Developments in Research Data Management in Academic Libraries: Towards an Understanding of Research Data Service Maturity

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This article reports an international study of research data management (RDM) activities, services, and capabilities in higher education libraries. It presents the results of a survey covering higher education libraries in Australia, Canada, Germany, Ireland, the Netherlands, New Zealand, and the UK. The results indicate that libraries have provided leadership in RDM, particularly in advocacy and policy development. Service development is still limited, focused especially on advisory and consultancy services (such as data management planning support and data-related training), rather than technical services (such as provision of a data catalog, and curation of active data). Data curation skills development is underway in libraries, but skills and capabilities are not consistently in place and remain a concern. Other major challenges include resourcing, working with other support services, and achieving "buy in" from researchers and senior managers. Results are compared with previous studies in order to assess trends and relative maturity levels. The range of RDM activities explored in this study are positioned on a "landscape maturity model," which reflects current and planned research data services and practice in academic libraries, representing a "snapshot" of current developments and a baseline for future research.

Introduction

In the last 10 years, an international agenda around research data management (RDM) has emerged. This has been driven by a number of inter-related factors, including increasingly data-intensive science, policy changes among research funders, a recognition of the critical requirement for a focused and coordinated approach to data stewardship in research institutions, and the economic and social imperative to improve access to research outputs for educational, public sector, and commercial organizations (Borgman, 2015; Pryor, Jones, & Whyte, 2014; Ray, 2014). Universities have begun to address this strategic objective, and a range of institutional stakeholders including academic libraries, have become engaged in developing policy, services, and infrastructure. Although their increasing focus on institutional support for RDM has drawn on the prior experience of libraries in developing digital services and open-access repositories, RDM has created significant new challenges for library managers. Furthermore, although it is evident that

libraries have begun to play a role in RDM, the nature and extent of that role remains unclear. This study reports the results of a major international survey of RDM activities and services in libraries, in order to contribute to the ongoing discussion.

The research takes an international approach and seeks to demonstrate the value of benchmarking RDM support practices taking place within individual institutions as indicators of national trends. Results from seven countries across Europe, North America, and Australasia are presented—the choice of countries in part driven by the desire to facilitate comparisons with earlier RDM surveys and to gauge the development of RDM activities and services within each country.

The research undertaken aimed to address the question of how academic libraries are currently supporting the management of research data in their institutions and how they are planning to develop services in the future. At the core of this was the objective of identifying the services currently offered by libraries, plus those in development or being planned. The identification of major challenges associated with RDM activities was also a central part of the research. In particular, key questions arising from RDM developments include how library-based services relate to other activities and actors elsewhere in (and beyond) the institution, and also how the delivery of such services impact on organizational structures in (and beyond) the library. Related to this, the question of the knowledge and skills of library staff associated with the delivery of RDM activities and how these can be enhanced, was seen as particularly important. The research approach undertaken enabled these questions to be addressed in such a way as to allow comparisons to be made over time (using previous studies) and across countries (because of the international reach of the study).

Literature Review

The potential for academic libraries to be substantially involved in RDM has been discussed for over a decade. Their potential role was proposed at a relatively early stage (Carlson, 2006; Hey & Hey, 2006; Lewis, 2010; Lyon, 2009) and then subsequently described in more detail by a number of authors such as Lyon (2012), Corrall (2012), and Cox, Verbaan, and Sen (2012). There is now a widespread professional debate about the exact nature of library engagement with RDM, the extent to which libraries may carry out a leadership role, the types of services that need to be provided, and the level of infrastructure that should be in place. The degree to which libraries can inform and influence wider institutional strategy for RDM is a key issue. There is evidence of libraries leading institutional initiatives in RDM, particularly around policy development (Cox & Pinfield, 2014; Pinfield, Cox, & Smith, 2014; Whyte, 2014b). At the same time, libraries are dealing with a complex set of challenges associated with RDM in their institutions, including low levels of engagement with key stakeholders (including researchers themselves), uncertainty about levels of technical infrastructure required, and problems in identifying

sustainable funding streams for RDM activity (Cox, Pinfield, & Smith, 2016; Pinfield et al., 2014). At supra-institutional level, library consortia, such as Research Libraries UK and CARL (Canadian Association of Research Libraries), have played a role in influencing national policy developments, including working with funding agencies and designated bodies, such as Jisc (UK), Australian National Data Service (ANDS), and Research Data Canada. The extent of the coordination of RDM activities by such organizations may then in turn influence RDM leadership demonstrated in institutions.

The development of research data services and the role of libraries have been examined in a number of empirical studies covering multiple institutions. Tenopir and collaborators (Tenopir, Birch, & Allard, 2012; Tenopir, Sandusky, Allard, & Birch, 2013, 2014) offer a useful set of benchmarking studies based on institutions in the United States. Corrall, Kennan, and Afzal (2013) have provided a set of international comparisons in a study including RDM and other library research support services in Australia, New Zealand, Ireland, and the UK, commenting, for example, that the UK appeared to be lagging behind Australasia in some critical areas. A quantitative study by Cox and Pinfield (2014), complemented by subsequent qualitative research (Cox, Pinfield, & Smith, 2014; Pinfield et al., 2014), have updated the situation in the UK and have illustrated the complexities involved in developing RDM programs at institutional level. This is supplemented by a survey undertaken by the DCC (Whyte, 2014b). A more recent analysis of research data services has taken the approach of investigating RDM activities via analysis of the webpages of selected libraries from the top 100 listed institutions in the *World's Best Universities, 2012* (Si, Xing, & Zhuang, 2015). These studies indicate that library-developed research data services to date have tended to focus on advisory, support, and training services (such as delivery of training for researchers or production of guides to data sources) to a greater extent than technical services (carrying out the ingest, storage, and preservation of data sets). Nevertheless, this is a rapidly changing landscape and so carrying out research as these services continue to develop, is important.

RDM activities and services are not developed by libraries in isolation. There are a number of other key stakeholders in the RDM space. Previous studies indicate these to be the IT services department and research support office in particular (Cox & Pinfield, 2014; Pinfield et al., 2014) and the need for collaboration between these groups is emphasized in the literature (Akers, Sferdean, Nicholls, & Green, 2014; Si et al., 2015; Wilson, Martinez-Uribe, Fraser, & Jeffreys, 2011). However, Verbaan and Cox (2014) have identified "conflicts and tensions" that arise in institutions with regard to professional "jurisdictions" in relation to RDM, and although they propose a possible "division of RDM roles" across these professional groups, there remains considerable uncertainty in this area. Moreover, within the library itself, there remains variation in the ways and the extent to which the department is being redesigned to

accommodate these new roles. Some libraries have created new teams within their structure to take forward the RDM agenda, others have distributed RDM responsibility among existing teams (Akers et al., 2014). In a number of cases, RDM support is incorporated into more general research support services (including bibliometrics and scholarly communication support), upon which there has recently been an increased focus in many academic libraries (Brewerton, 2012; Corrall, 2014; Corrall et al., 2013).

A particular related concern reflected in the practitioner and research literature is RDM workforce capacity and capability. Following early calls for action (Lyon, 2007; Swan & Brown, 2008), evidence of the need for reskilling has been presented by Auckland (2012), and more recent analyses of the different data roles including "data librarian" reported by Lyon and Brenner (2015). A small study of the specific skills and competencies required for different data roles arising from actual RDM positions evidenced by job postings, has emphasized the range of abilities and knowledge required (Lyon, Mattern, Acker, & Langmead, 2016). This has implications for the recruitment and training of librarians for RDM. iSchools may have a key role to play in providing graduate programs featuring RDM and data curation courses and advanced certificates (Lyon & Brenner, 2015). Continuing education and training for current library and information professionals is a necessity (Kennan, Corrall, & Afzal, 2014) and there are a range of data management training programs positioned in this space, for example, RDMRose (Cox et al., 2012), immersiveInformatics (Shadbolt, Konstantelos, Lyon, & Guy, 2014), and the MANTRA DIY Kit (MANTRA, n.d.) . A Research Data Management MOOC (Massively Open Online Course) was run on Coursera by UNC-Chapel Hill and University of Edinburgh in 2016. However, there remains a skills gap, and tackling this area is considered to be a key element in any academic library strategy for the future.

Discussions about developing RDM services and capabilities have sometimes used the concept of "maturity." Maturity in this context is tied in with the notion that as knowledge about, and services in, a particular area reach a full or complete level of development, they are "mature." The concept has been explored in software engineering (Paulk, Curtis, Chrissis, & Weber, 1993), digital preservation (Kenney & McGovern, 2003), and data intensive research (Lyon, Ball, Duke, & Day, 2012). Maturity models have also been applied in the RDM space, within institutions (ANDS, 2011), and within research projects (Crowston & Qin, 2011). In these models different levels of maturity are proposed according to different levels of services or infrastructure offered.

Despite its currency, the term maturity is, however, problematic. It might be taken to imply a single development path leading to a fixed mature finishing place. This is not normally the case. Also, terms like "immature" or "underdeveloped," sometimes associated with maturity models, might be seen as pejorative. Recognizing these potential problems is important in making use of the term;

nevertheless, the concept of maturity can be useful to inform analysis of a developing area such as RDM, as service and infrastructure offerings are investigated over time.

The current study builds directly on previous RDM surveys by the authors carried out in 2012 (Corrall et al., 2013; Cox & Pinfield, 2014) and on selected questions from the survey covering North America (Tenopir et al., 2012, 2015). It also builds on a 2014 survey of the UK by the Digital Curation Centre (Whyte, 2014b). The research was designed to afford longitudinal comparisons with these previous studies, giving rise to questions of developing services and how these might reflect RDM maturity.

Methods

A survey designed in the form of a questionnaire was selected as an appropriate strategy (Pickard, 2012), administered through an online instrument that enabled an approach to be made to a large number of academic libraries in diverse locations (Case, 2012) to elicit data about what academic libraries were doing and planning. The online questionnaire consisted of 27 questions focusing on RDM policy, funding, services, and managerial issues. The questions were designed to explore issues reflecting the purpose and objectives of the study and were developed using information gained from the literature on the subject, contacts in the field and, for comparative purposes, prior surveys on the topic. As the previous questionnaires were all slightly different, the questionnaire structure evolved with a focus on what was currently of interest in the academic library RDM space, whether academic libraries were collaborating with other internal or external organizations on RDM, and what knowledge and skill gaps currently exist. Four long questions sought to discover which of 22 different RDM related services identified in the literature (see Appendix F for a listing) were currently being offered and which services were future priorities. Participants were asked to rate specific service areas they were providing as "no service," "basic," "developing," or "well developed" service, providing an insight into service maturity levels. The questions differentiated between advisory services, such as training and web guidance, and technical services, such as running a repository. This approach was partly informed by analysis of the results of previous studies of RDM and libraries which have, as discussed, identified greater maturity in advisory rather than technical services. Of course, the distinction between advisory and technical services is not clear cut, but it was felt that a line could usefully be drawn between softer, more informational roles, and more technical services based on specialized skills and knowledge, such as providing a data repository or undertaking preservation. Some areas of activity were hard to classify, but we considered copyright to be a "technical" matter. From a pragmatic perspective, dividing the questions in two sections reduced the length of the list that respondents had to address, making it less intimidating and so helped maintain the response rate. Most questions in the survey as a whole, required participants to choose from a range of options and allowed a short comment, but some

TABLE 1.   Survey responses by country.

	Australia	Canada	Germany	Ireland	Netherlands	NZ	UK	Total
Invited institutions	39	74	48	8	16	7	169	361
Number of responses	34	17	8	7	12	7	85	170
% response rate	87	23	17	88	74	100	50	

questions asked participants to provide their own descriptions or open narrative answers.

Libraries from Australia, Canada, Germany, Ireland, the Netherlands, New Zealand, and the UK were invited to participate. The questionnaire was made available online using the subscription version of Survey Monkey ("Survey Monkey," n.d.) from September 8 to December 4, 2014. Personal invitations were sent to academic library directors in September 2014, with reminders sent in October and November 2014. Prior to release of the survey, the instrument was piloted by individuals within the target population in three different countries. Pilot feedback confirmed the terminology of the instrument and resulted in a number of minor clarifying changes. It also confirmed that it took approximately 20 minutes to complete the questionnaire. The research approach was approved by the University of Sheffield ethics approval process and involved informed consent from all participants and a commitment from the research team to ensure anonymization of individuals and organizations in the reporting of the data.

Although invitations to participate in the survey were e-mailed directly to library directors in the seven countries from published listings or lists obtained from the researchers' contacts, response rates were variable ($n = 170$) (Table 1). A large proportion of institutions that were invited to participate in Australia, New Zealand, the Netherlands, and Ireland, did complete the survey. Fifty percent of UK institutions completed the survey, which is comparable to the response rate in Cox and Pinfield (2014). The low proportion of responses from Canada and Germany was disappointing; the results from these countries are reported here but the findings may not be indicative of the full national picture and should be treated with care.

Other interpretive issues also need to be considered. There is marked variation in the size and composition of the higher education sectors in the different countries, and the low numbers of institutions in smaller countries makes robust statistical analysis of the data more challenging. Low numbers of responses from other countries may mean that results are likely to be unrepresentative of the sector as a whole; research-intensive institutions may be more aware of RDM issues and so more likely to respond. These institutions are also likely to be the most active in developing services, thus the data from the survey may systematically over-represent RDM activity in the sector as a whole. However, we suggest that the response rate, with the exception of those from Canada and Germany (as noted earlier), is high enough to be confident that the results from those responding would be found if nonresponding institutions had been included. In

theory, we could have investigated further the nonresponse bias, by contacting a sample of nonresponding institutions and checking to see if their responses did systematically deviate from those that did respond. We considered that this would be disproportionate to the claims being made in the paper. The fact that the results from this survey are not out of line with previous national-level studies also reinforces the plausibility of this survey. Further study would, nevertheless, be needed to fully validate the findings.

To facilitate cross-country comparisons, the results are presented here as percentages as well as numbers, to ameliorate the order of magnitude differences between the population sizes and response rates of participating libraries in the countries surveyed. Percentages are rounded and calculated for each country on a question-by-question basis in relation to the number of respondents answering the particular question or sub-question, as all questions were optional and not all respondents answered each question.

Prior UK surveys (Cox & Pinfield, 2014; Whyte, 2014b) and North American surveys (Tenopir et al., 2015, 2012), made distinctions between types of institutions, for example large research-intensive universities and teaching-led universities or colleges; in this paper, however, we consider the results through a national and international lens. The purpose of the study was to undertake an international comparison, and to consider the impact of national conditions on the overall development of RDM in the university sector, drawing on both quantitative and qualitative data. Most previous studies have been of single countries, so the data presented here are novel in relating to a number of countries. Other forms of comparison could be made, such as by type of institution, but that was not the objective of this particular investigation. There are issues at national level that make national-level comparisons worthwhile, including immediate factors (the stance of funding bodies or the availability of national support) or more underlying differences in the structure of higher education systems. Of course, the makeup of higher education in the different countries is not necessarily the same, and such differences have to be considered when evaluating the conclusions we draw from the data.

The majority of respondents in all countries ($n = 170$) were members of the library senior management team (Table 2) and therefore well-positioned to provide strategic insight, as well as a full operational overview of the RDM arena.

All data presented are from the questionnaire unless otherwise acknowledged, including quotations that are derived from free-text responses. Responses to multiple choice and matrix choice questions were analyzed using descriptive

TABLE 2.   Percentage of respondents in the library senior management team by country.

	Australia	Canada	Germany	Ireland	Netherlands	NZ	UK	Total
N respondents in library senior management team	26	15	5	7	7	5	66	361
N total respondents	34	16	8	7	12	7	85	170
% in library senior management team	76	94	63	100	58	71	78	
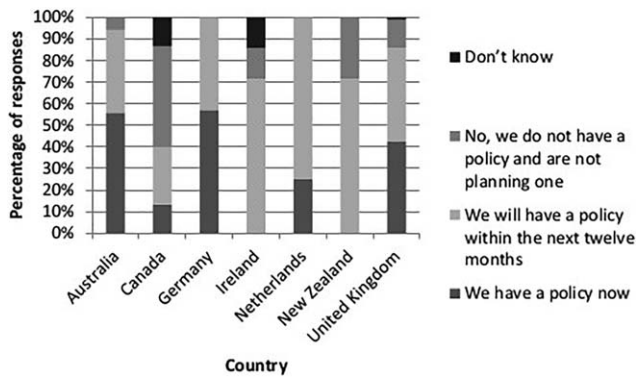
FIG. 1.   RDM policy development by country (see also Appendix A) ($n = 167$).

Findings

Research Data Management Policy and Governance

In most countries, a majority of institutions responding to the question about policies in late 2014 ($n = 167$) either already had an RDM policy or expected to have one in place within 12 months (Australia 94%, Canada 40%, Germany 100%, Ireland 71%, the Netherlands 100%, NZ 71%, UK 86%). "*We will have a policy in place within 12 months*" was the dominant position. However, with the exception of Germany and the Netherlands, there was a subset of institutions which did not have an RDM policy and were not planning to have one (Figure 1).

Although the absence of an RDM policy position may be said to "buck the trend," it could also be interpreted as reflecting the nature of national research funder expectations or the degree of institutional focus on RDM activities. In the UK where most institutions report a policy, the Engineering and Physical Sciences Research Council (EPSRC) has been influential in steering institutions towards developing an RDM policy and Jisc has funded a number of pathfinder projects (Cox & Pinfield, 2014). Similarly in Australia, the National Code of Conduct for Research (NHMRC/ARC/ Universities Australia, 2007) with its clear delineations about the respective roles of institutions and researchers, has been a factor as has project grant funding in the library:

statistics and visualization techniques (Myatt, 2007). Written answers to open questions were analyzed using thematic analysis approaches, in particular following the protocol outlined by Braun and Clarke (2006).

"*[The library are] Core members of working group on research data management road map for EPSRC requirements.*" (UK; SMT member)
"*The Library is a member of the University's eResearch Coordination Committee. The Executive Director of the Library chaired a working group sponsored by the Committee to develop the policy, based on the Code, extensive research of policies at other institutions and assistance from ANDS.*" (Australia; SMT member)

RDM policy development is a multistakeholder process with a range of participants (library, IT services, research office, legal office, and academic contributors). Leadership and initiative in RDM policy development came most commonly from the library or research office or a close partnership between the two (Table 3). These two organizational units are key research support stakeholders in most universities, although they may not necessarily have a tradition of working in close collaboration. It is perhaps surprising that there was not greater evidence of leadership from academics/faculty/researchers, whose research data outputs are so critical to peer-reviewed publications and subsequent career progression.

Institutions encountered challenges in developing effective RDM policies that balance the interests of the range of stakeholders involved. Many RDM policies were approved by a senior manager in the university such as the Pro Vice-Chancellor, Vice-President, or Vice-Provost for Research, often following wider consultation. Typically, a senior governance group such as the Research Committee or equivalent body, with faculty representatives (and chaired by PVC/ VP Research), oversaw and contributed to this process. A range of different groups were named as having a key role in the ongoing governance of RDM policy, reflecting the complexity of the area and the opportunities for new alliances:

"*The Library is the 'service owner' for the pilot Research Data Service. Service delivery is a matrix involving Library, IT and Research Office. Close academic partnership is ensured through a reporting line to the Research Data Management Storage Board (academic chair).*" (UK; SMT member)
"*University Librarian is Member of Project Board for Research Data Storage Project which is developing program (Project Board includes representation from Division of Research (2), Academic (1), Library (1), IT (1). Library Repository Manager is member of Business Advisory Group which advises the Project Board.*" (Australia; SMT member)

TABLE 3. Stakeholders perceived to be "leading" RDM in their institutions.

	Australia	Canada	Germany	Ireland	Netherlands	New Zealand	United Kingdom
Library lead	9	3	4	2	7	2	29
Library participated	16	2	3	0	5	1	35
IT services lead	0	0	4	1	0	0	6
IT services participated	19	1	3	1	8	3	52
Research office lead	19	3	4	0	5	0	31
Research office participated	8	1	3	2	4	2	29
Legal office lead	0	0	0	0	0	0	3
Legal office participated	15	1	4	1	6	1	20
Academic representatives lead	0	0	1	1	3	2	9
Academic representatives participated	17	1	5	1	7	1	44

Note: respondents could indicate that more than one or no group led or indicate that they did not know, therefore totals cannot be meaningfully presented.

TABLE 4. Institutions with RDM policies in Australia and the UK, comparison of previous studies.

RDM survey and year of publication	Australia			UK		
	%	N	Total N	%	N	Total N
2013 (Corrall et al.)	29	10	34	17	14	81
2014 (Cox & Pinfield)				32	25	81
2014 (DCC)				41	25	61
2016 (this study)	56	19	34	42	36	85

In some UK and Australian institutions, increasing maturity in RDM was becoming evident. For example, in some cases the RDM policy was just one element in a wider RDM roadmap or research data development strategy. Alternatively, temporary project groups were being transitioned into more permanent governance groups in the institution. However, at other institutions, governance arrangements were still unclear:

"At the moment it is not completely clear what our involvement in RDM-*governance* will be. We will start with a policy and of course make sure that the underlying services are up and running." (The Netherlands; SMT member)

Looking at results of selected earlier surveys where direct comparison is possible, there is evidence of a gradual increase in RDM policy implementation (taking the UK and Australia as two exemplar regions) (Table 4).

Research Data Services Establishment, Funding and Structures

Across the geographical zones investigated ($n = 164$) with the exception of Canada, many institutions have used audit tools, surveys or other evaluative methods to gain a better understanding of the internal landscape of research data; in Canada, 40% respondents are currently planning this activity. In the UK, the library in particular had frequently (44% institutions) either led or been involved in the study (Figure 2).

However, the results also show that in Australia, the library was involved in data audits or surveys to a lesser extent (24% respondents), suggesting a different stakeholder balance. In addition, in Canada, the Netherlands, and New
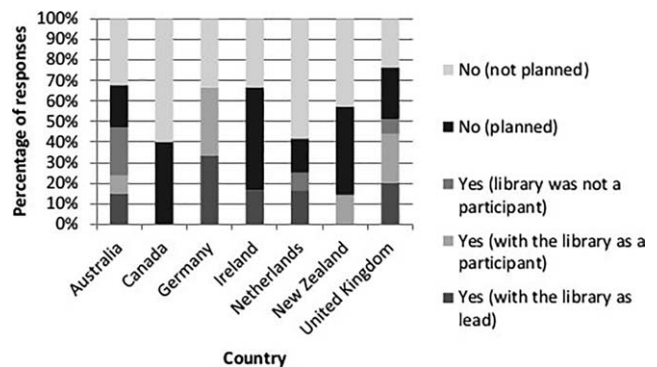

FIG. 2. Institutional audit, survey or evaluation of research data (see also Appendix B) ($n = 164$).

Zealand, 60%, 58%, and 43% institutions, respectively, were not planning any sort of RDM audit.

Participants were asked to comment briefly on the major challenges now and in the future, for libraries working in research data management. Although there were a wide range of responses, "resourcing" was the most commonly reported challenge by participants. The funding of RDM in all regions except Germany (although as noted previously, respondent numbers may not capture the whole picture for this country), were largely from financial resources which were not fixed term, a fact which may be viewed positively because the availability of only fixed-term funding was seen to constrain development. Recognition that funding for RDM will need to come from multiple sources was noted in response to the question on how RDM should be funded:

"Business as usual for research organisation; partly from central funding and partly from grant funding (where specific requirements cannot be met centrally)." (UK; SMT member)

A common view was that infrastructure funding should, at least in part, be allocated at supra-institutional level:

"Top-sliced funding for national services would be preferable to every institution trying to develop sophisticated services individually." (UK; SMT member)

At institutional level, a number of participants commented that resourcing was a particular problem in a context where there were no obvious sources of additional funding to the library budget. There was, however, acknowledgment that at least some funding, particularly for staff, might need to be secured through re-purposing resources within the library staffing budget:

"Within University Library, resources have been redeployed to grow staff numbers and capabilities in repository and research data management services. I have seen as essential for future of Library and taken resources away from areas of declining use and relevance (e.g., print collection acquisition and management for one)." (Australia; SMT member)

The importance of business planning was highlighted, but some participants noted that it was very difficult because of the complexity of the situation and a number of "unknowns":

"The main challenges relate to developing service capability, and the resource needed for a sustainable service in the long-term. Business planning is difficult with so many unknowns e.g., the volume of data for deposit and the amount of work involved per data set." (UK; SMT member)

Another of the major challenges highlighted by participants was the lack of "recognition of the need" for an institution-level approach to research data management. In some cases, there was a particular challenge in, "achieving institutional buy-in at senior level" (UK; SMT member). In other cases, there were reported problems in "convincing some academics and researchers of the importance and worth of RDM" (New Zealand; non-SMT member), or in "explaining the need and specifying/articulating the Library's role" (Canada; SMT member). In some cases, there was perceived lack of support from senior management in the library itself.

The survey sought to identify library collaborations and stakeholder partnerships, both internal to the institution and external, arising from RDM activities. Across all regions,

intrainstitutional collaboration appears to be central to research data services (RDS) establishment and development:

"RDM is a cross institutional activity. It requires the Library to work together with faculties, the research office, IT services and other academic committees in the university. This can be challenging." (New Zealand; non-SMT member)

The entity mentioned most often as a collaborator in service development was IT services, but this relationship was sometimes also mentioned as creating a challenge around issues of prioritization and coordination. The development of coordinated, cohesive and integrated services was identified as a challenging priority:

"The most [important] thing is to develop a common service by different departments of the university (Library, IT-Service, Research office) for the researchers." (Germany; non-SMT member)

In contrast to such apparently developing intrainstitutional collaboration, in New Zealand, Ireland, and the UK in particular, there was relatively little (maximum 22%) current collaboration with external organizations such as data centers or other universities or libraries (Figure 3).

There was a greater degree of current collaboration with external parties in Australia, Canada, Germany, and the Netherlands (77%, 67%, 60%, and 82% institutions, respectively). Several participants emphasized the need for cross-institutional collaboration in terms of sharing expertise and developing infrastructure and a number would have liked to have greater collaborative activity:

"I believe…cooperation on regional or national is necessary to use the limited resources in an efficient way." (Germany; SMT member)

Another issue explored in the questionnaire was how far library organizational roles and structures had been impacted by RDM. Results showed a predominantly "cautious" picture across all regions with many respondents reporting no or only minor organizational structure changes planned (Figure 4). A key challenge was achieving:

"Management recognition of the changing nature of work in academic libraries and support and encouragement for staff to reskill and refocus efforts, including restructuring positions to support staff to engage in RDM services." (Australia; non-SMT member)
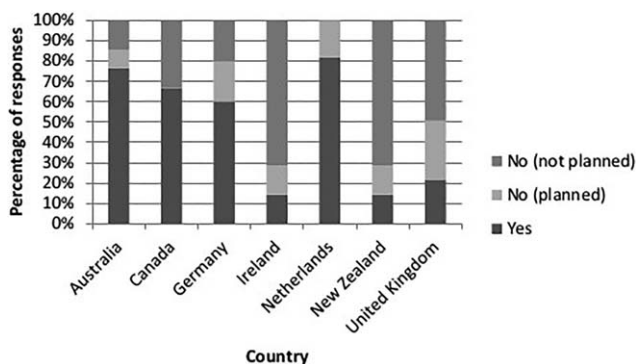

FIG. 3. Library partnerships for research data services: with external organizations (e.g., data centers) or institutions (e.g., other universities or university libraries) (*n* = 162) (see also Appendix C).

Advocacy, Advisory, and Support Research Data Services

The survey was designed to identify in detail the types of services which institutions already had in place or had planned. It distinguished between advisory and technical research data services. Advisory services included those

such as data management planning support, data-related training, and web resource guides. Technical services included provision of a data catalogue, creation of transformation of metadata for data sets, and curation of active data. Fuller results for Australia and the UK, for which there was a larger number of responses are presented in Appendix F. Respondents were given a choice to rate their services at different levels from "basic," "well developed" to "extensive," and their priorities from "low," "mid," to "top" priority. The tables show the rank order of different services, based on aggregating all levels of service for the current provision and based on the stated top priority, to represent respondents' priorities. The Appendix also shows the full range of services covered by the questions.

In relation to most service areas, the vast majority of respondents (NZ 100%, Canada 86%, UK 86%, Ireland 86%, Australia 76%, the Netherlands 75%), stated that either there was no research data advisory service (RDS) currently in place or that it was a basic service, indicating the continuing immaturity of the field. Only in the Netherlands and the UK were there reports of any extensive advisory services and these were few (8% and 1%, respectively). Exploring the extent of the ten specific services designated as advisory, the most common current service (i.e., identified as either well-developed or extensive) across most regions was "*Maintaining a Web resource/guide of local advice and useful resources for RDM*" (Australia 50%, Germany 40%, the Netherlands 42%, UK 26%); slightly fewer respondents reported basic services in this area (Germany 40%, Canada
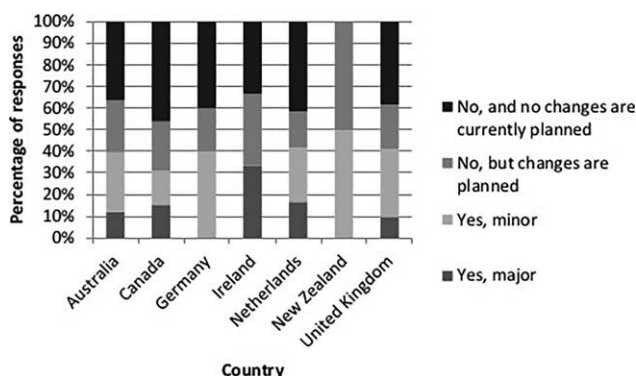

FIG. 4. Libraries and organizational restructuring in response to RDM requirements (*n* = 148) (see also Appendix D).

39%, Australia 38%, the Netherlands 33%, UK 33%). These types of advisory service are often light in terms of staff resources/effort and relatively easy to implement, drawing on existing RDM guidance materials, information and tools, but are effective in reaching a wide audience. It is easy to see why, in the early stages, this would be the first service to be developed.

"*Research data management training and/or data literacy instruction*" was currently positioned predominantly as a growing service (i.e., basic or well-developed service) in Australia 71%, UK 62%, Germany 60%, Canada 57%, and the Netherlands 42%. Because training is a well-established service category for academic libraries (in areas such as information literacy) and is accepted as a key component of existing staff liaison roles (Auckland, 2012), providing RDM training has the potential to integrate with existing training activities, and is a relatively low-risk/high-gain extension to the academic library service portfolio. Table 5 compares current findings with previous survey results for RDM training at all levels of service, showing growth in delivery of services over time.

The development of the other specified research data advisory services appeared to be patchy at best, with some pockets of well-developed or extensive services in, for example, the Netherlands: "*Promote awareness of reusable data sources such as data archives*" 50%, "*Data publication advisory services*" 42%, "*Data storage advisory services*" 33%; Australia: "*Access to tools to support* RDM" 32%. These services may be considered as more specialized, requiring greater expertise or knowledge of the field. Table 6 compares current findings with previous survey results for support for data management planning/RDM tools, again showing growth in delivery of services over time.

The importance of appropriate advocacy provided in parallel with service delivery, was highlighted by some respondents as a concern because of a "lack of interest from researchers" (Australia; SMT member). In some cases, lack of engagement from researchers was attributed to an anxiety with regard to data sharing and open data:

"*Some researchers may be anxious about making research data openly for sharing and reusing.*" (New Zealand; non-SMT member)

There was a conspicuous absence of an "*Advisory service on data analysis/mining/visualization*" reported by most respondents, with no service reported in Australia 79%, UK

TABLE 5. Libraries carrying out research data management training and/or data literacy instruction, comparison with previous studies.

	Australia			UK			North America		
RDM survey and year of publication	%	N	Total N	%	N	Total N	%	N	Total N
2012 (Tenopir et al.)							11	24	220
2013 (Corrall et al.)	26	9	35	14	11	77			
2014 (Cox & Pinfield)				36	29	81			
2014 (DCC)									
2016 (this study)	74	25	34	65	53	81			

TABLE 6. Libraries providing support for data management planning/RDM tools in place, comparison with previous studies.

RDM Survey Year	Australia			UK			North America		
	%	N	Total N	%	N	Total N	%	N	Total N
2012 (Tenopir et al.)							21	45	220
2013 (Corrall et al.)	21	7	33	9	7	80			
2014 (Cox & Pinfield)				31	25	81			
2014 (DCC)									
2016 (this study)	74	25	34	47	5	81			

TABLE 7. Libraries which run a data repository, comparison of previous studies.

RDM Survey Year	Australia			UK			North America		
	%	N	Total N	%	N	Total N	%	N	Total N
2012 (Tenopir et al.)							15	32	221
2013 (Corrall et al.)	54	19	35	38	30	80			
2014 (Cox & Pinfield)				24	19	81			
2015 (DCC)									
2016 (this study)	62	21	34	43	34	81			

74%, the Netherlands 67%, Germany 60%, Ireland 57%, and Canada 50%. There was also evidence of libraries retaining remote service delivery models which are not fully embedded in researcher workflows. The service option, "*Directly participate with researchers on a research project (as a team member)*" was not well-supported with 83% reporting no service in NZ, 75% the Netherlands, 71% Ireland, 62% UK, and 56% in Australia. This may relate to the scalability of such embedded activity, yet an aspiration to do this was apparent:

> "*…it really is about embedding good RDM practice among research active staff and students. If the library is not already embedded within the 'research space' then this is even more challenging, but also a fantastic opportunity.*" (UK; non-SMT member)

Moving from current RDM advisory and support services to future service priorities, the survey highlighted a suite of three research data service areas as top strategic priorities (>50% respondents) for Australia, the Netherlands, Ireland, and UK institutions: "*Advisory Services,*" "*Training,*" and "*RDM Web site development*" (all of the options are in Appendix F). Advisory services for "*Data Publication and Data Citation*" were a top priority in Ireland and NZ; "*Data Publication*" and "*Data Storage*" were a top priority in the Netherlands; "*Data Storage*" and "*Project Participation*" were top priority in Germany (the latter in contrast to all other countries). By ranking the advisory service top priority results, in the UK and Australia three services were selected by <25% respondents: "*Advisory service for data analysis/data visualization,*" "*Search/retrieval external data sources,*" and "*Project participation.*" In the Netherlands, the first two services were selected as a top priority by <25% respondents; however "*Project participation*" was considered a higher priority for future development (42% respondents).

Technical Research Data Services

Technical data services were investigated with 10 specific service offerings explored (the tables in Appendix F list the technical service offerings targeted in the survey). Overall, technical RDS were less developed than advisory RDS. The most common current technical data services (i.e.,

identified as either well-developed or extensive) across most regions were: "*Offer advice on copyright and/or intellectual and/or licensing property rights relating to data and data management*" (Germany 40%, Canada 36%, Australia 32%, Ireland 14%, UK 14%); and "*Run a data repository/archive/store*" (Ireland 29%, Australia 27%, Germany 20%, the Netherlands 17%, Canada 14%, UK 14%). Table 7 compares current findings with previous survey results for "*Run a data repository*" at all levels of service, showing continuing growth in delivery of this critical service over time.

In general, technical data services in academic libraries at the time of the survey might be best considered as basic services. "*Run a data repository*" was selected as "basic" by an average of 39% respondents and selected as "no service" by 43% across all regions. Only 7% considered this a well-developed service and 11% considered this an extensive service. "*Advisory services on curation of active data*" was considered a basic service by an average of 30% respondents (56% no service); similarly, "*Advisory services on technical aspects of long term data preservation*" was considered a basic service by an average of 24% respondents in all regions (62% no service), however there is considerable variability underlying these means. Six further technical services had "no service" as the predominant position of respondents; averages reported across all regions were "*Selecting, accessioning/deselecting data for deposit*" 72%, "*Provide a data catalogue*" 71%, "*Carrying out curation of active data*" 70%, "*Carrying out long term preservation of research data*" 70%, "*Preparing data for deposit*" 65% and "*Create/transform metadata for data*" 63%. Participants also highlighted some particular technical challenges:

> "*Storage Storage Storage…. How can we possibly convince researchers to manage their data when we have no space to store it?*" (Australia; SMT member)
> "*Understanding the diversity of types of data and the associated storage and metadata requirements.*" (UK; SMT member)

Data skills and capacity-building were also considered major challenges as was delivering RDM services at scale:

> "*Scale of the issue and capacity to respond on scale required an issue both for library and research office from*
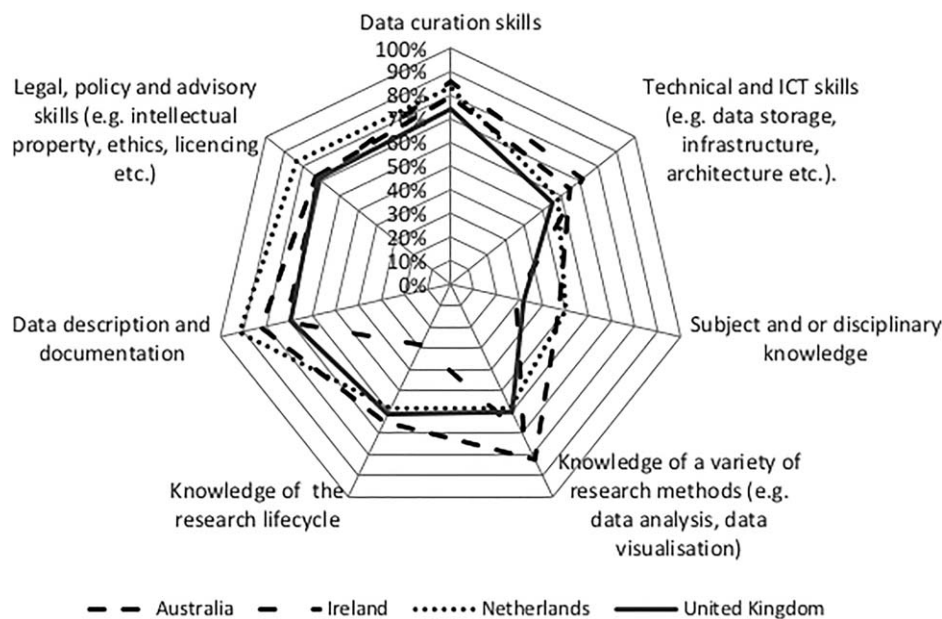
FIG. 5. Library RDM skill development needs, Australia, Ireland, the Netherlands, and UK (see also Appendix E for all responses).

technical and financial perspectives." (Ireland; SMT member)

Looking at future technical service priorities, the survey has highlighted two service areas as top strategic priorities (>50% respondents) for Australia, the Netherlands, and UK Libraries: "*Advice on copyright/IPR for data*" and "*Running a data repository*" (Appendix F). The latter was also a top priority for Germany and Ireland. Developing technical services for "*Metadata*" was a top priority in Australia; developing a "*Data catalogue*" was a top priority in the UK, "*Carry out long-term preservation*" was top priority in Germany, whereas "*Advisory service for curation of active data*" was a top priority in the Netherlands and Ireland. By ranking the advisory service top priority results, in the UK and Australia, one service was selected by <25% respondents: "*Curation of active data*"; in Australia, "*Advisory service on long-term preservation*" was also in this group. In the Netherlands, "*Carrying out long term preservation of research data*" was selected as a top priority by only <25% respondents.

Comparing the combined (advisory and technical) service results listing top priorities in the future for the UK and Australia (Appendix F) show some differences in the upper quartile. A group comprising storage, preservation and curation-related services are in the mid-range. Data analysis and project participation are uniformly considered to be low priority services for future development.

Staff Deployment and Skills

The survey findings suggest that responding institutions already saw themselves as having addressed staffing issues to some degree. The most common strategies they had used to "develop staff capacity and capability for research data

services" were to reassign existing staff (25%) or to recruit and reassign staff (25%). Other common responses were that they had already recruited new staff (12%) or planned to reassign existing staff (12%).

However, many respondents commented on the importance of RDM skills as a major concern:

"The major challenges include: skills development of library staff and, linked to this, building staff confidence in this territory." (UK; SMT member)

Hands-on experience with data was perceived to be essential in developing effective research data services and was identified as a key element of capacity-building:

"Being an efficient RDM practitioner is not something you can do just by re-skilling/upskilling - practical 'real life' experience is essential! Building RDM capability and capacity to deliver a relevant library-led RDM service is very time consuming." (UK; non-SMT member)

Finding new staff with the appropriate mix of data skills was a challenge:

"Small national pool of people with appropriate skills and knowledge." (UK; SMT member)

This survey revealed some similarities and differences in skills development requirements (Figure 5). An analysis of Australia, Ireland, the Netherlands, and the UK, revealed major identified skills gaps or weaknesses (high percentages of responses) associated with "*Data curation*," "*Legal, policy and advisory skills*," "*Data description and documentation*," and "*Research methods*." In contrast, there

TABLE 8. Approaches to staff RDM skills development in libraries.

	Australia (N = 33)		Canada (N = 9)		Germany (N = 4)		Ireland (N = 3)		Netherlands (N = 11)		NZ (N = 5)		UK (N = 56)	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
In-house staff workshops and/or presentations	25	75.8	7	77.8	2	50.0	2	66.7	5	45.5	2	40.0	38	67.9
Support for staff to take courses related to research data services	15	45.5	6	66.7	0	0.0	2	66.7	11	100.0	2	40.0	31	55.4
Support for staff to attend conferences or workshops on research data management	32	97.0	9	100.0	4	100.0	3	100.0	11	100.0	4	80.0	52	92.9
Collaboration with an academic program to develop professionals with skills related to research data services	5	15.2	5	55.6	1	25.0	1	33.3	2	18.2	1	20.0	5	8.9
Online tutorials	13	39.4	6	66.7	1	25.0	3	100.0	7	63.6	4	80.0	29	51.8
Webinars	28	84.9	8	88.9	0	0	2	66.7	6	54.6	5	100.0	28	50
One-day workshops	18	54.6	6	66.7	2	50.0	2	66.7	10	90.9	1	20.0	34	60.7
Multi-day workshops	13	39.4	3	33.3	2	50.0	2	66.7	8	72.7	1	20.0	14	25.0

were low percentages of respondents identifying "*Subject and disciplinary*" as a skills development need, although the Netherlands results suggested a stronger emphasis on the issue. This was unexpected given participants' recognition of the diversity of disciplinary data types, standards, formats and practices and comments in their answers to the question on challenges:

> "*Diversity of data management across disciplines. Solutions for one area do not necessarily work in another area.*" (Australia; SMT member)

Balancing these requirements with capabilities situated elsewhere in the institution was also a consideration:

> "*…library staff will not have the technical skills to advise on data storage, so will need to work in partnership with IT. Also, they are unlikely to have in depth discipline knowledge for every research project. The challenge will be to develop generic skills, while knowing where to refer to for technical or discipline-specific support.*" (UK; SMT member)

Although some existing roles (notably those of liaison librarians) were highlighted as being important in terms of acquiring new skills, in other cases it was recognized there was a need for new roles in the library with the relevant RDM skills.

Library staff can acquire new skills and knowledge in a variety of ways ranging from formal and structured learning methods such as those outlined earlier, to more informal and unstructured approaches such as shadowing and self-directed online learning. Table 8 presents an overview of skills development approaches taken by libraries in the different countries. Conferences and workshops are a popular choice across all countries; Webinars are more popular in

NZ, Australia, and Canada. Collaboration with academic programs shows the lowest take-up with an average of only 25% respondents highlighting this option; it is particularly low in the UK.

Discussion

This international survey has highlighted developments in the particular areas of RDM policy and governance, service development, and staff deployment and skills. These findings are further explored and interpreted here, with strands of the discussion brought together into a proposed RDM Maturity Model, which seeks to benchmark the current RDM landscape.

Policy and Governance

At the national level, Australia, the Netherlands, and the UK had a significant number of libraries and their institutions with a research data policy either in place or to be implemented within 12 months. In these countries, leadership from national policy makers and funders may reasonably be credited with a key role in pushing the agenda of RDM forward, including research funding agency requirements for example, EPSRC (UK). In addition, it is reasonable to assume that that the proactive advocacy for example, from the Australian National Data Service (ANDS) or the UK Digital Curation Centre, and support from ICT innovation organizations such as SURF (the Netherlands) or Jisc (UK), are likely to have had a significant impact encouraging adoption by institutions through providing guidance and creating a multilayered service environment.

At the institutional level, the survey respondents provided evidence that both the library and the research office have been effective in demonstrating leadership in coordinating

and promoting the development of RDM policies, with a mix of multistakeholder groups overseeing implementation and governance. Evidence of leadership by academic libraries, also shown by other surveys (Whyte, 2014b), is particularly visible in this study in the policy area. Such activity is arguably a critical part of the way libraries need to remodel services in an increasingly data intensive research environment (Lyon, 2012). Professional bodies such as SCONUL, RLUK, CAUL, and ARL, have an important role to play in highlighting changing leadership roles for Library Directors and CIOs, but the challenge is a complex one and touches on related issues, such as degree of library senior management influence within the institution and the perceived role of the library among researchers.

There was also evidence of library leadership in initiating research data audits or assessments. The varying national results for this area in this study may illustrate the different stages of maturity for universities and libraries, though it is likely that the promotion of audit tools developed by the DCC, have had a bearing on their prevalence in the UK. Data audit was not an area covered by previous surveys, so it is difficult to make temporal comparisons; however, the richness of published RDM surveys and audits, highlights the value of the exercise for institutions and libraries (Hodson & Molloy, 2013). RDM survey findings have been used to inform policy and roadmap development (Freiman, Ward, Jones, Molloy, & Snow, 2010) and service prioritization (Knight, 2013), often as a preliminary step before establishing a Research Data Service (Whyte, 2014a).

In the context of this dynamic approach to adoption of new RDM activities (including policy formulation), the more cautious approach to adapting organizational structures to optimize support for RDM was striking. This may be a direct result of limited funds to implement new services, prior structural changes relating to other drivers, for example, open access, a desire for incremental change rather than any radical re-engineering or an intention to minimize service (and staff) disruption, or it may reflect a risk-averse culture among academic libraries (or a combination of these). An alternative interpretation is that there have been broader changes in library research support, but not directly or simply tied to RDM (Corrall, 2014).

Advisory and Technical Service Development

Collaboration with a variety of internal and external service partners was a feature of the RDM landscape in organizations in all sectors. A mixed picture was revealed by this survey. Intrainstitutional collaboration appeared to be moving forward (adding scale and complexity to the provision), whereas there was less evidence of effective extrainstitutional partnerships. Most libraries in Australia, Canada, Germany, and the Netherlands reported they did have external partners, whereas the respondents from the other countries said they did not (Figure 3). A wide range of external collaborators were mentioned, including key data infrastructure support organizations, such as the Australian

National Data Service and national data support services such as the Data Archiving and Networked Services (DANS) in the Netherlands, or commercial partners like Arkivum. A number of intrainstitutional collaborations were also apparent, but the development of shared services (with some notable exceptions) appears to have been a low priority for libraries at this time, possibly illustrating the relative immaturity of RDM shared services. Tenopir et al. (2012) found similarly low evidence of library collaboration with other institutions regarding RDS in North America. Although there is evidence elsewhere of greater collaboration being considered (Whyte, 2014b), it is perhaps surprising not to see more evidence of this or of collaboration with external bodies in some countries, when publishers, professional societies, and data centers are such critical players in the research data arena.

Results presented here emphasized the research data service resourcing concerns of many library managers, and shared services may provide opportunities for implementing cost-effective infrastructure solutions. At the time the survey was conducted, during 2014 and 2015, there started to be a greater focus on the need to understand the full costs of sustainable data curation. The European Union funded Collaboration to Clarify the Cost of Curation Project (4C) has gone some way to build on prior costing tools and methodologies such as Keeping Research Data Safe (KRDS) and to synthesize information in this area. The ANDS Report (Houghton & Gruen, 2014) has sought to quantify the economic benefits of open data curation. However, there is scope for further focused case studies which help libraries (and their institutions) to plan collaboratively for data infrastructure and sustainable RDS.

Advocacy was a key component of the RDS portfolio. Academic libraries can contribute to culture change in relation to RDM by proactively promoting its direct and indirect benefits (Beagrie, 2011). However, the current absence of a clear value-chain link between good RDM practice by researchers, and incentives and reward mechanisms (such as assessment, credit, and tenure decisions), does not help to frame RDM activity as a researcher imperative. Rather, RDM is often viewed as something of a chore bringing little value to the data producer and most benefits to the consumer (Michener, Brunt, Helly, Kirchner, & Stafford, 1997). Although proactive advocacy can help to mitigate this position, funder policy changes together with recognition in institutional career and promotion decision making, are likely to have most impact in embedding good RDM practice.

As far as service provision was concerned, academic libraries appeared to be primarily engaging with RDM through provision of advisory services and they have yet to offer robust technical data infrastructure to support research activities. The six technical data service gaps identified in this survey, where the majority of respondents reported having "no service" (*selecting, accessioning/deselecting data for deposit*; *providing a data catalogue, carrying out curation of active data*, c*arrying out long term preservation of research data, preparing data for deposit,*
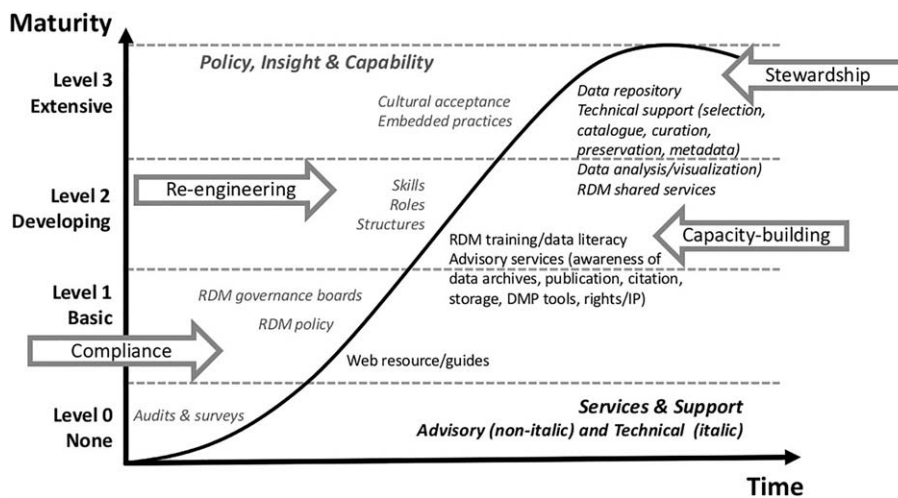
FIG. 6.   RDM maturity model showing the evolving maturity of the landscape of research data management and responses to key drivers influencing RDM development in academic libraries.

and *create/transform metadata for data*) all involve "hands-on" data work. Many are particularly associated with complex ingest and dissemination stages, ongoing maintenance and the long-term sustainability of a trusted data repository, which may often be regarded as IT-led, rather than library, services. In some cases, the limited library implementation may be partly because of services implemented at the institutional or national level, such as Research Data Australia (developed and supported by ANDS), which provides descriptions of, and links to, data from a number of institutional and organizational partners.

In addition to the aforementioned technical data services having a high number of reported "no service" responses some advisory services were also effectively absent from academic libraries, for example, "*Data analysis/mining/visualization*" advice and guidance, and "*Project participation.*" There may be many possible reasons for this finding, such as that the data analysis/visualization service is best supplied by another institutional unit, or there is a lack of relevant skills. Although it may be argued that such activities are potential areas for library-provided service development, they are ones where specialized expertise is required and, therefore, might be seen as better provided in academic schools rather than central services. The requirement that these service areas involve moving beyond traditional liaison-type roles to fully embedded or immersive roles, although discussed in the literature (Lyon, 2016; Lyon & Brenner, 2015; Martin, 2013; Mayernik et al., 2015), is undoubtedly challenging.

Staff Deployment and Skills

The provision of an extensive suite of research data services associated with specific data science roles (such as data librarian, or data steward/curator) requires a wide range of skills, competencies, knowledge, and experience reported in

the responses to the survey and in the literature (Kennan, Corrall, & Afzal, 2014; Lyon et al., 2016). This capacity can be acquired or built up in various ways: by hiring new staff members, through in-service training and education of existing staff, or by outsourcing tasks to other internal units or external organizations. This study provides evidence that all of these approaches were being used, including recruiting staff from outside of traditional candidate pools. However, capacity-building takes time to achieve, whether it is through recruitment or retraining and additional education for current staff using available materials (Cox et al., 2012).

Reported responses of the mismatch of professional development and training demand and supply suggests that although there continued to be demand, academic LIS programs are not currently positioned optimally to capture the clear market need for the RDM education and retraining revealed in this survey. Schools of Information Science (iSchools) and Library Schools have an important role in this context; they provide graduate-level programs for new-entrants into the field and they also offer Advanced Certificate level courses for mid-career staff, who want to extend their skills and knowledge to encompass research data services concepts and practices. The range of skills and knowledge perceived to be required by practicing information professionals has been explored in a number of initiatives such as DigCurv ("DigCurv," n.d.). Development of short courses suited to work-based learning or day release from academic libraries, may be an appropriate strategy for iSchools to help to fill the data services talent gap.

RDM Maturity Model

The survey revealed a complex international landscape of academic library re-engineering and repositioning support for data-centric research environments. Although there were indications of significant leadership activity from the library

community, there was also evidence of a less-developed service portfolio with much work still to be implemented. The scale and complexity of research data management support requirements mean that a wide range of services from advocacy to technical support, are needed at different stages of the research data lifecycle, and the skills and capabilities necessary are not consistently in place.

The range of RDM activities explored in this survey can be positioned within a simple "landscape maturity model" which reflects current and planned research data services and practice in academic libraries. This survey has demonstrated that different activities and services are at varying stages of maturity. The maturity model in Figure 6 shows the likely emergence of a mature landscape of research data services and activities over time, recognizing that there are currently very few "extensive" research data services shown by the survey findings. Most services were designated by respondents as either not present or immature and may only be expected to reach maturity sometime in the future, indicating an overall immature RDM landscape at the time of this survey. In contrast, the model shows that certain strategic/generic RDM activities have been designated by library respondents in this survey as reasonably mature now. We can, therefore, propose that a fully mature RDM landscape will only be achieved when a more comprehensive portfolio of research data services are fully operational. Less specialized advisory services and activities which may be seen as extensions of existing library efforts (e.g., training for data literacy, promoting data archives, and rights or IP guidance) may be likely to reach maturity more rapidly than the wholly new services (such as data analysis and visualization). However, a substantive group of technical data services (e.g., active data curation), currently not present in many academic libraries, are likely to take some time into the future to become established. In addition, the concept of librarians participating in research project teams (in the "immersive" service delivery model proposed by Lyon, 2016), is likely to take some time to be fully realized and can also be seen as a feature of a mature research data management landscape at a future point in time.

The model characterizes library responses to major drivers (the arrows in Figure 6), initially focused on "compliance," in response, for instance, to funder mandates (e.g., EPSRC in the UK have already been highly influential in the creation of institutional research data policy). The research community and libraries in particular also need to build "capacity" in areas such as developing RDM training, especially as research support requirements grow and open science practices develop. With increasing needs for long-term sustainability, there may be a growing requirement for the "re-engineering" of organizational structures and business processes (Lyon, 2016). Libraries, which have a long-held trusted "stewardship" role for manuscripts, books, journals, and other publications, may then in a similar manner, position new data repositories to complement established subject-based data archives. Academic libraries may also provide expert curatorial support and preservation guidance within the institution, which along with the repository would help to ensure long-term access to the archived research data which acts as critical evidence to validate the claims and assertions articulated within the scholarly record across all disciplines.

Future research could test the model, controlling for shared research data services offered across geographical regions or within institutions but beyond the library, for new research data services which become more extensive in scale, and are more embedded in research workflows. The balance between nationally provided and institutional-provided support could have a very great impact on what constitutes "maturity" for institutions. In addition, it seems likely that smaller, less-research-intensive institutions may have more limited or more specialist requirements and would not aim to achieve the same levels of service development. Thus "landscape maturity" for them may look different from the landscape maturity appropriate for research intensive institutions. Nevertheless, the concept of "maturity" still has value in helping to capture broad movements in a sector as a whole, particularly in order to facilitate institutional benchmarking and international comparisons.

Conclusion

This study has highlighted significant management concerns and a range of operational challenges for academic libraries in the research data management space. There are major opportunities for libraries to engage more deeply with RDM practice in new ways and to extend their support infrastructure to meet the complex demands of an interdisciplinary and multiscale data-intensive research environment. The limitations to this study (for example, the small sample size from some countries which presented obstacles to direct comparisons in certain areas) might be addressed by further research, by widening national coverage, as well as tracking changes over time. Nevertheless, the international comparisons which the data presented in this study have enabled, and the longitudinal comparisons of RDM development between this and previous studies highlighted, have produced a clear delineation of key RDM developments and issues. Evidence has been provided of the maturity of services increasing, particularly in the advisory and support (as opposed to technical) services; and it may reasonably be expected that the maturity of RDM activities and services in general will continue to increase. Also, an understanding of what constitutes maturity itself, is likely to evolve. In particular, the dimensions of policy and governance, service development, and staff deployment and skills have been identified as major foci for RDM development in many countries and will need to be monitored on an ongoing basis, to assess their contributions to increasing maturity.

permission, informed the development of some of our survey questions.

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Appendix A: RDM Policy Development by Country (Data Supporting Figure 1)

	Have a policy now		Will have a policy within the next 12months		Do not have a policy and are not planning one		Don't know	
	N	%	N	%	N	%	N	%
Australia (N = 34)	19	55.9	13	38.2	2	5.9	0	0.0
Canada (N = 15)	2	13.3	4	26.7	7	46.7	2	13.3
Germany (N = 7)	4	57.1	3	42.9	0	0.0	0	0.0
Ireland (N = 7)	0	0.0	5	71.4	1	14.3	1	14.3
Netherlands (N = 12)	3	25.0	9	75.0	0	0.0	0	0.0
New Zealand (N = 7)	0	0.0	5	71.4	2	28.5	0	0.0
United Kingdom (N = 85)	36	42.4	37	43.5	11	12.9	1	1.2
Total Respondents (N = 167)	64	38.3	76	45.5	23	13.8	4	2.4

Appendix B: Have Conducted an Institutional Audit, Survey or Evaluation of Research Data (Data Supporting Figure 2)

	Yes (library as lead)		Yes (library participant)		Yes (library not participant)		Yes - total		No (planned)		No (not planned)	
	N	%	N	%	N	%	N	%	N	%	N	%
Australia (N = 34)	5	14.7	3	8.8	8	23.5	16	47.1	7	20.6	11	32.4
Canada (N = 15)	0	0.0	0	0.0	0	0.0	0	0.0	6	40.0	9	60.0
Germany (N = 6)	2	33.3	2	33.3	0	0.0	4	66.7	0	0.0	2	33.3
Ireland (N = 6)	1	16.7	0	0.0	0	0.0	1	16.7	3	50.0	2	33.3
Netherlands (N = 12)	2	16.7	0	0.0	1	8.3	3	25.0	2	16.6	7	58.3
New Zealand (N = 7)	0	0.0	1	14.3	0	0.0	1	14.3	3	42.9	3	42.9
United Kingdom (N = 84)	17	20.2	20	23.8	6	7.1	43	51.2	21	25.0	20	23.8
Total Respondents (N = 164)	27	16.5	26	15.9	15	9.1	68	41.4	42	25.6	54	32.9

Appendix C: Library partnerships for research data services: with external organizations (e.g., data centers) or institutions (e.g., other universities or university libraries) (Data supporting Figure 3)

	Collaborating		Planned		Not planned	
	N	%	N	%	N	%
Australia (N = 34)	26	76.5	3	8.8	5	14.7
Canada (N = 15)	10	66.7	0	0.0	5	33.3
Germany (N = 5)	3	60.0	1	20.0	1	20.0
Ireland (N = 7)	1	14.3	1	14.3	5	71.4
Netherlands (N = 11)	9	81.8	2	18.2	0	0.0
New Zealand (N = 7)	1	14.3	1	14.3	5	71.7
United Kingdom (N = 83)	18	21.7	24	28.9	41	49.4
Total N = 162	68	42.0	32	19.8	62	38.3

Appendix D: Libraries and organizational restructuring in response to rdm requirements (Data supporting Figure 4)

	Yes, major		Yes, minor		No, but changes are planned		No, and no changes are currently planned	
	N	%	N	%	N	%	N	%
Australia (N = 33)	4	12.1	9	27.3	8	24.2	12	36.4
Canada (N = 13)	2	15.4	2	15.4	3	23.1	6	46.2
Germany (N = 5)	0	0.0	2	40.0	1	20.0	2	40.0
Ireland (N = 6)	2	33.3	0	0.0	2	33.3	2	33.3
Netherlands (N = 12)	2	16.7	3	25.0	2	16.7	5	41.7
New Zealand (N = 6)	0	0.0	3	50.0	3	50.0	0	0.0
United Kingdom (N = 73)	7	9.6	23	31.5	15	20.5	28	38.3
Total (N = 148)	17	11.5	42	28.4	34	23.0	55	37.2

Appendix E: Library RDM skill development needs (Data supporting Figure 5)

Skills needed	Data curation skills		Technical and ICT skills (e.g., data storage, infrastructure, architecture etc.)		Subject and or disciplinary knowledge		Knowledge of a variety of research methods (e.g., data analysis, data visualisation)		Knowledge of the research lifecycle		Data description and documentation		Legal, policy and advisory skills (e.g., intellectual property, ethics, licencing etc.)	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Australia (N = 33)	27	81.8	22	66.7	16	48.5	28	84.8	22	66.7	28	84.8	27	81.8
Canada (N = 13)	10	76.9	12	92.3	5	38.5	11	84.6	7	53.8	11	84.6	7	53.8
Germany (N = 5)	4	80.0	4	80.0	2	40.0	4	80.0	4	80.0	4	80.0	5	100.0
Ireland (N = 7)	6	85.7	5	71.4	2	28.6	5	71.4	2	28.6	5	71.4	5	71.4
Netherlands (N = 12)	10	83.3	7	58.3	6	50.0	7	58.3	7	58.3	11	91.7	10	83.3
New Zealand (N = 6)	5	83.3	5	83.3	4	66.7	4	66.7	4	66.7	5	83.5	6	100.0
United Kingdom (N = 72)	63	87.5	47	65.3	27	37.5	51	70.8	52	72.2	59	81.9	61	84.7
Total (N = 148)	125	84.5	102	68.9	80	54.1	110	74.3	109	73.6	123	83.1	121	81.7

Appendix F: Current services and future priorities for RDM in libraries, Australia and the UK compared ("Technical" services shaded)

Australia

Currently any level of service		Future top priority	
Maintaining a web resource/guide of local advice and useful resources for RDM	30/34 (88%)	Run a data repository/archive/store	21/34 (62%)
Offer a research data management advisory service to researchers	29/34 (85%)	Offer a research data management advisory service to researchers	21/34 (62%)
Offer data citation advisory services	27/34 (79%)	Offer a service creating or transforming metadata for data or data sets	20/34 (59%)
Offer advice on copyright and/or intellectual and/or licensing property rights relating to data and data management	27/34 (79%)	Offer advice on copyright and/or intellectual and/or licensing property rights relating to data and data management	20/34 (59%)
Offer research data management training and/or data literacy instruction	25/34 (74%)	Offer research data management training and/or data literacy instruction	20/34 (59%)
Provide access to tools to support research data management	25/34 (74%)	Maintaining a web resource/guide of local advice and useful resources for RDM	20/34 (59%)
Offer data publication advisory services	25/34 (74%)	Provide a data catalogue including your institution's research data	16/33 (48%)
Promote awareness of reusable data sources, such as data archives	24/34 (71%)	Offer data citation advisory services	16/34 (47%)
Offer data storage advisory services	22/34 (65%)	Offer data publication advisory services	13/34 (38%)
Provide support for search and retrieval of external data sources	22/34 (65%)	Provide access to tools to support research data management	13/34 (38%)
Offer a service creating or transforming metadata for data or data sets	22/34 (65%)	Provide advisory services on the curation of active data	12/33 (36%)
Run a data repository/archive/store	21/34 (62%)	Selecting, accessioning and/or deselecting and de-accessioning data/data sets for deposit in a repository	12/34 (35%)
Provide a data catalogue including your institution's research data	18/34 (53%)	Preparing data/data sets for deposit in a repository	12/34 (35%)
Selecting, accessioning and/or deselecting and de-accessioning data/data sets for deposit in a repository	17/33 (52%)	Offer data storage advisory services	11/33 (33%)
Provide advisory services on the curation of active data	17/34 (50%)	Promote awareness of reusable data sources, such as data archives	10/34 (29%)
Provide advisory services on the technical aspects of long term data preservation	15/34 (44%)	Carrying out long term preservation of research data	9/34 (26%)
Preparing data/data sets for deposit in a repository	15/34 (44%)	Carrying out the curation of active data	8/33 (24%)
Directly participate with researchers on a research project (as a team member)	15/34 (44%)	Provide advisory services on the technical aspects of long term data preservation	8/33 (24%)
Carrying out long term preservation of research data	11/34 (33%)	Directly participate with researchers on a research project (as a team member)	7/34 (21%)
Carrying out the curation of active data	11/33) (32%)	Provide support for search and retrieval of external data sources	6/34 (18%)
Offer an advisory service on data analysis/mining/visualization	6/34 (18%)	Offer an advisory service on data analysis/mining/visualization	4/34 (12%)