020; Khodiyar 2021).

David et al. (2020) warn that FAIRness literacy is the Achilles' Heel of applying the principles, and request that for the training of researchers of not specifically data skilled communities the understandability of what the principles require in practice must be improved.

For this purpose, ARIADNEplus and SEADDA promote using the FAIRify guidelines that have been developed in the PARTHENOS project (until October 2019), in which several partners participated. The FAIRify guide[11] provides twenty guidelines for making research data as reusable as possible based upon the FAIR principles. Each guideline has recommendations for both researchers and repositories as it is recognised that different perspectives or priorities may apply to each case.

A generally better understanding of the FAIR principles by repository staff than researchers can be assumed, but the implementation of the principles is often not sufficient. Dunning et al. (2017) reviewed 37 very different repositories and databases. They found that for many FAIR facets less than half of the repositories/databases were compliant. This did not come as a surprise because, as the authors write:

"The 15 facets of the FAIR principles are all short sentences. Their brevity gives the impression that they are all items that can be checked off. However, our analysis shows that the FAIR principles are much trickier than this. Some facets appear to overlap (e.g. the plurality of attributes in R1 and rich metadata in F2). Some are vague (e.g. the qualified references of I3), others are open ended (the recursive request of I2 that '(meta)data use vocabularies that follow FAIR principles'), while others require interpretation from external parties (e.g. the domain relevant community standards of R4). Some appear to be technical in scope (A1, A2 and A3, for example) whereas others are more policy driven (the policy on the retention of metadata in A4)" (Dunning et al. 2017: 187).

Consequently, they identified many misconceptions of repositories related to the principles' definition and implementation, as did the survey of the Research Data Management Working Group of the Association of European Research Libraries (LIBER). This survey received responses by managers and technical staff of 32 repositories (Ivanović et al. 2019). A study by EOSC-NORDIC of nearly 100 repositories using an automatic procedure to evaluate the FAIRness of their metadata found considerable shortcomings in this regard (EOSC-NORDIC 2021).

Repositories that are certified as trustworthy data repositories based on the CoreTrustSeal[12] criteria may be better off regarding compliance with the FAIR principles (Mokrane & Recker 2019). But there are not many such repositories in Europe and worldwide, including repositories of ARIADNEplus project partners, Archaeology Data Service (UK), Austrian Centre for Digital Humanities and Cultural Heritage, Data Archiving and Networked Services (Netherlands), and Swedish National Data Service. The Archaeology Data Service describes in detail the specific ways in which they ensure compliance with all aspects of FAIR.[13] A comprehensive survey on the FAIRness of repositories would indeed

[11] PARTHENOS Guidelines to FAIRify data management and make data reusable. Zenodo, https://doi.org/10.5281/zenodo.2668479

[12] CoreTrustSeal, https://www.coretrustseal.org

[13] The ADS and the FAIR Data Principles, https://archaeologydataservice.ac.uk/about/adsFAIR.xhtml

require spelling out the FAIR principles and ways, often different possible ones, in which they could be fulfilled, and then ask dedicated staff whether any of these or others are implemented in their repositories.

4.2.3 FAIR versus/and "open access"

The question of how FAIR repositories are must necessarily consider the levels of "open access" they provide. The phrase "open access" is often not explained well which leads to misunderstanding. The matter indeed is quite difficult. In practice three levels of access can be distinguished:

- (1) Access to the repository: how one can get into it, e.g., with or without registration;
- (2) Access to metadata, i.e., information about the data the repository holds; a repository may allow users accessing all information or restrict access to some of it (e.g. administrative or sensitive information);
- (3) Access to the actual data, i.e., download or use it in some way on the repository platform; the repository may not allow everybody access the data but for example only on request (permission to be granted) or for registered legitimate users.

Misunderstanding also created the often-used phrase that one can "freely access" a repository, metadata, or data. Here "freely" means that no restrictions apply on any of the three levels, but often this is also understand as "for free", i.e. that one does not have to pay for the access. Advocates of strict open access require that the repository user should not have to pay anything.

The widely referenced "Open Definition" of the Open Knowledge Foundation defines "open" briefly as: *"Open means anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness)"*.[14] Details are then given on criteria which should be fulfilled so that data, content or knowledge can be considered as open, especially that it should be shared under an open license or in the public domain.

Licensing is also a key principle in FAIR, as *"R1.1. (meta)data are released with a clear and accessible data usage license"*. The main difference to open access (meta)data is that the FAIR principles do not imply that the data is "open" or "free" in the sense of uncontrolled and free of charge access and reuse.

As Mons et al. (2017) explain, *"None of these principles necessitate data being 'open' or 'free'. They do, however, require clarity and transparency around the conditions governing access and reuse. As such, while FAIR data does not need to be open, in order to comply with the condition of reusability, FAIR data are required to have a clear, preferably machine readable, license."*

They also highlight that the different approach of FAIR in this regard allows participation of data holders that otherwise could not be involved: *"The transparent but controlled accessibility of data and services, as opposed to the ambiguous blanket-concept of 'open', allows the participation of a broad range of sectors – public and private – as well as genuine equal partnership with stakeholders in all societies around the world"* (Mons et al. 2017).

4.2.4 Survey questions for repositories

The ARIADNEplus survey covers many different topics and therefore had to keep things simple. A comprehensive survey on the FAIRness of repositories would have to explain the participants each of the 15 FAIR principles and ways, often different possible ones, in which a principle could be fulfilled, possibly distinguishing different degrees of FAIRness.

[14] Open Knowledge Foundation: The Open Definition, https://opendefinition.org

This is hardly possible in an online survey. Therefore, for the ARIADNEplus survey questions have been elaborated which cover important aspects the FAIR principles address and can be easily answered by respondents who know how different things are implemented at their repository.

These questions concern (meta)data identifiers, metadata richness, vocabulary in use, (meta)data discovery (i.e., search interface of the repository and/or external search platform), and licensing. Avoided are too technical questions (e.g., communication protocols) and some specific metadata related questions (e.g. formal knowledge representation or qualified references to other (meta)data).

What the FAIR principles do not address are critical issues repositories are arguably more interested in, for example, are there clear policies to support FAIR and open data policies? How should these be implement in practice? How should data access be improved? Can we demonstrate that data is being reused? In addition to surveying some aspects of the FAIR principles, these questions have been included in the survey (*Section 4.4*). In some responses information is anonymised as the survey participants have been assured of confidentiality.

4.3 Repository support of FAIR

This section covers the survey results for FAIR-related questions. The questions concern identifiers, metadata richness, vocabulary in use, data discovery, and licensing of data user want to use. Regarding data discovery the survey addressed both via a search interface of the repository and via external search platforms with which it shares metadata.

4.3.1 (Meta)data identifiers

The survey respondents were asked, *"Are deposited data assigned globally unique and persistent identifiers (e.g. DOI, Handle, URN or other)?"* All 60 respondents answered it, 29 said "Yes", 11 "No", and 20 selected the additional option "Not yet". The answer option "Not yet" was included as the survey also invited repositories to participate that currently are being set up and may not yet have implemented procedures for assigning unique and persistent identifiers.

***Further information/comments**:*

Comments mainly stated the type of identifiers, seven DOIs, four Handles, and two Archival Resource Key (ARK) identifiers. For example,

- *A DOI will we be used for every public item in the collection.*
- *Handles are assigned to each file that is publicly available.*
- *Ongoing project to obtain sustainable ARK identifiers.*

Comments also described the implemented or planned approach for identifiers:

- *If we are talking about the [directory of archaeological sites], that is based on data coming from different sources (in fact a collection of metadata), the answer is yes. Every record has a unique identifier.*
- *The archive is maintained by the museum and there is no financial support for getting DOIs for all files. At present 1.18 million files are available online, but it is increasing rapidly. Therefore, each site has a unique identifier that is used for all documents that belong to that site.*
- *Coded (DM) shelving locations; URLs for digitized associated records; unique site designation numbers for site locations.*

- *We use our own ID system in which we guarantee persistence, however we plan to implement also Handles.*
- *Work in progress: An API has been developed and DataCite domain obtained. The university library will manage DOI minting.*

4.3.2 Metadata richness

The survey respondents were asked, *"Are deposited data described with rich metadata, i.e. many descriptive attributes?".* All 60 respondents answered it, 47 said "Yes", 13 "No".

***Further information/comments (e.g., metadata standard in use?)**:*

Five comments stated that Dublin Core is being used, for example,

- *Use modified Dublin Core with additional fields related to archaeological data*
- *Qualified Dublin Core*
- *Dublin Core, Data Cite*

Several other comments gave more detailed information, including as other metadata standards General International Standard Archival Description (ISAD(G) and Encoded Archival Description,

- *The data is described according to General International Standard Archival Description (ISAD(G)). The metadata can be exported in Dublin Core, EAD and tabulated format.*
- *Rich metadata in EAD format is available online for the scanned part of the archive. The metadata of the database is not yet accessible (database being migrated to an open source system).*
- *Each set of deposited data accompanied by multiple metadata description.*
- *IP schema built on space/time/material attributes.*
- *We provide metadata templates according to file format, [link to guidelines for depositors].*
- *Metadata extracted from data publications, with additional attributes applied as required. The quality is variable.*
- *We use Spectrum 5 for metadata organisation.*
- *Own repository standard is used.*
- *All deposited metadata is related to the process, more than the results; i.e. what kind of research was undertaken, by whom, how much did it cost, where are the reports and files, where will the finds be deposited, what were previous steps and what are following steps, ... But no things such as 'we excavated an Iron Age settlement'.*
- *The record sheet is not very complex but it contains enough fields to decently describe the archaeological sites. Every record has also two spatial attributes: point and polygon.*
- *The metadata structure for scientific data has been investigated and is being developed in the ARIADNEplus project.*

4.3.3 Vocabulary support

The survey respondents were asked, "*What vocabulary does the repository support?".* Five pre-defined answer options were given for kinds of vocabularies, concerning the user community (international, national, or only by the repository) and formalisation (e.g., following thesaurus standards, list of terms

or keywords given by depositors). In an open text field respondents could also specify other vocabulary support or give comments. *Table 4* presents the distribution of the pre-defined options selected across the 60 survey respondents, who could select multiple answers.

Table 4: What vocabulary does the repository support? You can tick multiple answers. N=60	
International vocabulary (for example, Getty Art and Architecture Thesaurus)	19
National vocabulary (e.g., a thesaurus of a national authority or association)	25
Own standardised vocabulary (e.g., an own thesaurus)	35
Own list of terms	25
Keywords given by depositors	17

Many respondents said that their repository uses more than one vocabulary, 39 of the 60 respondents, of which 20 selected two, 17 three, and two even four of the pre-defined categories. These can be used for the metadata records of deposited single items (e.g., publications, fieldwork or laboratory report) or records of project archives, possibly also for different types of content within them (e.g. various content of an excavation).

Most often repositories in our sample use an own standardised vocabulary (e.g., thesaurus), 9 out of 35 only this. Where in addition also other vocabularies are being used, this often is a national vocabulary (10), an own list of terms (10), or both (5); some of these repositories in addition also use an international vocabulary or keywords given by depositors. Among the repositories using a national vocabulary (25) are the 10 already mentioned (who use it in addition to an own standardised vocabulary), and 10 other cases. Three of these only use the national vocabulary, six in addition an international vocabulary, and three of these also keywords given by depositors. Five repositories use only an international vocabulary and two in addition an own list of terms or keywords given by depositors. Five repositories use an own list of terms and keywords given by depositors.

***Further information/comments**:*

Some comments indicate use of the multilingual Getty Art and Architecture Thesaurus (AAT), particularly a mapping of own terms to matching ones in the AAT. Such mappings to a common vocabulary (thesaurus, gazetteer or other) support searches across different repositories, for example, in the ARIADNEplus network of repositories. Some related comments are,

- *We use the IdRef repository for person authorities, PeriodO for periods, and align the geographical indexes to GeoNames. Other descriptive fields, such as languages, follow the ISO standards. Work is underway to align Getty and Pactols for other entities (Natures, Domains, etc.).*
- *Right now we map the terms from our own list to Getty Art and Architecture Thesaurus, Geonames and Wikidata.*
- *In this case, there is no national authority, but we are the highest authority for this type of information. Some of our thesauri do map to the Getty AAT.*
- *We use the multilingual thesaurus PACTOLS which is aligned with the Getty AAT.*
- *Terms are mapped also to Getty AAT but the implementation itself is still on the way.*

Some other vocabularies mentioned are,

- *AAT and Dutch vocabulary called ABR*
- *Getty TGN, LCSH* [Getty Thesaurus of Geographic Names, Library of Congress Subject Headings]

- *FISH document types thesaurus*
- *nomisma.org*
- *As far as I know also Nasa dictionary has been included for techniques.*

One comment explains why own lists of terms, derived from user keywords are being used: *Environmental archaeology covers many research domains (ecology, geology, archaeology,...) and so no list covers everything needed. We have taken a pragmatic approach of user keywords with periodic cleaning and harmonization. Mapping to international and national vocabularies will be undertaken in the future, but will not be a core of the database.*

4.3.4 Repository search interface

The survey respondents were asked, *"Does the repository provide a metadata search interface?".* All 60 respondents answered it, 36 said "Yes", 10 "No", and 14 "Not yet".

The answer option "Not yet" was included as the survey also invited repositories to participate that currently are being set up and may not yet have implemented a search interface. 17 respondents said that their repository is in preparation. The answers "No" and "Not yet" sum up to 24, hence also some repositories in operation did not have a metadata search interface, but other ways to navigate and browse information about their collections.

***Further information/comments**:*

Further information provided by respondents often was a link to the search interface of the repository, and one respondent wrote that there is more than one interface allowing to search different parts of the repository database.

Other comments concerned the status of the interface development, e.g. *"Under development - Alpha version"* or *"This is planned in the database migration project"*.

Comments also explained the metadata or metadata model for searches, e.g. *"For basic metadata/ descriptive/links, not technical metadata"* or *"CIDOC CRM syntax will be employed".*

4.3.5 External search platforms

The survey respondents were asked, *"Does the repository make metadata available to external search platforms/engines?".* All 60 respondents answered it, 25 said "Yes", 26 "No", and 9 "Don't know".

Many respondents said that their repository does not share metadata with external search platforms or did not know. These include 17 repositories currently being set up and 18 in operation. It appears that some of the latter do not see a need to make their holdings findable also via external search platforms or for some other reasons cannot do this. There can be many reasons, for example, the user base of the repository is well known and not expected to increase, lack of a suitable external platform, a legacy metadata management system that does not support metadata harvesting.

***Further information/comments**:*

Respondents gave further information on platforms to which metadata is being provided or how it is made available, for example,

- *Including ARIADNE, Europeana, Heritage Gateway, MEDIN portal*
- *For instance to Europeana or ARIADNE*
- *To Europeana*

- *The [directory of archaeological sites] can be access online through a specific interface and an extract of data can be access in the Romanian portal of open data: data.gov.ro*
- *Metadata is made available as OAI-PMH*
- *For instance, an OAI-PMH repository is available and functional, [link to the OAI-PMH endpoint]*
- *API of the archaeological information system, [link to the API]*
- *We use dublin core api connectivity to data aggregators*
- *Through a number of API feeds, plus landing pages for sites*
- *The database has been exported in a triplestore with associated metadata and is therefore searchable via a SPARQL endpoint.*
- *Most of the reports and find catalogues are available on line.*
- *Most metadata is publicly available, apart from privacy sensitive data.*
- *Not yet. We are reengineering our infrastructure, and in the next months this service will be available.*

4.3.6 Licence frameworks

The respondents were asked, "*Which licence frameworks does the repository support?".* They could select multiple answers from seven pre-defined options and add information in an open text field. *Table 5* shows the distribution of the pre-defined options selected across the responses of the 60 respondents.

Table 5: Which licence frameworks does the repository support? You can tick multiple answers. N=60	
Public Domain Dedication, e.g., CC0, PDDL or other.	16
Users must only give attribution, e.g., CC BY, ODC-By or other.	22
Users must share new work under the same license, e.g., CC BY-SA, ODC-ODbL or other.	12
Do not allow commercial use, e.g., CC-BY-NC or other.	17
Do not allow derivative works, e.g., CC BY-ND or other.	9
Own terms and conditions, incl. some restrictions (e.g., non-commercial, no derivatives or other).	29
All or most works are fully copyright protected.	20

A closer analysis of the responses showed that in our sample of repositories four approaches to licensing are present:

- *Restricted approach:* 19 repositories – 8 with "All or most works are fully copyright protected"; 11 in addition also apply "Own terms and conditions, incl. some restrictions" or state that commercial use or derivative work is not allowed.
- *Open approach:* 16 repositories – 4 only Public Domain Dedication, 6 only Attribution, 3 both and 1 also a Share-Alike licence, 2 only a Share-Alike license.

- *Mixed approach:* 8 repositories – Here very different conditions apply: all hold Public Domain data while other data requires setting various restrictions, defined by own terms & conditions or standard licenses.
- *Various restrictions or mainly against commercial use:* 17 repositories – 12 respondents selected only the answer "Own terms and conditions, incl. some restrictions (e.g., non-commercial, no derivatives or other)"; 5 only indicated that commercial use of content is not allowed.

***Further information/comments**:*

Some respondents stated the preferred license/s of the repository and exceptions or restrictions,

- *Open access data have CC0 / CC-BY licenses, excavation records may have more restrictive licenses.*
- *Default licence is now CC-BY - but depositors can select other options.*
- *Mainly CC BY 4.0 or CC BY-SA is the case and a part CC0.*
- *We support licenses from Creative Commons, Open Definition, RightsStatements.org, Open Source Initiative, [links to the licenses]*
- *We have a legal right to publish the reports, but this right does not stipulate reuse. On the other hand, since most of the data can be seen as scientific data, this might make little difference.*
- *For commercial users we prefer to give access on the base of a specific written request in order to know better what are the needs and purposes of the reuse of the data.*
- *This is not yet explicitly stated in the metadata, but will be (and thus improving our FAIR score).*

4.4 Enabling open data access

The results of the questions on the "FAIRness" of the surveyed archaeological repositories provide insights in current practices regarding important requirements for data discovery, access, and use. However, the FAIR principles intentionally do not cover some arguably more important issues and requirements.

These include questions concerning open data access policies (e.g., established or missing) and control of access (e.g., sensitive data, access only for legitimate users), which are addressed in this section. Also addressed is the question of how to improve data access. For this question the FAIR principles give general recommendations, while our survey is interested in what the responding repository see as necessary to improve. Moreover, the critical issue is addressed whether repositories can demonstrate not only increasing access to the data they hold, as found during the COVID-19 crisis, but also that it is being reuse for various purposes.

4.4.1 Support of open data policies

The survey respondents were asked *"What would help the repository most to support open data access and reuse policies?".* Seven answer options were pre-defined, and the respondents could also specify others or add further information/comments. *Table 6* shows the distribution of the pre-defined options selected across the responses of 56 respondents.

Most respondents selected from to two to all answer options. Where only one option was chosen this was heritage regulations to set policies/rules (5), clear guidelines by heritage authorities (1), and defined internal/institutional rules to follow (1).

Heritage regulations to set policies/rules (39 respondents) and clear guidelines by heritage authorities (36) were the main help needed by most repositories to support open data access and reuse.

Next came the challenge to overcome barriers of users to deposit open and reusable data (29) which, for example, includes concerns of researchers about open licensing and that their data might be misused. Respondents also considered as important training of repository staff to support new policies on open/FAIR data (28).

Table 6: What would help the repository most to support open data access and reuse policies? N=56	
Heritage regulations to set such policies/rules	39
Clear guidelines of heritage authorities	36
Research funding bodies to set such policies/rules	21
Clear guidelines of research funding bodies	15
Defined internal/institutional rules to follow	23
Training of repository staff to support new policies	28
Overcome barriers of users to deposit open and reusable data	29

Policies/rules and clear guidelines of research funding bodies appear as less important. However, this is very likely because there are not many repositories mainly for academic archaeological projects in our sample. Repositories which are for both academic and preventive archaeology considered heritage regulations (laws) and clear guidelines of heritage authorities more important than policies and guidelines of research funding bodies.

***Further information/comments**:*

This survey question was among those which received most comments by respondents. Obviously, the question of how to support open data access and reuse policies is very important for repositories. The respondents stressed the importance of heritage regulations, raising awareness and good practices. Furthermore, training was considered as important for both researchers and repository staff, and appropriate technical systems could help much to support open data access and reuse policies. Respondents also thought the survey results could help, for example, *"I wait for the results to improve the management of our repository".*

Legal regulations or institutional guidelines

- *Data access and reuse are depending on common law and privacy guidelines.*
- *Changes in legislation.*
- *Significant support (incl. money) and guidance for data creators; national guidelines on archaeological data management*
- *A unique regulatory framework for research bodies' and Heritage Management offices' data would be very useful.*
- *I believe the obligation to publish research data in a repository would help most to set up the other necessary actions listed above.*
- *The establishment of clear guidelines could held to support open data access and reuse policies*

- *Simplification of legislation of Hellenic Ministry of Culture for providing access to archaeological content*
- *In Serbia, since 2018 there are recommendation / obligation to state agencies, research and cultural heritage institutions to allow open data access and reuse.*
- *Regulations are strict because of looters who could damage archaeological sites if they had access to the information*
- *One of the main difficulties in opening up data widely lies in the French exception to copyright for teacher-researchers, who remain the owners of copyright documents (photographs, etc.). The [archaeological association] has put in place a charter for open science and a proactive policy in this area, while supporting researchers in opening up their data.*
- *Within the [consortium of archaeological institutions] we are establishing a guideline on the FAIR principles for archaeological data management.*
- *National and international level difficulties to support open access and reuse policies. We need to think both at the same time.*
- *Bottom-up support to open data access is the only way for creating awareness of the importance of open archaeological data, and this is the way we followed for many years, and we are still following, nonetheless without a strong requirement by Heritage regulation and Research funding bodies, a long time will be between now and a significant adhesion to open data access in archaeology. In the meanwhile, open archaeological data will remain a niche sector in archaeology.*
- *Regulations and training of repository staff are not enough – we need free external (university, national, international) services which help us in this task. There is a balance between making a useful system with lots of data and monitoring and following policies and regulations. We prioritise the former.*
- *Difficult question to answer. I think we are more or less as open as we can be given the current legislation.*

Awareness, knowledge and training

- *Educating professionals to understand and accept that they work for the general public.*
- *More knowledge of and awareness of open data and open licensing is needed by all involved parties*
- *The rise of awareness amongst professionals on the importance of sharing data and making data accessible*
- *Training of researchers/depositors is also very relevant. Otherwise researchers often are afraid of e.g. CC BY.*
- *It is a matter of trust and communication.*
- *FAIR principles.*

Good practices

- *The most important of these statements is the last one; a mechanism to overcome any kind of barriers*
- *It is important to demonstrate best practice in open data.*
- *A great accessible website to the information!*

Trained staff and technology

- *The creation of a real repository is at the basis of this. Open data is not a problem, the creation of a repository is.*
- *Without additional funding, further development of the repository is not possible due to lack of adequately trained and paid staff. Salaries in corporations are a significant competition.*
- *More human resources assigned to the repository*
- *Our institute need IT specialists.*
- *Better SW and HW infrastructure and discipline in handing over research documentation from archaeological investigations.*
- *Support interoperability with other repositories.*
- *Updated systems*

4.4.2 Control of data access

The respondents were asked *"How can people access data in the repository?"* and could select from five pre-defined answers those which apply. *Table 7* presents the answers across all 60 respondents.

Table 7: How can people access data in the repository? (select the option/s that apply). N=60	
Open access, no registration required	35
Open access, but registration required	8
Legitimate registered users only (e.g. archaeologists, cultural heritage managers,…)	18
Access based on request (permission to be granted)	26
Internal staff only	9

A closer analysis of the answers showed that in our sample of repositories three approaches are present:

- *Open access:* 24 repositories – 21 respondents selected only "Open access, no registration required", 3 only "Open access, but registration required"
- *Some data open access, other restricted:* 15 repositories – All have data that can be accessed without registration and other data only accessible for legitimate registered users and/or with permission granted; 3 respondents also ticked "Open access, but registration required" and 2 "Internal staff only"
- *Restricted access:* 21 repositories – Data is accessible for legitimate registered users and/or with permission granted; 2 respondents also ticked "Open access, but registration required". "Internal staff only" was added by 5 and at 2 repositories in development only staff were allowed to access the data, at others also based on request

***Further information/comments**:*

In comments respondents explained why different conditions for access apply; at repositories in development in future various conditions will be set.

- *Access levels are based on user roles, data content sensitivity and copyright/licensing.*
- *Several levels of access are set: full access in administrator mode; restricted access to a set of data, on request (mission manager, etc.); open access to all for public data or data for which distribution rights have been granted.*
- *Legitimate registered users can access all data (even sensitive) and download everything. Other users can access the majority of data (except sensitive data and GPS coordinates) + short reports of excavations.*
- *Open access to the database, but sensitive data only available to registered users/internal staff*
- *Culturally Sensitive data, as defined by Descendant communities, have restricted access. Consent to access granted by those communities, not the institution.*
- *Depends on what the depositors chose; access can be public, academic (via eduGAIN) or restricted.*
- *It depends on people's rights*
- *Various levels of access to data*
- *Open access - only part of metadata.*
- [Open access, no registration required]: *Please bear in mind that our repository does not have the full excavation archive, only what's formally required to be submitted by law.*
- *Some data is only available in our facilities due to data protection regulations.*

Repositories in development:

- [Access based on request (permission to be granted)]: *Further access options are planned after the publication of the repository.*
- [Access based on request (permission to be granted)]: *Will be opened to the public.*
- [Internal staff only]: *It is for now, as I think, that should be changed over time and have open access.*
- *Now the repository is accessible only to internal staff. For the future we are planning to release the data with different degrees of openness.*

4.4.3 Improving data access

The respondents were asked, *"What would help the repository most for improving data access?".* Seven answer options were pre-defined, and the respondents were asked to select up to 3 options most important for their repository. *Table 8* shows the distribution of the pre-defined options selected across the responses of all 60 respondents, for repositories in preparation (17), and already operative ones (43).

Regarding all responses it proved difficult to identify clear patterns as the respondents selected many different combinations of answers and did not always follow the request for maximal 3. However, four options for improving data access have been selected more often than others. These are "Improve or replace the existing data management system", "Improve the quality of metadata", "Provide metadata to external search platforms/engines" and "Use Linked Data to interlink own and other (meta)data".

For a deeper look into the data the responses for repositories in preparation and for operative ones have been analysed separately. Obviously, these have some different needs which surfaced in the analysis.

Respondents of the repositories in preparation (17) often wanted to improve the data management system (11). These more often than others also wanted to align own with other vocabulary (e.g., international or national thesaurus) and/or use advanced ontologies (e.g. CIDOC-CRM). The respondents who were satisfied with their data management and vocabulary wanted their data to be found by providing metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.

Table 8: What would help the repository most for improving data access? Select up to 3 options most important for your repository. N=60

	All (60)	In prep. (17)	Operative (43)
Improve or replace the existing data management system	30	11	19
Improve the quality of metadata	34	8	26
Replace or align own with other vocabulary (e.g., international or national thesaurus)	19	6	13
Use advanced ontologies (e.g., CIDOC-CRM)	15	6	9
Provide metadata to external search platforms/engines	27	9	18
Use Linked Data to interlink own and other (meta)data	26	5	21
Enable better access to complex or high-volume data objects (e.g., 3D models, LiDAR data)	19	4	15

In the responses from repositories in operation (43) three priorities of some of them could be identified. Among those who wanted to improve or replace the existing data management system (19), for nine the main reason appeared to be enabling better access to complex or high-volume data objects (e.g., 3D models, LiDAR data). Regarding additional ways to improve access to data this group of repositories had no other common priority. Another group of seven repositories had in common the priorities to improve the metadata quality and to replace or align own with other vocabulary. Furthermore, a group of repositories had in common the priorities to provide metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.

***Further information/comments**:*

Comments concerned work aimed to improve data access or what is needed for this purpose:

- *We are already doing most of the things listed.*
- *Our database contains over 676,000 records. A lot of work has been done to clean up, harmonize and link the metadata, but this work still in progress.*
- *We are working on our infrastructure in order to improve the metadata quality and metadata availability to external engines. The new infrastructure will be online before the end of the year.*
- *Actually we are now in the process of migrating the data to a new archiving system.*
- *International metadata and platform*
- *Adding chronological and/or typological metadata would be interesting, but the general consensus is that this would be a considerable amount of work that submitting archaeologists (a commercial sector) are not able to carry out.*

- *Vital is our need to develop a robust query module through graph database (non-SQL) to facilitate enable research.*
- *Being a hit in a Google search will increase access to the repository.*
- *Staff well trained in data stewardship and LTP* [long-term preservation]*, including IT staff experienced in the topic.*

4.4.4 Access during the COVID-19 pandemic

For repositories it is important to collect and analyse access data for reporting on its use and identifying where access procedures could be improved. For some repositories it is crucial being able to present access data that confirms demand, for example, when they must apply for funding. Where repositories support legal regulations (e.g., a repository of a heritage authority) or they are mainly for staff and affiliated researchers the level of access is not as important.

The survey respondents were asked, *"Does your organisation collect and analyse repository access data?"* and of 56 respondents 29 said "No" and 27 "Yes". The latter were further asked if there has been an increase or decrease of access during the COVID-19 pandemic. 24 respondents said that overall, there was an increase, only three a decrease. They were also asked if they could give an estimate or other related information.

Table 9: Does your organisation collect and analyse repository access data? N=56	
Yes	27
No	29
If yes: has there been an increase or decrease of access during the COVID-19 pandemic? N=27	
Overall, an increase	24
Overall, a decrease	3

Overall, an increase:

Respondents reported increased access with percentages from 5% to over 100%:

- *50-200%, however, it was parallel to significant upgrade of services which was probably more influential than COVID*
- *In the lockdown the increase was over more than the hundred percent*
- *100%*
- *In pre-Covid we had 5000-6000 access/month, during Covid it was between 7000 and 10.000/ month* [for on average 5500 accesses/month before and 8500 during COVID-19 the increase is 55%]
- *25%*
- *5%*

Other increases:

- *Approximately 5% increase in new users*
- *The number of downloads of the reports increased by 39% compared to the previous year*

- *30% more data has been sent in digital format*

Overall, a decrease:

- *20%*
- *It is almost the same, maybe about 10%*

4.4.5 Data re-use is difficult to demonstrate

Re-use of data archived in accessible digital repositories is a very important topic in the data management community. While data access figures are good to have, being able to show significant data re-use for new research and other purposes can demonstrate even better that fund for data preservation and access are well invested. For funders of data repositories, it is the clearest indication of a return on investment.

Data shared by others can be re-used for different purposes, e.g., inclusion in a research dataset or community database, use for comparison, as test data, etc. (Geser 2019c: 50-58; Huggett 2018; see also the ongoing research and discussion in SEADDA 2020).

However, for repositories data re-use is difficult to demonstrate, because if there is re-reuse it takes place outside of what they can easily track and measure. Therefore, some repositories actively scan the literature of fields of research they serve for mentions of re-use of the data they hold (Cousijn & Lammey 2018).

In recent years infrastructure and processes for identifying data citation in publications have been implement, particularly DataCite, but also Crossref, Scholix (Scholarly Link eXchange) and others. But these capture only a fraction of the use of shared data due to several reasons, which include that many repositories do not assign DataCite DOIs, publishers of journals, proceedings and others not requesting proper data citation, researchers not following citation standards or acknowledging data use only informally.

The ARIADNEplus survey asked, *"Does the repository collect information about date re-use (e.g. references in publications or other sources)?".* 56 respondents answered the question, 9 said "yes", 47 "no".

***Further information/comments**:*

Most comments describe collecting information about date re-use as difficult and not very successful or planned in future:

- *Some data are cited in scientific publications and a link is made to the record in the database.*
- *The organisation can collect and analyse some of the access data, but this is rarely done. Mostly just general statistics on page views and unique visitors to web services.*
- *We are obliged to do so by law, however, it is not very successful process so far.*
- *There is no personnel at hand to do this in a consistent way.*
- *This is tricky. Very tricky. We monitor citations through Google Scholar – it gets maybe half of them after some combination of citations, and complement with periodic manual checking (e.g. [link to list of literature]).*
- *It is difficult to track the re-use of the data. References in publications are difficult to record.*
- *Not yet (2 respondents)*
- *It is one of the steps we would like to implement in future.*

4.5 Summary of results and suggested actions

This chapter presented selected results of the archaeological repositories survey that are particularly relevant for understanding and supporting their needs regarding FAIR data, data policies, how to improve data access, and other pertinent questions.

4.5.1 Survey participation and results

Survey participation

The survey gathered information about 60 repositories, 43 operative and 17 currently being set up. The responses provide information on one or more repositories located in most European countries as well as repositories in other countries.

Most of the organisations at which the repositories are or will be based are research centres or institutes (20), universities (13), and heritage authorities or agencies (16). The sample of repositories also includes five based at museums, two at archival institutions, and one is being provided by a national archaeological association.

Most survey respondents are responsible for more than one task, often including project management, collections development, and digital archiving/curation. 20 of the respondents are directors or deputy-directors of repositories, of which five are also digital archivists/curators. Less present are respondents responsible for IT systems management or user access services and support.

Surveying FAIRness and data access policies

Over the last few years, the FAIR data principles, published in 2016, have been adopted by research funders, institutes, and researchers to promote the access to research data through data repositories and infrastructures. However, no wide knowledge of researchers and repositories in how to apply the principles in practice can be assumed.

In the international Figshare "The State of Open Data" surveys the percentage of researchers who claimed being familiar with FAIR increased from 15% in 2018 to 20% in 2020. Other respondents had heard of FAIR, but did not consider themselves familiar with the principles, or had never heard of the principles. Awareness of researchers of the principles and the understanding of what the principles require in practice must be improved.

Surveys on the compliance of repositories with the FAIR principles have shown that their implementation is often not sufficient. Many misconceptions of repositories related to the principles' definition and implementation have been identified.

Repository support of FAIR

FAIR-related questions of the archaeological repositories survey concerned (meta)data identifiers, metadata richness, vocabulary in use, data discovery, and licensing. Avoided were questions on FAIR principles that are very technical (e.g., communication protocols) and some specific metadata related questions (e.g., formal knowledge representation or qualified references to other (meta)data).

(Meta)data identifiers

Nearly half of the repositories (29) already assign deposited data globally unique and persistent identifiers, often DOIs but also Handles or Archival Resource Key (ARK) identifiers.

Metadata richness

The majority of repositories (47) thought that deposited data are described with rich metadata (i.e., many descriptive attributes). Mentioned were Dublin Core and archival metadata standards, i.e., Encoded Archival Description or General International Standard Archival Description (ISAD(G).

Vocabulary support

The repositories use different kinds of vocabularies concerning the user community (international, national, or only by the repository) and formalisation (e.g., following thesaurus standards, list of terms or keywords given by depositors). Most of the repositories use more than one vocabulary (39), 20 indicated use of two, 17 three, and two even four. Most often an own standardised vocabulary is being used (35), at nine repositories only such a vocabulary (e.g., thesaurus). Also, a national vocabulary and/or an own list of terms is being used quite often, each at 25 repositories, but seldom as the only vocabulary. In addition, also an international vocabulary (19) and/or keywords given by depositors (17) are being used, but also seldom as the only vocabulary.

Repository search interface

36 of the repositories said that they provide a metadata search interface while 24 did not or not yet. Among the latter some may provide other ways to navigate and browse information about their collections.

External search platforms

35 repositories did not share metadata with external search platforms. It appears that some do not see a need to make their holdings findable also via external search platforms or for some other reasons cannot do this. There can be many reasons, for example, the user base of the repository is well known and not expected to increase, lack of a suitable external platform, a legacy metadata management system that does not support metadata harvesting.

Licence frameworks

At the repositories different license frameworks are applied. A very restricted approach is present at 19 repositories, e.g., all or most works are fully copyright protected and/or own terms and conditions are applied that include some restrictions (e.g., non-commercial, no derivatives or other). 16 repositories have an open approach, e.g., only Public Domain Dedication, only Attribution, or both. A mixed approach has eight repositories which all hold Public Domain data while other data requires setting various restrictions, defined by own terms & conditions or standard licenses. Furthermore 17 repositories apply various restrictions, 12 own terms and conditions, incl. some restrictions, and five only do not allow commercial use of content.

Enabling open data access

Survey questions on open data access concerned whether there are policies for such access, restrictions applied by repositories, how to improve data access, and how to demonstrate that data is being reused.

Support of open data policies

Repositories need policies and guidelines so that they can support open data access and reuse. Most needed is a clear position of heritage authorities in this regard, 39 repositories required regulations and 36 clear guidelines by the authorities. Next came the challenge to overcome barriers of users to deposit open and reusable data (29) which, for example, includes concerns of researchers about open licensing and that their data might be misused. Respondents also considered as important training of repository staff to support new policies on open/FAIR data (28). Some respondents also considered

that sharing of good practices and appropriate technical systems could help much to support open data access and reuse policies.

Control of data access

Answers to the question of how people can access data stored in the repositories showed three different approaches. 24 repositories had an open access approach, i.e., no registration is required. 15 repositories had data that can be accessed without registration and other data accessible for legitimate registered users and/or with permission granted. At 21 repositories data was accessible only for legitimate registered users and/or with permission granted.

Improving data access

Answers to the question on what would help the repositories most for improving data access showed that four options were considered more often than others:

- Improve or replace the existing data management system (30 respondents),
- Improve the quality of metadata (34),
- Provide metadata to external search platforms/engines (27),
- Use Linked Data to interlink own and other (meta)data (26).

Analysis of the responses for repositories in preparation (17) showed:

- These often wanted to improve the data management system (11), and more often than others also to align own with other vocabulary (e.g., international or national thesaurus) and/or use advanced ontologies (e.g., CIDOC-CRM).
- Repositories that were satisfied with their data management and vocabulary wanted their data to be found by providing metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.

In the responses of repositories in operation (43) some indicated common priorities while others did not:

- Quite some repositories wanted to improve or replace the existing data management system (19); for nine the main reason appeared to be enabling better access to complex or high-volume data objects (e.g., 3D models, LiDAR data).
- Also, two smaller groups of repositories with other common priorities could be distinguished: One group primarily wanted to improve the metadata quality and to replace or align own with other vocabulary; another group had in common the priorities to provide metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.

Access during the COVID-19 pandemic

Asked whether the repository collects and analyses access data of 56 respondents 29 said “No”. The 27 respondents who said “Yes” were further asked whether there has been an increase or decrease of access during the COVID-19 pandemic. 24 respondents said that overall, there was an increase, reporting increases from 5% to over 100%.

Data re-use is difficult to demonstrate

For repositories data re-use is difficult to demonstrate, because if there is re-reuse it takes place outside of what they can easily track and measure. Indeed, asked whether the repository collects information about date re-use (e.g., references in publications or other sources) only nine of 56 respondents said “Yes”.

4.5.2 Conclusions and suggested actions

Conclusions from the survey results and recommendations for activities of ARIADNEplus, SEADDA and other initiatives are:

Repository support of FAIR

- *(Meta)data identifiers:* 29 of the 60 repositories surveyed assign deposited data globally unique and persistent identifiers, but for more this would be beneficial. Initiatives for state-of-the-art repositories should provide advice on how to assign such identifiers.
- *Metadata richness:* The majority of repositories (47) are satisfied with the metadata they provide, which suggests no need for targeted support activities. However, in the responses to the question what would help most for improving data access 34 repositories considered improvement of the quality of metadata. Hence this is still an important topic for advice on good practice.
- *Vocabulary support:* Most of the repositories use more than one vocabulary (39), often two (20) or three (17). Often an own standardised vocabulary (35) and/or a national vocabulary (25) is being applied. But quite some of the repositories use less formalised means such as an own list of terms and/or keywords given by depositors (e.g., eight use only this, nine in addition also an own standardised vocabulary). Therefore, advice on how to standardise vocabulary and/or align it with an international one (e.g., Getty AAT) would be beneficial.
- *Data discovery:* 24 repositories do not have a metadata search interface and 35 do not share metadata with external search platforms. The reasons for this would be worth investigating in order to advice on how metadata could be provided to data search platforms such as the ARIADNE portal.
- *Licence frameworks:* While 16 repositories have a very open approach regarding data re-use, 19 have a very restricted one, and 17 repositories apply some restrictions. Advice on copyright clearance or why some restrictions should be reconsidered (e.g., no commercial use, no derivatives or other) may be helpful for increasing the potential of data re-use.

Enabling open data access

- *Support of open data policies:* Most needed is a clear position of heritage authorities in this regard, 39 repositories required regulations and 36 clear guidelines by the authorities. Also, other support is needed, for example, 28 repositories considered as important training of repository staff to support new policies on open/FAIR data.
- *Control of data access:* At 21 repositories data is only accessible for legitimate registered users and/or with permission granted, in addition 15 repositories have such restrictions for some of the data, while 24 repositories have an open access approach (i.e., no registration is required). Reducing barriers to data access would require mechanisms for not disclosing sensitive data on which advice could be given.
- *Improving data access:* The repositories considered what would help them most for improving data access:

  Often this included

  - Improve or replace the existing data management system (30 respondents),
  - Improve the quality of metadata (34),
  - Provide metadata to external search platforms/engines (27),
  - Use Linked Data to interlink own and other (meta)data (26).

Analysis of the responses for repositories in preparation (17) and in operation (43) separately showed some specific needs. For example:

- Repositories in preparation that were satisfied with their data management and vocabulary wanted their data to be found by providing metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.
- For some repositories in operation that were not satisfied with their data management system the main reason appeared to be enabling better access to complex or high-volume data objects (e.g., 3D models, LiDAR data).
- Among the repositories in operation also one group primarily wanted to improve the metadata quality and to replace or align own with other vocabulary, and another group provide metadata to external search platforms and possibly interlink own and other (meta)data using the Linked Data approach.

The results show that repositories could benefit much from advice and support in several respects, from the perspective of ARIADNEplus particularly regarding improvement of metadata, providing metadata to the ARIADNE catalogue and portal, and Linked Data.

Analysis of data access and re-use

Repositories also need advice and possibly support regarding information about data access and re-use:

- *Data access:* 29 of 56 respondents said that their repository does not collect and analyse data access figures, although this might allow identifying where access procedures could be improved and better reporting on repository usage.
- *Data re-use:* No information about data re-use (e.g., references in publications and other sources) is being collected according to 47 of 56 respondents, although re-use for new research and other purposes demonstrates best that funds for data preservation and access are well invested.

Finally, encouraging for the open/FAIR data agenda is that 24 of the 27 repositories which analyse data access reported that during the COVID-19 pandemic overall there was an increased access, reporting increases from 5% to over 100%. It seems likely that the COVID-19 crisis made archaeologists more aware of the importance of publicly shared data, data repositories and discovery and access services.

5 Virtual Research Environments (VREs) workshops

Among the next steps to progress beyond the achievements of the original ARIADNE project is to provide Virtual Research Environments (VREs) for archaeological research communities. A VRE can be generally defined as an online working environment that provides services and tools combined and tailored for the research tasks and data types of a community of researchers. The envisaged ARIADNEplus VREs will be Cloud-based environments that offer researchers services and tools for research tasks beyond what the Data Portal supports.

This chapter presents the ARIADNEplus VRE use cases workshops that are being conducted to collect needs and requirements of archaeological research communities for VREs and prepare the co-design of relevant VREs by archaeologists and technical experts.

The first section addresses the challenge of providing VREs for archaeological communities and ARIADNEplus' overall approach for this. Next the VRE workshops are described, their purpose and approach, and the presentations and discussions of the first two workshops already held; currently two additional workshops are planned. Finally, the results of the first workshops are summarised and suggestions given for the development of VREs.

5.1 Towards ARIADNEplus VREs

Providing VREs for archaeological research communities is one of the most ambitious innovation goals of ARIADNEplus. The related challenges include that archaeology has many subfields, with shared as well as different needs regarding research tools, and use of a Cloud-based research environment to carry out research tasks online is not yet a common practice of archaeologists. Therefore, some reservations to move away from established practices and acquire new digital skills may have to be overcome.

An ARIADNE study in 2017 on the development of VREs in the humanities found only few such projects in archaeology (ARIADNE 2017). The main variant of an online environment for research was (and arguably still is) the Web GIS of an excavation project. Other variants for different purposes included project wikis, use of social media platforms, collaboration on a shared database or digital archive, and 3D Virtual Reality systems, but mainly to present research results.

Where proper VREs have been developed in related domains, e.g., digital classics (Babeu 2011), these tended to be stand-alone systems, implemented and customised using various technologies. In recent years the development clearly has been VREs on top of common and increasingly Cloud-based research infrastructure. Still, there remain some contradictory or at least difficult to fulfil expectations from a VRE, i.e., open vs. controlled, flexible vs. tailored, and domain vs. cross-domain.

Archaeology is a multi-disciplinary field of research in which researchers require knowledge and data from different domains of research. Therefore, ARIADNEplus integrates data resources from many more archaeological domains and methods than the original ARIADNE project. For example, this includes palaeo-anthropology, bioarchaeology, inorganic materials study and dating, burial archaeology, environmental archaeology, ancient buildings, inscriptions (epigraphy, rock carvings), and others.

The advanced ARIADNE Data Portal is already an effective research tool that exploits the integrated information on the "what", "where" and "when" of archaeological research objects. Thereby new types of research can be carried out by experimenting with the various search filters, for example

comparison of settlement patterns or artefacts found in different regions relating to different cultural periods. This type of research was not possible to achieve so effectively before.

In addition to the Data Portal, ARIADNEplus VREs will provide more specific services and tools which research communities can use for different tasks and types of data. The VREs will be configured for the needs of domains of research but may also support inter-/multi-disciplinary projects.

The VREs will be implemented on the D4Science platform of project partner Italian National Research Council, Institute of Information Science and Technologies (CNR-ISTI, InfraScience).[15] D4Science provides "VREs-as-a-service" and supports open science practices (Assante et la. 2016; Assante et al. 2019). The VRE provide generic functionality (e.g., user authentication & authorization, communication, data storage, metadata, etc.) and research-specific tools communities of different disciplines for their tasks.

ARIADNE already offered e-research services such as the Visual Media Service, which enables effective online publication and exploration of enhanced images (e.g., Reflectance Transformation Imaging - RTI) and 3D models of buildings and artefacts, and Natural Language Processing (NLP) was demonstrated for information extraction from archaeological reports in different languages. In ARIADNEplus these services are being advanced and new ones developed, for example, geo-spatial services and services for semantic annotation and linking of data resources.

The generally Cloud-based services can be integrated in VREs, but also used stand-alone when only the specific functionality is needed. On a general note, providing research tools online in a Cloud-based environment avoids researchers investing effort to acquire, implement, maintain, and upgrade them. Instead of dealing with IT issues the researchers can focus on their research questions and collaboration.

5.2 The VRE use cases workshops

5.2.1 Purpose and approach

Virtual Research Environments (VREs) must be co-designed by archaeologists and technology experts to ensure that a relevant and fit for purpose research environment is being developed. However, many archaeologists are not familiar with or even aware of VREs as envisaged by ARIADNEplus, and technological VRE developers with an archaeological background are rare as well. Therefore, "a bicycle made for two" approach (Pollard & Bray 2007) is necessary in which archaeologists and technology experts learn from each other in the process of co-designing relevant and fit for purpose VREs.

To kick-start the development, a series of VRE use cases workshop are planned. The purpose of the workshops is to promote thinking of archaeological research communities represented in ARIADNEplus about which data-related research tasks could be supported by services of a VRE. This is expected to generate "wish lists" of VRE services and general and domain-specific community requirements for services, which provide the basis for functional descriptions of the VREs.

Two workshops have already taken place with participation of partners, affiliates, and external experts. These workshops each addressed two of the thematic domains represented in ARIADNEplus: Geospatial and Mortuary Data and Research (January 2021), and Ancient DNA and Environmental Data and Research (May 2021). Two further workshops are planned which will be held in the coming months: Archaeological Sciences (involving domains in addition to aDNA research), and Spatial Applications, in view of ARIADNEplus Pilots in which the spatial dimension plays a particularly important role.

[15] D4Science, https://www.d4science.org

The sections that follow summarise the presentations and discussions of the first two workshops. The final section of this chapter highlights the main results and gives recommendations for the development of ARIADNEplus VREs.

5.2.2 VRE workshop 1: Geospatial and Mortuary Data and Research

The first workshop addressed the integration of geospatial/GIS data services in the ARIADNEplus research environments (i.e., Data Portal and domain VREs) and tools researchers in mortuary research need from a VRE to tackle their research questions. The workshop was organised by Guntram Geser (Salzburg Research, Austria) who in the preparation phase discussed with the presenters needs of domain researchers, the workshop approach, and specific topics. The workshop took place on the 28th of January 2021 with 52 participants on the Zoom platform.

Workshop introduction

In his introduction Franco Niccolucci, the project co-ordinator, stressed that the development of VREs is one of the most ambitious goals of the ARIADNE initiative in its second phase, and the expectation that some of the project's Pilots will use VREs to demonstrate innovative research enabled by ARIADNEplus.

Guntram Geser then set the scene for the workshop, explaining the overall purpose of the VRE use cases workshops, and the proposed approach for the development of VREs, particularly that these must be co-designed by archaeologists and technological experts. He also addressed some VRE user requirements that are often mentioned in the literature, including authorized access and use, intuitive user interfaces, easy-to-use data analysis tools, support of communication and collaboration, and clear data use and sharing conditions. In addition, he mentioned the required set of data-related functions such as storage, search & retrieval, processing, among others. Advanced, tightly integrated services also support research workflows. New users will need some initial training for using a VRE.

Geospatial data for research in ARIADNEplus

David Novák (Institute of Archaeology of the Academy of Science, Czech Republic) started his presentation pointing out that geospatial/GIS data is a topic for all research domains represented in ARIADNEplus as almost all archaeological information includes geographical data, it is the *"reverse side of all the other coins"*.

However, archaeological research communities often use different spatial representations, principles of structuring information, and levels of detail. An analysis of geospatial/GIS datasets of project partners made clear that integration in the Data Portal and VREs of their spatiotemporal data at item level is challenging due to the high heterogeneity. But for collection-level inclusion of datasets in the ARIADNEplus data catalogue the existing AO-Cat model provides what is needed.

Novák then addressed different ways geospatial/GIS data could be integrated in the ARIADNEplus system:

a) integration in specific domains as defined by the Application Profiles of the respective research communities and executed in the standard data aggregation process,

b) integration of pre-selected datasets available in standardised formats, i.e., as geospatial services,

c) full item-level integration of all available datasets regardless of the purpose, format, coverage, and content.

Novák's preference for the integration of geospatial/GIS data above what a) offers, clearly was b), selecting relevant available services, while c) appeared as too ambitious, due to the identified heterogeneity of the data.

Regarding relevant services, as selection criteria he proposed considering if they are used regularly, hence needed most, and have some characteristics that support integration and usage. These included,

- Standard: services implemented according to widely applied standards,
- Interoperable: easy to describe, make accessible and use,
- Contextual: interdisciplinary, providing proxy data archaeologists need from other disciplines,
- Consistent: available for most regions,
- Comparable: providing harmonized content types.

Next Novák illustrated the variety of relevant geospatial services regarding their content showing examples from the Czech Republic. These include heritage lists and maps of monuments and sites, historical maps, basic data such as topography and administrative boundaries, various environmental data (e.g., geology, hydrology, pedology, land use), and content from remote sensing (e.g., orthophoto maps, LiDAR data visualisations).

Novák also noted that there are different services regarding their data type, e.g., Web Map Service (raster data), Web Map Tiled Service (raster data), Web Feature Service, Web Coverage Service, and others. He proposed that any public servers can be considered but excluded should be WebGIS applications and of course datasets that are not accessible online.

Novák suggested that a survey of the project partners could help to identify the available heritage data services for their country/region and a selection of the most important proxy data services. Structured metadata about the services could be collected using an online form, including information about source, licensing, content description, etc.

Where possible, services should be as much as possible integrated into the Data Portal map interface, and for GIS data it should offer common tools such as layer selection, feature identification, attribute table viewer. Finally, Novák emphasised that the integration of relevant geospatial services could significantly support and raise the use of other data available in the ARIADNE system, by providing heritage related data as well as data archaeologists need from other disciplines.

In the following discussion, it was suggested that what archaeologists need as contextual data for their research could be defined in the ARIADNE knowledge base, with metadata about and links to relevant services. This raised the question how data from the integrated services would be passed to services within the ARIADNE infrastructure, the Data Portal as well as VREs which should support the use of geospatial data. Here the Geoserver of the D4Science platform was mentioned as an available service for handling geospatial data needed in VREs on the platform. It was suggested that geospatial datasets of partners could be used as test cases for exploring the best approach for this.

The next step regarding the integration of external services was to identify relevant services, as suggested by Novák. It was pointed out that the description of the services should include the scale and resolution of the data available from a service, otherwise the value of the metadata would be limited. The INSPIRE[16] infrastructure for spatial information in Europe provides such information and the INSPIRE metadata could be considered as a common standard.

[16] INSPIRE, https://inspire.ec.europa.eu

Mortuary data and research

Next on the agenda was the field of mortuary archaeology, in ARIADNEplus led by Edeltraud Aspöck (Austrian Centre for Digital Humanities and Cultural Heritage). She introduced the workshop participants to research questions, data and digital tools of this field using the example of early medieval cemeteries for her analysis.

Aspöck explained that this field of research had started with human remains and artefacts and grown to include funerary practices, social organisation, past identities, migration, etc., and application of ever more scientific analyses to support insights into many aspects of the past. The medieval period she selected because mortuary data is the main source of information on the period between the 5th and 11th centuries with many available datasets. Cemeteries contained between tens to hundreds of graves with skeletal and various other remains that are being excavated and analysed.

Aspöck then briefly addressed the basic data on cemetery sites that is included in the Data Portal, which is collection-level data including dating (time-period), location (coordinates), and subjects relevant for the collection dataset. She emphasised that this information is good for identifying available collections, but not for exploring them. Regarding how a typical mortuary data record could be modelled she explained that it would first give the data on "Where, When, What" of the cemetery, next for the graves (e.g., position, dating, features), and then for the finds (e.g., human remains, grave goods, etc.).

Aspöck distinguished three types of datasets in mortuary archaeology, which concern documented studies of excavated finds; data resulting from post-excavation analysis (e.g., stratigraphy, documentation of graves, research reports, spreadsheets, drawings, or photographs); and data from more specialised research, for example, on mortuary practices in a region based on the analysis of features of graves and various remains.

Typical research questions on funerary practices, social structure and organisation concern who was buried at a cemetery, i.e. demographics such as age and gender; variation between cemeteries and changes over time; variation of funerary treatment according to age at death and gender; clusters of graves due to family or other group affiliations (e.g., genetics); social status of individuals inferred from related grave goods and scientific analyses (e.g., nutrition); post-depositional events such as reuse of graves or graves reopened for other practices.

Data analysis methods for the research questions include statistical analysis of demographics and funerary treatments over time, including correspondence analysis/seriation (for dating), analysis of the mapping of graves and spatial and social patterning of graves based on nearest neighbour characteristics, among others.

Regarding some desired functions and tools of a VRE, Aspöck included in the "wish list":

- Query different types of existing datasets, as mentioned above, e.g., data from typical post-excavation analysis or more specialised databases,
- Carry out basic and advanced data analyses of own data, e.g., demographics and funerary treatments over time, produce and analyse grave mappings, nearest neighbour analysis, etc.
- Create links to other datasets, e.g., to reference contextual data or for comparison,
- Visualise research results with charts and maps/GIS,
- Use 3D models of finds for documentation, including annotation, ideally connected to a knowledge base,
- Use Artificial Intelligence to analyse images, e.g., auto-classify photographs or drawings of graves to identify certain features such as disturbances.

In the following discussion workshop participants particularly appreciated Aspöck's suggested modelling of typical mortuary data records, from the cemetery to individual graves and on to individual finds and analysis. It was recognised that the cemetery and individual graves are covered well by the new ARIADNE AO-Cat (data catalogue) model regarding "Where, When, What" questions, including mapping the described graves of a cemetery and, where comparable data are available, the distribution of similar graves in a larger area (e.g. region, country and beyond).

Thus, the Data Portal could allow searches on very interesting research question. However, specific data for a grave, such as analysis of remains, cannot be covered with the AO-Cat and therefore not queried in the Data Portal. Possible is that the landing pages of grave records provide links to available detailed documentation and analysis of finds. For such information a VRE could be developed that provides functionality and tools for mortuary archaeology from the above "wish list".

Example: THANADOS

Jan Hasil (Institute of Archaeology of the Academy of Science, Czech Republic) presented THANADOS - The Anthropological and Archaeological Database of Sepultures.[17] THANADOS is a state-of-the art mortuary archaeology system, that applies open-source technology (OpenAtlas[18]) and advanced data standards (e.g., CIDOC-CRM) for the documentation, visualisation and analysis of archaeologically and anthropologically investigated burials (Filzwieser & Eichert 2020).

THANADOS builds on technical and data-related results of the Medieval Cemeteries at the Periphery of the Carolingian World (MEDCEM) project[19], which was coordinated by the Archaeological Institute of the Czech Academy of Sciences in Prague. While MEDCEM focused on examples of early medieval cemeteries in Austria, Bohemia and Moravia, THANADOS aims to cover all such cemeteries in the area of present-day Austria.

The THANADOS system comprises descriptions, classifications, images and (where available) 3D models of finds and features, detailed osteology data, and more. It allows the user to browse the data at very detailed levels, conduct various queries, including intra-site as well as inter-site searches of cemeteries, visualise them with maps, plots etc., and export the data in different formats for further research. The system is based on detailed metadata, vocabulary for burial archaeology and anthropology, and provides an API for Linked Open Data.

The THANADOS project is hosted at the Natural History Museum Vienna (Prehistory Department) and the Austrian Archaeological Institute, in cooperation with the Austrian Centre for Digital Humanities and Cultural Heritage (ACDH-CH). The project started in June 2019 and is funded by the go!digital NextGeneration programme of the Austrian Academy of Sciences.

Hasil proposed that ARIADNEplus should investigate a possible co-operation with THANADOS as the projects follow the principles of FAIR data and have implement common standards. It was agreed that co-operation between the two projects should be pursued, which after the workshop resulted in an agreement with the developer team at the Natural History Museum in Vienna to integrate datasets.

D4Science VRE success stories

The ARIADNEplus VREs will be implemented on the D4Science platform based on its VREs-as-a-service model. D4Science has been successfully used by research projects in fields such as earth, environmental and marine sciences (examples in Zhao & Hellström 2020), but not yet for archaeological research.

[17] Thanados, https://thanados.net

[18] OpenAtlas, https://openatlas.eu

[19] MEDCEM, https://medcem.aiscr.cz

Massimiliano Assante of CNR-ISTI's D4Science group introduced the workshop participants to the VRE approach of D4Science and presented two successful uses of VREs in the field of environmental sciences. The examples highlighted their use of several available D4Science services, including the D4Science Geoserver, and proved to be quite an eye-opener.

The example of the Alien and Invasive Species VRE concerned the Puffer fish (a highly toxic fish) which has colonised parts of the Mediterranean and caused serious problems for fishermen. The goal was to predict to which areas the fish were likely to spread next. To achieve this, required the dedicated VRE support scientists scattered across different organisations to collaborate, make available data, and niche models in the VRE geospatial catalogue, and use large scale computing facilities for data mining and analysis running different algorithms quickly. The result was that the Puffer fish will very likely spread from the south-east Mediterranean up to Sicily and the Ionian Sea.

Importantly, the example also demonstrates an advanced Open Science approach: collaboration of scientists sharing open data, models, and algorithms, re-useable workflow with reproducibility of all steps. In technical terms, executed processes are described with the OGC - Web Processing Service standard, workflow steps are available as-a-service. Finally, an open access paper describes this successful project (Coro et al. 2018).

The second VRE, Protected Areas Impact Maps, concerned monitoring Maritime Protected Areas (MPA's) using spatial data. Over 40% of our oceans show anthropogenic impact and countries are required to comply with the Convention on Biological Diversity, the Aichi targets. In this example, the task was to create a tool to examine seagrass and mangroves that had to be accessible, user-friendly and with fast analysis. The result was MPA Reporting which accesses data and services through the D4Science platform, using Data Miner (a built-in facility). The tool has a dedicated catalogue and uses WFS links to access actual resources. Repeatability of processing and results is built in.

The two VRE use case gave the workshop participants an idea of what can be achieved by using VREs. For example, VREs similar to the Alien & Invasive Species VRE could be designed for environmental archaeology research questions for which data is available or could be mobilised; a VRE like the Maritime Protected Areas VRE could support the management and protection of cultural heritage sites, e.g. concerning erosion and other impacts of sea-level rise on sites at coasts due to climate change. The VRE use cases also demonstrated that D4Science has available services for effective handling of geospatial data.

The discussion following the two VRE use case focused on how to design VREs as archaeologists are not IT developers. It was agreed that a technical developer was needed to assemble available components and co-creation could be supported. It was proposed to keep things simple and to develop a procedure which identified who did what and to start with the requirements and some simple examples. How VREs can use the ARIADNE database needs to be explored. All the issues raised affect the Pilots of the project which will also use VREs and it was suggested that the VRE use cases and Pilots needed to get together to define their requirements.

5.2.3 VRE workshop 2: Ancient DNA and Environmental Data and Research

In the focus of the second workshop were ancient DNA and Environmental Archaeology data and research and what VREs could offer these two new scientific domains in the ARIADNE initiative. The workshop was organised by Guntram Geser (Salzburg Research, Austria) who in the preparation phase discussed with the presenters needs of domain researchers, the workshop approach, and specific topics. The workshop took place on the 6th of May 2021 with 22 participants on the Zoom platform.

Workshop introduction

After a welcome by the project co-ordinator Franco Niccolucci, the workshop host, Guntram Geser, explained the approach of the VRE workshops and summarised the results of the first workshop. He also described the setup of the second workshop and why particular topics have been chosen for the presentations.

Geser explained that for the two presentations on ancient DNA (aDNA) the common focus is on contextual information for samples used for aDNA studies. Access to contextual information for samples is generally relevant for all domains of scientific analyses of materials represented in ARIADNEplus. Hence the presentations on aDNA will not go much into how aDNA analyses are being produced in specialised laboratories (see the excellent primer Orlando et al. 2021). Rather the focus will be on the information archaeologists need to put the results in perspective. For them the question is what do the aDNA results mean related to other results of the archaeological investigation on the analysed material and sites from which the samples have been collected. The challenge for a VRE here is to support the linking and access to various contextual information for this purpose.

Regarding the two presentations on environmental archaeology, Geser explained that each will describe an existing digital research system, the Strategic Environmental Archaeology Database (SEAD) for environmental reconstructions, and dataARC, which supports research on the interactions between North Atlantic environments and people by linking data and knowledge from different disciplines. Describing the setup, use and perceived potential for improvements could yield insights on needs of researchers for VRE services also in other domains of research.

Finally, as an introduction to the two presentations on aDNA, Geser provided a snapshot of recent developments in the field of aDNA studies: He described it as a rapidly expanding field of research, illustrated with figures of searches of DataCite and OpenAIRE, e.g. OpenAIRE for the years 2012-2021 had indexed over 7,500 aDNA related works, including 1,300 datasets. There is an expansion from the initial focus on remains of hominids and large-bodied animals to various animals, plants, bacteria, and sediments. In recent years, in addition to newly excavated remains, ever more samples for aDNA studies are sourced from various natural and cultural history collections (Green & Speller 2017).

Understanding the complexity of aDNA studies in archaeology

Eugenia Tabakaki of the Institute of Molecular Biology and Biotechnology of the Foundation for Research and Technology Hellas (Greece) gave an overview of the study of aDNA highlighting the many uses and issues faced by researchers in the fast-growing field of archaeogenetics. She explained how aDNA is used to study several scientific questions that were impossible to answer with conventional archaeology methods. Studies include looking at humans, both as individuals and as communities, plants and animals and the extinction or expansion and migration of all of these, along with the impact of changes in cultural practices, infectious diseases, etc.

This is a highly multi-disciplinary area involving experts from biology, geology, chemistry, to name just a few, and which generates large amounts of data even before the samples reach the lab. Challenges such as degradation and contamination of samples are commonplace, and the context of biological material is very important to be able to get meaningful research results. Tabakaki also pointed out the dependence of sample preservation and genetic analysis with the natural environment. An important goal for aDNA researchers is an open environment for bio-archaeological data which is inter-linked, discoverable, and accessible.

Maria Theodoridou of the Institute of Computer Science of the Foundation for Research and Technology Hellas (Greece) then presented the ARIADNEplus Application Profile for aDNA which aims to support linking of the sample data with contextual and other information. A typical application would be to examine bone and teeth samples from an ancient necropolis using aDNA techniques to

determine genetic sex, genetic diseases (e.g. sickle cell anaemia and thalassemia) and pathogens resulting from malaria.

The aDNA workflow is intensive and starts with the identification and selection of samples likely to allow generation of useable aDNA results. Next comes the complex process of transfer of source material, preparation for sequencing, and the actual sequencing of the aDNA. Having generated a large quantity of scientific data, specific bioinformatics tools are applied, depending on the scientific question, and the researchers can finalise their analysis and publish the aDNA results.

Regarding the aDNA Application Profile, Theodoridou explained that it is based on the CIDOC Conceptual Reference Model (CRM) and a number of compatible models widely used in archaeology, and is aligned to the ARIADNEplus Catalogue Ontology (AO-Cat) and the CRM for Heritage Sciences (CRMhs). She then presented the modelling of a sample that will be used for aDNA analysis, using certain ontology classes, S13 Sample and E20 Biological, and the relevant properties for recording all the contextual data such as the details about the archaeological excavation.

Theodoridou also briefly addressed the metadata model of AncientMetagenomeDir (Fellows Yates et al. 2012)[20], a community curated resource of lists of all published shotgun-sequenced ancient metagenome or microbial genome-level enriched samples. Such data is important for example for ancient microbiomes analyses and environmental reconstructions using sedimentary aDNA. The metadata model of AncientMetagenomeDir could be mapped to the AO-Cat to include their data records in the ARIADNEplus catalogue and portal.

The discussion following the aDNA presentations started with a question on the potential to use the CRM class E92 Spacetime Volume to document how samples move from the fieldwork in mortuary archaeology or a museum physical anthropology collection on to become in a laboratory derived sources for aDNA sequencing and analysis, and publication of the results. It would have to be seen whether this could work in practice, using an extended aDNA Application Profile, with Theodoridou stating a preference for following general ARIADNEplus principles of keeping things simple.

Only briefly touched upon was that in the field sciences standards are being developed to integrate data generated from and related to samples or specimens. For example, led by the Alliance for Biodiversity Knowledge the biodiversity archives and research community currently aim to standardise “Digital Extended Specimens” (Miller 2021). A group of US research institutes, natural history museums, and the Open Context archaeological repository proposes to standardise “iSamples” and create digital services for handling them (Davies et al. 2021).

The System for Earth Sample Registration (SESAR)[21] has already implemented services for sample metadata cataloguing, including International Geo Sample Numbers (IGSN). An IGSN serves as unique identifier for citing and linking a sample to data and publications and track its use from the field to the lab and beyond. SESAR supports sample hierarchies so that research material derived from a sample (e.g., a thin section or powder) can be cited while maintaining a connection of this subsample to the parent sample’s metadata in the SESAR registry.

In the workshop discussion the point was raised that to produce reliable results using aDNA analysis, it is important to record as much contextual information as possible about the sampling together with all the information about the processes during the analysis, e.g., for evaluating good or bad pre-treatments. As well, to be able to retrace analytical steps for repeatability and to be able to decide which interim data to preserve.

[20] AncientMetagenomeDir, https://github.com/SPAAM-community/AncientMetagenomeDir

[21] System for Earth Sample Registration (SESAR), https://www.geosamples.org

There was consensus that providing more sample-related contextual information could help unlock insights and lead to better informed interpretation of aDNA study results. If researchers have access to accurate, consistent, complete, and reliable contextual data they can build a culture of integrity in the field of aDNA, i.e., integrity of aDNA research question, sampling, and interpretation. This might help overcome conflicts between archaeologists and aDNA scientists due to sometimes exaggerated conclusions drawn from results of aDNA analyses (Callaway 2019; Eisenmann et al. 2018; Källén et al. 2021; Sykes et al. 2020, amongst many publications on this topic).

Environmental reconstructions and research on human-environment interactions

In the second part of the workshop on environmental archaeology the two presenters each described an existing digital research system, sharing insights into VRE needs and requirements of researchers that are relevant also for other domains of research.

In his presentation *From sampling to environmental reconstruction, and vice versa*, Phil Buckland (Umeå University) described how the Strategic Environmental Archaeology Database (SEAD)[22] brings together data from various sampled and studied remains (e.g. sediments/soils, plants, animals) to enable reconstruction of environmental conditions of past landscapes. Samples of remains can be from natural deposits as well as archaeological sites. Archaeological field and laboratory work is one of the sources for environmental reconstructions and, in turn, benefits from the knowledge generated based on the integrated data (Kohler et al. 2018). Very important in this regard is of course the dating (age range) of samples to allow matching them to archaeological periods.

The setup of SEAD supports the aggregation of data through to analysis, and links to other projects and systems from which data are drawn as well as shared with. Initially developed for the aggregation of data from laboratories in Sweden, SEAD has become an important provider of paleobiological data to international initiatives such as the EarthLife Consortium.[23] The consortium aims to make all paleobiological data easily discoverable, accessible, and analysable by bridging databases with a common Application Programming Interface (API) and shared vocabulary (Uhen et al. 2021).

Buckland explained that to ensure reliable, transparent and reproducible results, the flow of the laboratory work and analysis data have to be described and ideally data from every stage should be saved. The data aggregated then allows broad synthetic research and interpretation as well as addressing specific research questions, for which the SEAD database allows different levels of data linking and visualisation.

As an example, Buckland mentioned the use of ecological data and species distribution maps for fossil insects in archaeological research. An important distinction he made is between such research using data level linking and research using interpretation level linking as in the dataARC project, where aggregated ecological data for samples in SEAD have been linked to concepts in dataARC.

The following discussion was on the technical feasibility of providing tools for an Environmental Archaeology VRE. In his presentation Buckland mentioned that SEAD allows powerful searches over varied datasets, but it is not easy to define them when new data has been added, and it requires quite some computing resources. Pasquale Pagano (CNR-ISTI InfraScience) suggested that his team could set up a VRE on D4Science that provides Jupyter Notebooks, RStudio and their Data Miner service to specify and execute data computing tasks on the ARIADNEplus Cloud-based infrastructure.

This suggestion was appreciated; however, it should be noted that the technical knowledge and know-how of the average user did not include R or Python programming skills and most lacked of time to acquire them plus lots of training materials are required. The point was made that this sort of training

[22] SEAD - Strategic Environmental Archaeology Database, www.sead.se

[23] EarthLife Consortium, https://earthlifeconsortium.org

should be provided by universities and research institutes (not ARIADNEplus), but if the project can show what can be achieved, then this would encourage archaeologists to demand and learn these skills.

The final presentation was given by Rachel Opitz (University of Glasgow) on dataARC[24] which has been funded by the National Science Foundation (USA). dataARC is a community backed research environment focussed on understanding the interactions between North Atlantic environments and people by linking data and knowledge from different disciplines.

The partners contribute different research resources, from SEAD data (i.e., pollen and insect data) to the Icelandic Sagas (descriptions of early medieval landscapes). The partners share the aims to support research practices that add value to data and enable interdisciplinary studies of long-term human-environment interactions in the North Atlantic region. For these purposes dataARC developed data integration, discovery and visualization tools that support innovative exploration of shared data resources using a concept map based on CIDOC-CRM. The semantic mapping interlinks many higher-level concepts that relate to data in different types of resources through combinators which connect data to concepts.

The concepts are described with scope notes by researchers with different disciplinary backgrounds so that different understandings of research objects can lead to multiple semantic mappings. Opitz gave the example of the concept of "driftwood" which can be understood as a biological object (related to trees), as a legal object (in relation to resources), and as an actor in an economic system (Pálsson & Opitz 2019). The dataARC search tool[25] has been developed to encourage exploration of the data resources for interdisciplinary research. Users can select on the search interface concepts represented on the semantic map to query the data resources, and the tool presents matched, related, and contextual results.

The search tool has been designed to meet several goals, including to highlight small datasets (i.e., prevent larger data sources from overwhelming others), avoid over-interpretation and speculation, explain how search results are generated, and provide motivating examples. The key outputs from dataARC in technical terms are the cross-database search tool, Application Programming Interface (API), documentation, extension tools (e.g., ecosystem explorer), and use case examples.

ARIADNEplus can learn from dataARC how to design VREs and tools so that they encourage use by taking account of concerns of scholars regarding data sharing and re-use. Some design principles Rachel addressed are that research tools should enable

- Give people credit for and control over their data,
- Balancing between wanting data used and not wanting it misused,
- Show their work to gain recognition and feedback,
- Value expertise while also encouraging wider use of data,
- Encourage exploration outside disciplinary boundaries,
- Use of infrastructure and data for other projects.

Other principles important specifically for dataARC were to favour deep exploration over speed and support the recognition of ambiguities and interpretive and data messiness.

In the following discussion it was highlighted that both dataARC and ARIADNEplus apply the CIDOC-CRM, which raised the question if the dataARC concept map could be combined with the ARIADNEplus

[24] dataARC – Enabling Research on the Long-Term Human Ecodynamics of the North Atlantic, www.data-arc.org

[25] DataARC Search Tool, https://ui.data-arc.org

implementation of the CIDOC-CRM, or perhaps a semantic VRE might be created on top of different CRM based concept maps. Maria Theodoridou, ARIADNEplus' expert for the CIDOC-CRM, mentioned that it can be applied in very different ways, but from a brief look into the dataARC concept map before the workshop it seems that there could be potential to combine it somehow with how ARIADNEplus uses the CRM.

Another suggestion was that VREs which like dataARC enable mappings of concepts from different disciplinary perspectives, as in the example of "driftwood", could benefit from a service that provides multi-vocabulary support for such mappings. In dataARC the users who create mappings explain their understanding of concepts with own scope notes which allows flexibility. In addition, it might be beneficial enabling use of established thesauri of different disciplines for these annotations and querying data resources. Repositories and databases use terms from domain thesauri for tagging and indexing data they contain hence this could support searches yielding results with different domain contexts.

Suggestions for VRE services

The final discussion focused on the question which kinds of VRE services would add value to the existing ARIADNEplus research data infrastructure and open opportunities for collaboration with other infrastructures.

One suggestion by Holly Wright (Archaeology Data Service, UK) referred to the flow of data derived from research samples addressed in the aDNA and environmental archaeology presentations. She thought that ARIADNEplus could consider services providing data management support for the process from generating raw data, to interim data products, on to deposition of shareable data in a repository, which are usually related to publications.

Comments on this were that in research data management it indeed is important to be able to trace steps in the data generation and analysis, and from the archiving perspective to decide which intermediate datasets should be preserve. This would make the research more transparent and replicable but could fill quite some data storage space. Moreover, to reproduce research would require making available also method descriptions, software code, specific algorithms, etc.

This linked back to the suggestion of Pasquale Pagano to set up an ARIADNEplus VRE on D4Science that allows specifying and executing data computing tasks. As this would use Jupyter Notebooks, RStudio and other open-source resources, Open Science requirements such as replicability could be fulfilled quite easily.

Julian Richards (Archaeology Data Service, UK) thought ARIADNEplus could benefit a lot from implementing a VRE service that enables users to run queries, pre-defined or specified by them, over the ARIADNEplus database (RDF triple store) to get simple descriptive statistics on "what, where, when" questions and use a variety of standard mapping tools, e.g., the interpolation and density functions. What would also be needed is a mechanism to download the results of a filtered query of the Data Portal into a VRE, or a SPARQL query interface within a VRE to produce the same data subsets.

Douglas Tudhope (Hypermedia Research Group, University of South Wales, UK) picked up the suggested need of a VRE service for annotation of research objects with different domain vocabularies. Tudhope mentioned that such a service will be developed in ARIADNEplus by the team at University of South-Wales. He also considered that an ARIADNEplus Wikidata type resource could encourage collaboration between research groups employing multiple vocabularies. Moreover, he noted that services are needed to traverse Linked Data of related projects. An example of a case study was the Dendro Demonstrator[26] in the original ARIADNE project, which focused on data and reports (in

[26] ARIADNE: Demonstrator for data integration case study, http://ariadne-lod.isti.cnr.it/description.html

different languages) on wooden objects and their dating with dendrochronological techniques. Tudhope thought that reviving the demonstrator could stimulate ideas for other data integration case studies and engage collaborators, for example in the field of environmental archaeology.

5.2.4 Next two VRE use cases workshops

Two further workshops are already planned which will be held in the coming months:

VRE workshop 3: Archaeological Sciences

This workshop will be organised by The Cyprus Institute, Science & Technology in Archaeology Research Center (Cyprus) and continue the analysis of potential applications of VREs to scientific data domains present in ARIADNEplus, i.e., Paleo-archaeology, Bioarchaeology, Inorganic Materials Study, Dating methods such as Dendrology.

VRE workshop 4: Spatial Applications

This workshop will be organised by the Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Institute of Archaeology (Slovenia) and focus specifically on the spatial research dimension of VREs, available services (e.g., the Cloud-based Geoserver), and data resources for the research, remote-sensing data like LiDAR, for instance. The workshop will also support ARIADNEplus Pilots in which the spatial dimension plays a particularly important role.

5.3 Summary of results and suggested actions

Key results of the workshops

The VRE workshops stimulated thinking of archaeological research communities represented in ARIADNEplus about which data-related research tasks could be supported by a VRE.

The workshops confirmed that VREs must be co-designed by archaeologists and technology experts to ensure that relevant and fit for purpose research environments are being developed.

The presentation of success stories of uses of D4Science-based VREs, although not yet in archaeology, was quite an eye-opener for the around 50 participants of the first workshop on what can be achieved using such VREs. One example also demonstrated that this includes conforming to Open Science principles in computing-intensive fields of research (e.g., sharing of executable workflows, models, algorithms, etc.).

The presentations and discussions yielded many insights into general and specific user needs and requirements, including that the design of VREs must take account of concerns of scholars related to data sharing and re-use.

An important general conclusion is that the development of VREs must consider thoroughly the research questions, datasets, and analysis methods of the intended VRE user community.

The example of mortuary archaeology illustrated that demand for a VRE can mean support with tools for research that is widely common in a field of research, or new research methods in that field, or both. A presented “wish list” of desired functions and tools of a mortuary archaeology VRE included, among others, tools for basic data analysis, use of annotated 3D models of finds for documentation, and an artificial intelligence system for image recognition and analysis.

Very important is also to make clear what research the advanced ARIADNE Data Portal already supports with the underlying knowledge base and available search functionality and where a dedicated VRE would be needed. Discussion of the example of mortuary archaeology helped a lot to make this distinction clearer.

Reference systems of fields of research

It proved to be very useful to have in the workshops examples of state-of-the-art systems in fields of archaeological research represented in ARIADNEplus. Describing the setup, usage, perceived issues, and potential for improvements can yield insights into needs and requirements of researchers for VRE services also in other domains of research.

For mortuary archaeology the reference example was THANADOS. THANADOS and ARIADNEplus follow the principles of FAIR data and have implement common standards (e.g., CIDOC-CRM). It was suggested that co-operation between the two projects should be pursued, which after the workshop resulted in an agreement with the developer team at the Natural History Museum in Vienna to integrate datasets. Work on the integration has already started.

Also very useful were the presentations and discussions of the two reference examples for environmental archaeology, dataARC and SEAD, with some particularly noteworthy insights.

The presentation on dataARC highlighted the requirement that the design of VREs must take account of concerns of scholars related to data sharing and re-use, e.g., give users credit for and control over their data, and balance between wanting data used and not wanting it misused.

The presentation of SEAD made clear that domain research data infrastructures and VREs must support internal purposes but should also be capable to share data with other initiatives, in the case of SEAD the broader initiative of the EarthLife Consortium to bring together all paleobiological data based on the FAIR data principles. The discussion of SEAD internal processes also let to the suggestion of a generic VRE for data computing and analysis, which is already set up on the D4Science platform (see below).

Complex workflows

Workshop presentations included description of the complex data-focused workflows of archaeological research communities. This made clear that the development of VREs should investigate such workflows and be clear about which tasks a VRE can support.

A full-blown VRE for research data management would support the whole process from the generation of raw data to interim data products, data analysis and interpretation, and deposition of shareable data in a repository, usually related to a publication reporting the study results. Such a VRE could make the research more transparent and replicable, but to reproduce research would require making available also method descriptions, software code, specific algorithms, etc.

It was proposed to follow ARIADNE's general approach to keep things simple and start with some not too complex case studies.

Suggested VRE services

Several ideas for VRE services were suggested that will be explored further, are in development or already implemented. The following list describes suggested services from the user perspective:

- Define and execute data computing tasks: such a VRE, called ARIADNEplus_Lab, is now available on the D4Science platform. It provides Jupyter Notebooks, RStudio, DataMiner and other data processing and analysis resources.
- Run queries, pre-defined or specified by the user, over the ARIADNEplus database (RDF triple store) to get simple descriptive statistics on "what, where, when" questions, and use a variety of standard mapping tools, e.g., the interpolation and density functions.

- Annotate research objects with different domain vocabularies: Such a service is being developed; also suggested was that an ARIADNEplus Wikidata type resource could encourage collaboration between research groups employing multiple vocabularies.
- Annotate 3D models of finds for documentation purposes was included in the "wish list" for mortuary archaeology; such a service will be part of the advanced Visual Media Services.
- Natural Language Processing (NLP) of documents was not addressed in the workshops but is already available.
- Use Artificial Intelligence for image recognition and analysis, e.g., auto-classify photographs or drawings of graves based on certain features, was also included in the "wish list" for mortuary archaeology. Such a service is not on the list of planned ARIADNEplus services but might be considered.

General services or procedures:

- One suggestion was that what archaeologists need as contextual data for their research, e.g., from geospatial data services, could be defined in the ARIADNE knowledge base, with metadata about and links to relevant services.
- Generally needed is a mechanism to download the results of a filtered query of the Data Portal into a VRE, or a SPARQL query interface within a VRE to produce the same data subsets.
- Services will also be needed to traverse Linked Data of related projects. An example is the ARIADNE "Dendro Demonstrator". It was suggested to revive it to stimulate collaboration on other data integration case studies.

Geospatial data services

Geospatial data are very important for most archaeological research communities represented in ARIADNEplus. Integration of many available geospatial data services could significantly support and raise the use of other data available in the ARIADNE system. Heritage related data as well as data archaeologists need from other disciplines should be considered.

In the first VRE workshop the approach for the integration of geospatial data in the Data Portal and VREs has been clarified. It differs from the procedures for the description and aggregation of geospatial data of partners together with other datasets. The approach is to select available geospatial data services and describe these in the ARIADNE data catalogue. For the selection of relevant services several criteria have been defined (e.g., current use, coverage, technical standards, etc.).

A survey of the project partners was proposed to identify the available heritage data services for their country/region and a selection of the most important proxy data services. Structured metadata about the services should be collected using an online form, including information about source, licensing, data description (e.g., coverage, scale, resolution), etc. The INSPIRE metadata schema was mentioned as a reference for this.

Where possible, services should be as much as possible integrated into the Data Portal map interface, and for GIS data it should offer common tools such as layer selection, feature identification, attribute table viewer. For handling geospatial data in VREs on the D4Science platform the available Geoserver can be used, which is foreseen in some of the ARIADNEplus Pilots.

Contextual data for research samples

In archaeology the data-focused workflow of sub-domains (i.e., subject experts) typically starts with data derived from samples collected in fieldwork, but in many cases also with samples from specimen

collections. The importance to have access to as much information as possible about sample contexts for the interpretation of research results was emphasised.

The discussion concerned samples used for aDNA studies, but it is a requirement for all scientific analyses of materials represented in ARIADNEplus. Archaeologists need the contextual data to put the analysis results in perspective. For example, what do the aDNA results mean related to other insights of the archaeological investigation of sites from which samples for aDNA analysis have been collected. The challenge for a VRE here is to support the linking and access to various contextual information for this purpose.

Regarding take-up of new data standards, ARIADNEplus could benefit from looking into standards and systems that are being developed for data generated from and related to samples. For example, the "Digital Extended Specimens" of the Alliance for Biodiversity Knowledge and "iSamples" of an initiative in which the Open Context archaeological repository participates.

6 Final remarks and outlook

This report is titled “Final report on community needs”, as given in the Description of Work of the project, however the project work will continue for fourteen months, and additional activities focused on identifying and supporting community needs will be carried out.

In addition to the two Virtual Research Environment (VRE) use case workshops reported, another two are already planned. One workshop will focus on VRE needs and requirement of researchers in archaeological sciences present in ARIADNEplus in addition to ancient DNA, i.e., Paleo-archaeology, Bioarchaeology, Inorganic Materials Study, Dating methods such as Dendrology. Another workshop will focus on the spatial research dimension of archaeological VREs and specific data such as remote-sensing data like LiDAR, for instance. This workshop will also support ARIADNEplus Pilots in which the spatial dimension plays a particularly important role.

There is also demand for user needs and requirements work concerning the use of specific technology-based ARIADNEplus services. For example, the Visual Media Services have been identified in the COVID-19 impact study as relevant for cultural heritage institutions interested in using 3D models for the presentation of heritage objects and sites.

Furthermore, needs and requirements will also be investigated for potential users of services beyond researchers and professionals in archaeology and cultural heritage, for example, citizens actively engaged in archaeological activities (“citizen science”).

Finally, it is worth noting the high value of the ARIADNE and ARIADNEplus community needs surveys for the ARIADNE initiative and the whole field of archaeology in Europe and beyond. The surveys in 2013 and 2019 are the only existing large surveys on data management practices of archaeologists, with over 600 completed questionnaires analysed in 2013 and nearly 500 in 2019. The survey on archaeological repositories with rich information about 60 repositories is to our knowledge, the largest thus far on repositories supporting one discipline, as well as the specific topics such as domain data policies and FAIR data.

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