Caring for Indigenous Data to Evaluate the Benefits of Indigenous Environmental Programs

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Abstract

Advances in open data, big data and data linkage allow us to analyse more data and on a larger scale than ever before. However, this brings with it the challenge of ensuring that Indigenous data sets are used in a way that protects Indigenous rights to that data and maximises benefits for Indigenous peoples. The CARE principles for Indigenous data governance— Collective Benefit, Authority to Control, Responsibility and Ethics—were developed to protect Indigenous data sovereignty, but there are few examples of how to translate these principles into practice. In this paper, we show how these CARE principles can be applied to data collection, integration, analysis and translation practices. Our case study is a project that used data reported by Indigenous ranger groups to capture the multiple benefits of Indigenous land and water management activities. Through this case study, we offer a framework for the design and use of CARE-informed data practices, which can be embedded into project design to enable the ethical and responsible use of Indigenous data to improve Indigenous policies and services. Such practices are critical in the context of ongoing demand for Indigenous data for bureaucratic purposes, and Indigenous interest in using that data to influence management and policy decisions affecting their estates and resources.

Keywords Indigenous data governance · Environmental management · Indigenous knowledge · Indigenous policy · Big data

Introduction

Technological and policy developments have enabled data to be amalgamated and used in a range of new ways to inform environmental science and decision-making (Chan et al. 2011). This includes national and global data sets designed to enable regular and timely assessment of bio-cultural diversity and ecosystem services (e.g. https://ipbes. net/global-assessment-report-biodiversity-ecosystem-services). The integration and use of big data has also helped to illuminate the importance of Indigenous peoples, lands and stewardship to biodiversity (Garnett et al. 2018; Leiper et al. 2018; Pert et al. 2020), and the importance of biodiversity to Indigenous peoples' cultural land and water management activities and enterprises (Robinson et al. 2016). Yet there is ongoing tension around how technocratic data systems classify, co-opt and capture certain aspects of Indigenous knowledge desired by the state, and the subsequent disempowerment this can create for local Indigenous communities and their agendas for their lands and their lives (Nadasdy 2004). Finding ways to protect Indigenous peoples' right to govern the use and interpretation of their own data is critical to addressing this tension (Robinson et al. 2016; Johnson et al. 2016; Austin et al. 2019).

In this paper, we reflect on research done in Australia to consider how the CARE principles for Indigenous data governance—Collective Benefit, Authority to Control, Responsibility and Ethics (see Fig. 1)—can enable the ethical and responsible use of Indigenous data to improve policies and services that support Indigenous communities. The research was conducted following calls from Indigenous groups across Australia to support partnerships that deliver shared priority outcomes for Indigenous Cultural

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Fig. 1 CARE Principles for Indigenous Data Governance need to inform each step of data collection, integration, analysis and translation practice. Source: GIDA 2019
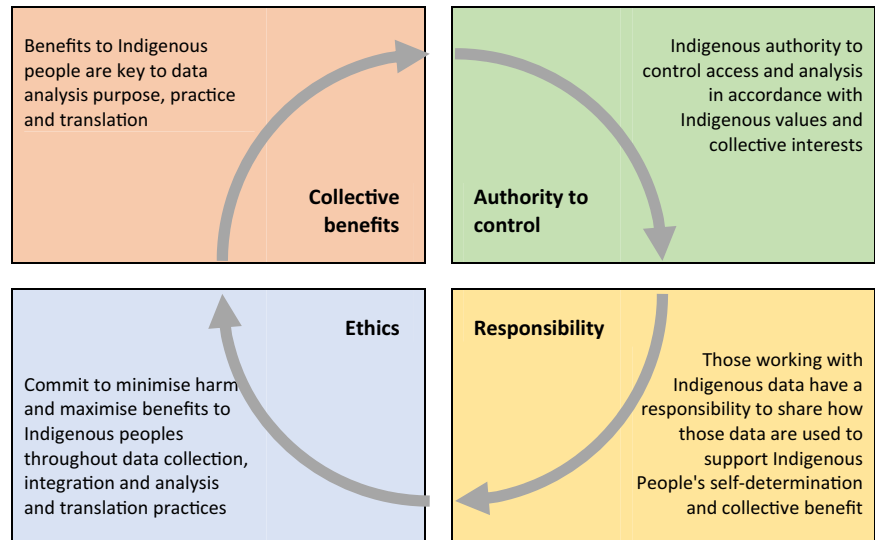
and Natural Resource Management (ICNRM) activities, and for data to be made more useful for Indigenous land and sea management and decision-making (Australian Government 2017).

The CARE principles seek to create value for Indigenous peoples from data about them, in ways that are grounded in Indigenous world views and realise opportunities within the knowledge economy. These principles have been endorsed by the Global Indigenous Data Alliance (GIDA), which is the international peak body for Indigenous data sovereignty (IDS) as part of a growing effort by Indigenous groups to assert greater control over the application and use of Indigenous data and Indigenous Knowledge for collective benefit.

We present a case study to show how these CARE principles can be embedded into data collection, integration, analysis and translation practices. Our case study focuses on data used to evaluate Indigenous Cultural and Natural Resource Management (ICNRM) activities, which Indigenous local ranger groups submit to government programs for the purpose of evaluating the outcomes of their activities for funding bodies. ICNRM activities have grown in number across the globe as projects receive co-investment from Indigenous communities, government agencies and non-governmental organisations (Austin et al. 2018; Brondizio and Le Tourneau 2016; Pert et al. 2020). Indigenous groups managing ICNRM activities are increasingly asked to collect data to report on the benefits of these activities, which extend beyond environmental outcomes to include social, cultural and economic benefits for Indigenous rangers and communities (Barber and Jackson 2017; Jarvis et al. 2018; Rainie et al. 2017).

It is vital that Indigenous people have a say in how ICNRM data is collected, analysed and translated to assess if desired outcomes are being achieved. While Indigenous-specific approaches to evaluation are becoming more widely

recognised and valued, best-practice guidelines are largely focused on local, case study-specific data collection methods and analysis (e.g. Robinson et al. 2016; Wiseman and Bardsley 2016). Finding ways to scale up evaluations of ICNRM outcomes to inform decisions at the policy and program level requires consideration of 'two-way' evaluation methods that value Indigenous knowledges and desired outcomes (Austin et al. 2018; Corrigan et al. 2018). This paper adds to this growing body of work by focusing on the 'care' of large data sets and secondary data that can be used to evaluate programs supporting ICNRM activities.

Using Big Data to Evaluate the Benefits of Indigenous Environmental Programs

While there is growing interest in how big data sets can inform national and international biodiversity assessments and decisions, there is also growing acknowledgement of the importance of local and Indigenous peoples and knowledge in bio-cultural diversity and critical ecosystem services (Brondizio et al. 2016; Díaz et al. 2015; Pert et al. 2015). This raises important questions about Indigenous data governance, including questions about the ethical dimensions of analysing ICNRM data that has been re-purposed and re-scaled to evaluate programs supporting ICNRM activities.

Sustainability science has helped to address some of the challenges that arise when working with multiple knowledge systems that reflect different ethics, world views, principles and truths (Robinson and Wallington 2012; Whyte et al. 2016). Critical to this effort is what Johnson et al. (2016) describe as weaving—that is, collaborations that respect the integrity of each knowledge system for a particular purpose, in this case evaluations of the benefits of

ICNRM programs (cf. Tengö et al. 2017). Weaving emphasises the interactive and dynamic aspects of knowledge co-production, sharing and translation, and the work involved to ensure that these relationships are underpinned by mutual respect that allows for differences in world views (Verran and Christie 2007).

Weaving indigenous knowledge and western science together needs to recognise that intellectual and cultural rights are attached to indigenous knowledge, and that this knowledge is connected to kin relationships. Together, these shape decisions about how, when and under what conditions knowledge can be shared (Johnson et al. 2016). It is crucial that Indigenous knowledge is a foundation of this knowledge weaving effort. Otherwise data collection and knowledge sharing and co-production practices can be influenced by what Bourdieu (1977) describes as habitus—a set of social, cultural and political 'spaces' individuals occupy and translate into capital, which Walter (2010) argues includes race—to describe the skills and dispositions that affect the (positive and negative) attributes certain world views place on a given entity, and the sociocultural and political processes by which certain views are empowered, actioned and reproduced. This can underpin environmental program dispositions around how western science and Indigenous knowledge is perceived and plays a central role in power relations surrounding if and why science and Indigenous knowledge is used in environmental management decision making and evaluation—or not (Kerins 2012; Devon and Hoover 2019).

The habitus surrounding collaborations that create and translate ICNRM data is important for several reasons. First, research institutions' perspectives and practices make it possible to analyse Indigenous survey or census data (usually collected by non-Indigenous people about Indigenous people) without necessarily requiring an ethics review or the inclusion of Indigenous perspectives. For example, Australia's national ethics guidelines allow institutions to decide whether research using de-identified human data requires an ethics review (NHMRC 2007). This dynamic also affects power interactions between western science and Indigenous Knowledge in terms of what knowledge is deemed credible by the state and how multiple sources of evidence is used (or not) to evaluate benefits from ICNRM activities (Barber and Jackson 2017; TallBear 2014).

Second, at the time of conduct of this research, ethics guidelines published specifically for research with Aboriginal and Torres Strait Islander people and communities (AIATSIS 2020) did not sufficiently or directly address the ethical issues that arise in research using large data sets or secondary data. The Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) has since updated their ethics guidance (AIATSIS 2020) to now include recognition of some of the specific ethical considerations relevant to the re-

use of existing data about Aboriginal and Torres Strait Islander peoples. This responds to calls from Indigenous ethics scholars who highlight the need for research to no longer be about Indigenous people without informed consent but instead be grounded in Indigenous rights and benefit sharing (Walter et al. 2020; Kukutai and Taylor 2016). Most of the focus of this research ethics reform and data sovereignty discussion draws on lessons learned from research with local community-based studies (e.g. Johnson et al. 2016; Todd 2014). These insights are relevant to big data analysis. Data analysis conducted without appropriate Indigenous input or without ethics-informed research design and governance has significant potential to do direct or inadvertent harm to the people and communities to which the data belong, and/or the wider Indigenous population, through misrepresentation and decontextualised analysis (Davis 2016; Kwaymullina 2016). Walter and Suina (2018, p. 233) argue that the result is "an absence of an Indigenous presence from Indigenous data production [which] has resulted in an overwhelming statistical narrative of deficit for dispossessed Indigenous peoples around the globe".

Indigenous groups are cautious about the collection and use of data to describe their local stewardship efforts, particularly when the data is collected for government program objectives that impose notions of 'useful' indigenous–environment interactions for sustainability and ignore benefits that are supported by indigenous communities (Kukutai and Taylor 2016; Kerins 2012; Povinelli 1992). The concept of 'useful' human–environment interactions has a long and problematic history for many Indigenous peoples, whose hunter–gatherer relationships with the environment were used by colonisers to designate Indigenous people as 'backward' and justify acquisition of sovereignty over Indigenous territory (Robinson 2016). Legacies of this world view persist in ICNRM partnerships. In addition, these legacies have been imposed on evaluations of the efficacy and benefits of ICNRM work, and are reflected in the insufficient resources and support that are available for the stewardship, knowledge-sharing and cultural practices that Indigenous people view as important to care for their country (Fache 2014; Austin et al. 2019).

Weaving also requires the mobilisation of multiple knowledges, values and governance systems that can contribute to collaboratively evaluating and designing ways to achieve sustainability (Sterling et al. 2017). The concept of reconciliation is a helpful foundation for knowledge-weaving work and the tasks of mobilising, translating, negotiating, synthesising and applying multiple knowledges for decision-making (Tengö et al. 2017). Feir and Hancock (2016) emphasise that reconciliation through research is based on an awareness of the past, acknowledgement of the harm that past research agendas and practices have inflicted on Indigenous people, and the need for concrete actions that

ensure research—such as the compilation and analysis of Indigenous data sets—can benefit and be used by Indigenous communities and organisations. The need to care for and reconcile Indigenous data will undoubtedly continue to grow, given the significant changes anticipated for ICNRM groups and activities following the emergence of new digital technologies and capabilities, including real-time monitoring through sensors, big data and machine learning.

Issues around Indigenous data sovereignty and concepts of habitus, ethics and power opens up important questions about the capability of efforts to curate data systems associated with Indigenous ranger work to accommodate the knowledge frameworks and assumptions of ICNRM impacts that underpin cross-cultural collaborations between Indigenous and non-Indigenous environmental management partners (Duncan et al. 2018; Robinson and Wallington 2012). Frameworks have been developed to weave together a diversity of knowledge systems to inform biodiversity assessments and decision-making (e.g. Tengö et al. 2017; Austin et al. 2019). We build on these frameworks but note a growing focus on how data created from these knowledge collaborations can ensure benefits for and minimise harm to Indigenous communities (Lovett et al. 2019; Kukutai and Walter 2016).

Research around the care of Indigenous data has focused attention on the information supply chains between data supplier and end user, the social architecture surrounding data platforms that can empower Indigenous people and their information needs, and the right to create value from Indigenous data in ways that are grounded in Indigenous world views and realise opportunities in the knowledge economy (Pulsifer et al. 2011; Scassa and Taylor 2017). A key challenge has been to ensure that Indigenous data is used in a way that protects Indigenous rights to that data and maximises benefits for Indigenous peoples (Fogarty et al. 2018).

The Global Indigenous Data Alliance created the CARE principles for Indigenous data governance to protect Indigenous data sovereignty, and to reflect the crucial role of data in advancing Indigenous innovation and self-determination (GIDA 2020). Yet there are few examples of how to translate these CARE principles into practice. This becomes particularly important when data is used to evaluate the merit or worth of an Indigenous policy or program, where it is critical to incorporate Indigenous peoples' perspectives, priorities and knowledges into the metrics for evaluation (Australian Productivity Commission 2020; Te Arawhiti Office for Māori Crown Relations 2019).

Research Context and Approach

This 12-month project was funded by a collaboration with Commonwealth Government agencies in Australia who are custodians of data related to natural resources and the environment, including data offered by ICNRM groups. In the Australian context, ICNRM refers to activities that receive Aboriginal and Torres Strait Islander community and Commonwealth co-investment for a range of environmental and cultural stewardship and management activities (Austin et al. 2018). Government programs that support ICNRM efforts often employ Indigenous rangers and can also engage Indigenous Elders and communities in knowledge-sharing and on-ground management activities (Australian Government 2017).

A key priority for this project was to discover and synthesise new evidence in existing government program data sets in order to enhance reporting of ICNRM benefits and investigate how the research process can care for Indigenous data in an ethical way. A Project Steering Committee was established to enable whole-of-government input from key federal agencies that fund Indigenous environmental programs, as well as agencies that hold data on Indigenous business operations, education and training. Indigenous stakeholder input was facilitated through a networked approach with key national bodies, and project briefs and updates were provided to key Advisory Committees within each agency specifically established to facilitate Indigenous input (i.e. the Environmental Protection and Biodiversity Indigenous Advisory Committee, Commonwealth Department Indigenous Staff Network members, the Indigenous Land and Sea Management Board and the Northern Australia Biosecurity Framework Reference Group).

To start the project the team got access to the DataLab and was asked by the Project Steering Committee and overall PEAN Advisory Committee to focus its efforts on the cultural and economic benefits of ICNRM activities. To assist with this work, the team was given access to large data sets that contained information on environmental management and ICNRM activities and outcomes. This included data from the national Monitoring, Evaluation, Reporting and Improvement Tool (MERIT; Australian Government Productivity Commission 2020), which aggregates all environmental project activities supported through various programs. Although each program has different goals and approaches, they are all designed to enhance biodiversity, build greater environmental resilience, and develop community, Indigenous ranger, capacity to participate in sustainable development programs across the Australian landscape. The team also accessed a Commonwealth Government database that records Indigenous ranger activities in Indigenous Protected Areas (IPAs), which are part of Australia's natural reserve system.

The team accessed publicly available data on Indigenous corporations (https://www.oric.gov.au/) and a similar set of data on Indigenous businesses held by Supply Nation (https://supplynation.org.au/). De-identified information on Indigenous business annual turnover and other factors was

obtained from the Business Longitudinal Analysis Data Environment (BLADE) database by list-matching with the Office of the Registrar of Indigenous Corporations (ORIC) and Supply Nation lists. The data was accessed on a highly restricted basis, with strong privacy controls in place, within the Australian Bureau of Statistics (ABS) secure DataLab environment (https://pmc.gov.au/public-data/data-integration-partnership-australia). Team members underwent DataLab training so that relevant social and economic data was appropriately and ethically analysed, shared and published in accordance with the strict privacy guidelines and requirements of the ABS under the Census and Statistics Act 1905.

In total, the team examined more than 22,000 site records, representing more than 5300 ICNRM projects undertaken across Australia between 2011 and 2019 and reported in the IPA and MERIT databases (Watson et al. 2020). We used the CARE principles to guide our data collection and analysis process, ensuring that Indigenous views and aspirations informed our research questions and data outcomes. Specifically, the principles guided how we (a) co-designed the data project; (b) collected, analysed, repurposed and integrated data; and (c) determined what big data can (and cannot) capture about the benefits of ICNRM activities in Australia.

We began by breaking the research process down into five discrete stages: project design, data collection, data integration, data analysis and data translation. We then identified the key steps within each of these five stages, evaluated those steps against the four CARE principles, and made modifications to those steps where necessary to support alignment with the CARE principles.

Draft plans for each stage of the research process were shared with the Project Steering Committee on an ongoing basis, facilitating iterative co-development of a CARE-informed research plan. Once finalised, this enabled the team to conduct carefully designed research that protected Indigenous data sovereignty by appropriately recognising Indigenous peoples' rights; handling data in an ethical, respectful and considered manner; producing useful analysis that aligned with Indigenous peoples' priorities for the project; and ensuring that data and findings were only shared publicly with the consent of Indigenous representatives.

Results

Guided by the CARE principles, researchers worked with the Project Steering Committee and Advisory forums to determine what data should be collated, how it should be analysed and interpreted, and the purpose(s) for which it should be used. This process resulted in a set of co-designed practices around project design, data collection, data analysis, data integration and data translation, all of which focused on embedding Indigenous data sovereignty into the research.
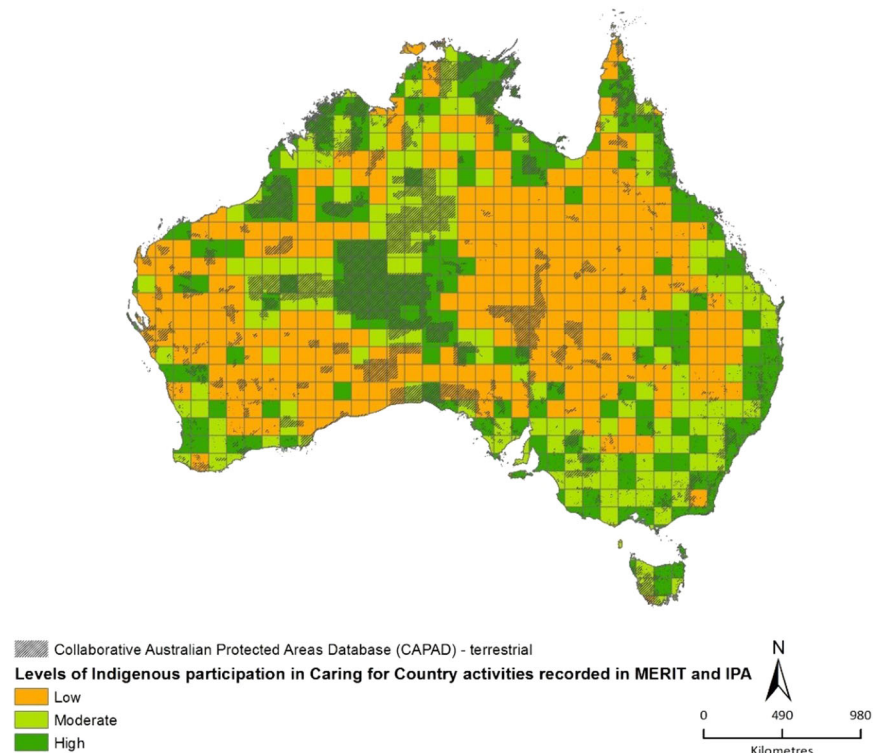
Project Design

Researchers collaborated with the Project Steering Committee and Indigenous Agency Advisory Committees to co-design the project's goals. This process was informed by a framework developed in consultation with Indigenous ranger groups across Australia, which identifies outcomes these groups wish to achieve for healthier country, strengthened culture and language, healthier people, families and communities; and, greater economic opportunities (https://www.socialventures.com.au/work/prime-minister-and-cabinet-indigenous-environment-branch/). Indigenous representatives identified the research questions they wished to explore, and researchers then identified the necessary data sets to facilitate this research. This iterative process provided a pathway for the research team to apply the principle of Collective Benefits, because it established a foundation for inclusive development and enabled Indigenous people to define the desired benefits of repurposing the data. Indigenous collaborators also gained greater awareness of existing big data sets that contain Indigenous data, enabling them to advocate for equitable outcomes.

Data Collection

Data collection for this research involved obtaining permission to use existing data sets that contain Indigenous data. The CARE principle of Authority to Control recognises Indigenous peoples' rights and interests in data about them and empowers them to control access to and use of such data. This principle was challenging to implement during the data collection stage of the project, as the data sets required for the project are held by governmental and private entities, where there are few Indigenous data governance structures or processes in place. However, the Project Steering Committee included representatives from the government entities that hold the required data sets, and these individuals played an important role in brokering input from Indigenous representative groups within each agency. The consent terms for the secondary use of this data did not require direct permission from the people who collected and entered the data into each database and opens up an opportunity for improvement in future consent terms. Input from Indigenous representative groups offered a step towards increased data control for Indigenous communities, both in terms of data interpretation and the sustainable management of land and water.

The Project Steering Committee also highlighted the need to consider context when evaluating the benefits of ICNRM activities, as activities and benefits in desert inland areas are difficult to compare with those delivered in tropical or southern coastal areas. The team responded to this guidance in two ways. First, remoteness was considered in the analysis. Recognising that population density varies considerably in

Fig. 2 National scope of Commonwealth funded program Indigenous cultural and natural resource management (ICNRM) activities and correlation with the nation's iconic environmental areas. Note: Records are based on Commonwealth-supported projects reported in MERIT and IPA databases and funded between 2011 and 2019. Maps are corrected to account for the fact that fewer projects are located in remote areas (Watson et al. 2020)

Collaborative Australian Protected Areas Database (CAPAD) - terrestrial
Levels of Indigenous participation in Caring for Country activities recorded in MERIT and IPA
Low
Moderate
High

Australia, from densely populated coastal areas through to very remote and sparsely populated deserts, we stratified the data by remoteness using ABS remoteness area classifications (see Watson et al. 2020 for details on additional steps). Second, we added two case studies to the project (not reported here), enabling differences in Indigenous land and water management activities and outcomes in different parts of the country to be highlighted and incorporated into the research. Final approved outputs from this effort will be available on the Physical Environment Analysis Network website which co-funded this research (https://www.pean.gov.au/).

Figure 2 illustrates an output from our work to integrate the CARE principles into data collection to highlight the environmental benefits of Indigenous Natural and Cultural Resource Management (ICNRM) activities. The map shows that Indigenous Australians play a significant role in the delivery of Commonwealth-supported projects. Indigenous stewardship focuses on many important cultural and natural land and sea scapes, including many of the nation's iconic areas (e.g. World Heritage sites).

Data Integration

Based on feedback from the Project Steering Committee, the research team explored the economic benefits of ICNRM activities for Indigenous businesses. This work highlighted that practices around data integration make it difficult to implement the CARE principles, as efforts are constrained by what is technically feasible. While Indigenous representatives did not play a role in the data integration process, researchers conducted ongoing checks within the team and with the Project Steering Committee in an effort to conduct appropriate and ethical data integration practices that minimised harm and maximised benefits for Australia's ICNRM sector. Researchers incorporated this principle into their decision-making, including decisions about which data sets to integrate, and what scale and level of detail to use for the integration (noting that it is also a key principle behind the release, or otherwise, of analysed data from the secure DataLab environment). For example, ORIC and Supply Nation data sets were integrated with the MERIT and IPA data sets at the national level in order to protect the identity of Indigenous business and ranger groups because these analytic units could become identifiable at a local scale. Our data integration work highlighted that capacity building in data architecture and management among Indigenous communities would support greater implementation of the CARE principles during this stage of the research process.

Data Analysis

Researchers took care to ensure that data was analysed in a way that produced useful results that could assist with efforts to evaluate the benefits of ICNRM activities. An important first step was to identify policies that were relevant to the project's agreed goals and collective benefits,

and to make contact with government agency staff who
were responsible for addressing particular policy questions
that would benefit from the project's data. Researchers then
adopted an iterative approach to data analysis, conducting
ongoing checks to ensure that the results of the analysis
remained policy-relevant and would minimise harm and
maximise benefits for Indigenous communities. Indigenous
representatives were involved in this iterative process as
draft findings were shared with the inter-agency Steering
Committee for feedback and review. This enabled the
analytical focus and outputs of the research to be refined
throughout the project. For example, the analysis used to
show the national scope of ICNRM activities (Fig. 2) was
adjusted based on feedback from the Steering Committee
that this analysis needed to account for remoteness because
ICNRM groups that are scattered and smaller in remote
parts of Australia are unable to undertake the same level of
activities as those ICRNM groups in less remote regions.

Under the CARE framework, a key aspect of data ana-
lysis is ensuring that the resulting data can support and
appropriately represent the outcomes that matter most to
local ICNRM groups. The principle of Authority to Control
recognises Indigenous peoples' authority to control how the
ICNRM sector and its benefits are represented and identified
within data. By applying the CARE principles, the research

team recognised that local Indigenous ranger groups often
prefer to use 'stories of change' to report on the benefits of
their activities, but that these stories are often not captured
well in quantitative (or even qualitative) data for natural
resource management evaluation purposes (Hunt et al.
2009). To address this, the team used an artificial intelli-
gence (AI) language model (word2vec) to translate the text
of each story of change into numeric representations
(Mikolov et al. 2013). AI text analysis was then applied to
the stories of change to enable more accurate reporting on
the cultural and economic benefits of on-ground activities
across Australia (see Fig. 3). This AI text analysis provided
insights into how local stories can be combined into a
national narrative about the cultural and economic benefits
reported from ICNRM activities across Australia. Even so
this analysis does highlight the reality that large-scale ana-
lysis such as this cannot and should not replace local
ICNRM insights and approaches to describe and report on
the multiple impacts and benefits of ICNRM activities.

Data Translation

Researchers embargoed project analysis results until Indigenous
representatives had consented to their public release, protecting
Indigenous peoples' rights to control where and how their data

is used. Project analysis results were reviewed in regional workshops and by the Project Steering Committee, providing mechanisms for Indigenous peoples to determine how their land and water management activities, territories, employment, businesses, world views and knowledges are represented and identified within data. Results from the project have been written in language that is accessible to non-scientists, and will be shared on the Federal Department of Environment and Energy's Physical Environment Analysis Network website (https://pean.govcms.gov.au/projects/northern-australia) upon approval by the Indigenous review process described above.

Discussion and Conclusion

ICNRM activities have grown in number across the globe. Indigenous groups are increasingly asked to collect data to report on the benefits of these activities, which extend beyond environmental outcomes to include social, cultural and economic benefits for Indigenous rangers and communities. It is vital that Indigenous peoples have a say in how this ICNRM data is collected, analysed and translated for the purposes of determining if desired outcomes have been achieved. While local, Indigenous-specific approaches to evaluation are becoming more widely recognised and valued, there are few examples of how to use this data to scale up evaluations of ICNRM outcomes to inform policies and programs. This paper adds to this growing body of work by exploring how the CARE principles can be applied to re-purposing large data sets and secondary data to evaluate programs supporting ICNRM activities.

Using big data to tackle complex sustainability science challenges can introduce new possibilities and rich insights into human–nature interactions, as well as the complex mechanisms that sustain both (Dufva and Dufva 2019; Hudson et al. 2016). However, it can also create challenges for scientists in how this data is accessed, analysed, interpreted and reported. For example, the open data movement argues that data-sharing should be supported by making data findable, accessible, interoperable and reusable (FAIR principles). This emphasis on data-sharing is problematic for Indigenous peoples because this data often represents insights from diverse Indigenous knowledge systems that have different protocols governing how knowledge is shared and with whom (Walter 2016). The data may also have been collected for a specific purpose without taking possible reuse or open data-sharing into account.

Environmental management researchers need to take concepts surrounding Indigenous data sovereignty seriously when designing and negotiating projects, reporting outputs and outcomes from those projects, and using data from Indigenous groups and/or ICNRM activities. Establishing project governance mechanisms (such as an Indigenous

project steering group) can ensure the purpose and benefits of data collection and analytical efforts are negotiated with Indigenous inputs, including how the research can benefit ICNRM groups and activities. Concepts surrounding ethics, power and rights underpinning the CARE principles also need to underpin researcher efforts to ensure data analysis and outputs, recognise Indigenous intellectual and cultural property rights and Indigenous knowledge sharing protocols that vary within nation states and across the globe. This can be difficult for researchers using big-scale data sets to navigate and may require nested research governance arrangements to enable Indigenous strategic oversight and locally negotiated inputs at key stages of the research process.

As this research highlights, support for Indigenous data sovereignty raises important questions about how Indigenous inputs can be woven into analysing large data sets, data provided by ICNRM groups in this case, to give a richer picture of the outcomes sought by these groups. These issues are of critical importance, given the increased awareness of the need to appropriately engage Indigenous peoples, respect their inherent rights and interests, and recognise the value of their knowledge and practice in evaluations of environmental management (Díaz et al. 2015, Brondizio and Le Tourneau 2016). Efforts to understand ICNRM benefits from Indigenous ranger perspectives highlight the need for local voices and Indigenous-led approaches to guide the *habitus* around the data and data management practices that are used to evaluate ICNRM activities, as well as the protocols that govern how the outcomes of ICNRM activities are shared (cf. Maiam Nayri Wingara 2020). It is therefore essential to determine how to incorporate local voices and Indigenous-led approaches when scaling up, amalgamating and re-analysing data to inform national programs that support Indigenous communities. The CARE principles for Indigenous data governance can empower Indigenous people to create value from Indigenous data and ensure that policy and management decisions are grounded in Indigenous world views.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

References

Austin BJ, Robinson CJ, Lincoln G, Dobbs R, Tingle F, Oades D et al. (2018) Mobilising Indigenous knowledge for the collaborative

management of Kimberley Saltwater Country: WAMSI Kimberley Marine Research Program Final Report. Western Australian Marine Science Institution, Crawley

Austin BJ, Robinson CJ, Mathews D, Oades D, Wiggin A, Dobbs RJ et al. (2019) An Indigenous-led approach for regional knowledge partnerships in the Kimberley region of Australia. Hum Ecol 47:577–588. https://doi.org/10.1007/s10745-019-00085-9

Australian Government (2017) The Indigenous land and sea management outcomes framework. Australian Government, Canberra

Australian Government Productivity Commission (2020) Indigenous evaluation strategy draft. Australian Government, Canberra.

(2020) Guidelines for ethical research in Australian Indigenous studies. AIATSIS, Canberra

Barber M, Jackson S (2017) Identifying and categorizing co-benefits in state-supported Australian Indigenous environmental management programs: international research implications. Ecol Soc 22:11. https://doi.org/10.5751/ES-09114-22021

Bourdieu P (1977) Outline of a theory of practice. Cambridge University Press, Canberra

Brondizio ES, Le Tourneau F-M (2016) Environmental governance for all. Science 352:1272–1273. https://doi.org/10.1126/science.aaf5122

Chan L, Kirsop B, Arunachalam S (2011) Towards open and equitable access to research and knowledge for development. PLoS Med 8: e1001016. https://doi.org/10.1371/journal.pmed.1001016

Corrigan C, Robinson CJ, Burgess ND, Kingston N, Hockings M (2018) Global review of social indicators used in protected area management evaluation. Conserv Lett 11:e12397. https://doi.org/10.1111/conl.12397

Davis M (2016) Data and the United Nations Declaration of the rights of indigenous peoples. In: Kukutai T, Taylor J (eds) Indigenous data sovereignty: towards an agenda. ANU Press, Canberra, p 25–28

Devon M, Hoover E eds (2019) Indigenous food sovereignty in the united states: restoring cultural knowledge, protecting environments, and regaining health. University of Oklahoma Press, Norman

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N et al. (2015) The IPBES conceptual framework—connecting nature and people. Curr Opin Environ Sustain 14:1–16. https://doi.org/10.1016/j.cosust.2014.11.002

Dufva T, Dufva M (2019) Grasping the future of the digital society. Futures 107:17–28. https://doi.org/10.1016/j.futures.2018.11.001

Duncan T, Villarreal-Rosas J, Carwardine J, Garnett ST, Robinson CJ (2018) Influence of environmental governance regimes on the capacity of Indigenous peoples to participate in conservation management. Parks 24(2):87–102. https://doi.org/10.2305/IUCN.CH.2018.PARKS-24-2en

Fache E (2014) Caring for country, a form of bureaucratic participation. Conservation, development, and neoliberalism in Indigenous Australia. Anthropological Forum 24:267–286. https://doi.org/10.1080/00664677.2014.939576

Feir D, Hancock RLA (2016) Answering the call: a guide to reconciliation for quantitative social scientists. Can Public Policy 42:350–365. https://doi.org/10.3138/cpp.2016-018

Fogarty W, Lovell M, Langenberg J, Heron M-J(2018) Deficit discourse and strengths-based approaches: changing the narrative of Aboriginal and Torres Strait Islander health and wellbeing. The Lowitja Institute, Melbourne, https://www.lowitja.org.au/content/Document/Lowitja-Publishing/deficit-discourse-strengths-based.pdf

Garnett ST, Burgess ND, Fa J, Fernández-Llamazares A, Molnár Z, Robinson CJ et al. (2018) A spatial overview of the global importance of Indigenous lands for conservation. Nat Sustain 1:369–374. https://doi.org/10.1038/s41893-018-0100-6

Global Indigenous Data Alliance (GIDA) (2020) CARE principles for Indigenous data governance. GIDA. https://www.gida-global.org/care

Hudson M, Farrar D, McLean L (2016) Tribal data sovereignty: Whakatohea rights and interests. In: Kukutai T, Taylor J (eds) Indigenous data sovereignty: towards an agenda. ANU Press, Canberra, p 157–178

Hunt J, Altman JC, May K (2009) Social benefits of Aboriginal engagement in natural resource management. Centre for Aboriginal Economic Policy Research, Australian National University, Canberra

Jarvis D, Stoeckl N, Hill R, Pert P (2018) Indigenous land and sea management programs: can they promote regional development and help 'close the (income) gap'? Aust J Soc Issues 53:283–303. https://doi.org/10.1002/ajs4.44

Johnson JT, Howitt R, Cajete G, Berkes F, Louis RP, Kliskey A (2016) Weaving Indigenous and sustainability sciences to diversify our methods. Sustain Sci 11:1–11. https://doi.org/10.1007/s11625-015-0349-x

Kerins S (2012) Caring for country to working on country. In: Altman J, Kerins S (eds) People on country, vital landscapes, Indigenous futures. The Federation Press, Sydney, p 26–44

Kukutai T, Taylor J (eds) (2016) Indigenous data sovereignty: toward an agenda. Centre for Aboriginal Economic Policy Research, Canberra, 10.22459/CAEPR38.11.2016

Kukutai T, Walter M (2016) Recognition and indigenizing official statistics: reflections from Aotearoa New Zealand and Australia. Stat J IAOS 31:317–326. https://doi.org/10.3233/sji-150896

Kwaymullina A (2016) Research, ethics and Indigenous peoples: an Australian Indigenous perspective on three threshold considerations for respectful engagement. AlterNative: Int J Indigenous Peoples 12:437–449. https://doi.org/10.20507/AlterNative.2016.12.4.8

Leiper I, Zander KK, Robinson CJ, Carwadine J, Moggridge BJ, Garnett ST (2018) Quantifying current and potential contributions of Australian Indigenous peoples to threatened species management. Conserv Biol 32:1038–1047. https://doi.org/10.1111/cobi.13178

Lovett R, Lee V, Kukutai T, Cormack D, Rainie SC, Walker J (2019) Good data practice for Indigenous data sovereignty and governance. In: Daly A, Devitt SK, Mann M (eds) Good data. Institute of Network Cultures, Amsterdam, p 26–36

Maiam Nayri Wingara (2020) Good data practices for Indigenous data sovereignty and governance. Maiam Nayri Wingara. https://www.maiamnayriwingara.org/s/Good-data-practices-for-Indigenous-Data-Sovereignty-and-Governance-submitted.pdf

Mikolov T, Chen K, Corrado G, Dean J (2013) Efficient estimation of word representations in vector space. arXiv:1301.3781.

Nadasdy P (2004) Hunters and Bureaucrats: Power, Knowledge, and Aboriginal-State Relations in the Southwest Yukon. UBC Press, Vancouver

National Health and Medical Research Council (NHMRC) (2007) National statement on ethical conduct in human research 2007 (updated 2018). Australian Research Council and Universities Australia, Commonwealth of Australia, Canberra

Pert PL, Ens EJ, Locke J, Clarke PA, Packer JM, Turpin G (2015) An online spatial database of Australian Indigenous biocultural knowledge for contemporary natural and cultural resource management. Sci Total Environ 534:110–121. https://doi.org/10.1016/j.scitotenv.2015.01.073

Pert PL, Hill R, Robinson CJ, Jarvis D, Davies J (2020) Is investment in Indigenous land and sea management going to the right places to provide multiple co-benefits? Australasian. J Environ Manag 27(3):249–274. https://doi.org/10.1080/14486563.2020.1786861

Povinelli EA (1992) Labor's lot. The power, history and culture of Aboriginal action. Chicago University Press, Chicago

Pulsifer PL, Laidler GJ, Taylor DRF, Hayes A (2011) Towards an Indigenist data management program: reflections on experiences developing an atlas of sea ice knowledge and use. Can Geographer 55:108–124. https://doi.org/10.1111/j.1541-0064.2010.00348.x

Rainie SC, Rodriguez-Lonebear D, Martinez A (2017) Policy brief: Indigenous data sovereignty in the United States. Native Nations Institute, University of Arizona, Tucson, https://static1.square-space.com/static/58e9b10f9de4bb8d1fb5ebbc/t/5b297686f950b7690cf0f9a9/1529443976962/Policy+Brief+Indigenous+Data+Sovereignty+in+the+United+States+V0.3+copy.pdf

TallBear, K (2014) Standing with and speaking as faith: a feminist-Indigenous approach to inquiry 10(2) Journal of Research Practice Article N17. Retrieved from http://jrp.icaap.org/index.php/jrp/article/view/405/371.

The Global Indigenous Data Alliance (GIDA) Research Data Alliance International Indigenous Data Sovereignty Interest Group (2019) CARE principles for Indigenous data governance. https://static1.squarespace.com/static/5d3799de845604000199cd24/t/5da9f4479ecab221ce848fb2/1571419335217/CARE+Principles_One+Pagers+FINAL_Oct_17_2019.pdf

Todd Z (2014) Fish pluralities: Human-animal relations and sites of engagement in Paulatuuq, Arctic Canada. Etudes/Inuit/Stud 38(1-2):217–238

Robinson CJ (2016) Hunting for country and culture: the challenges surrounding Indigenous collaborative partnerships on the coast of northern Australia. In: Margerum RD, Robinson CJ (eds) The challenges of collaboration in environmental governance: barriers and responses. Edward Elgar Publishing, Cheltenham, p 355–368

Robinson CJ, James G, Whitehead PJ (2016) Negotiating Indigenous benefits from payment for ecosystem service (PES) schemes. Glob Environ Change 28:21–29. https://doi.org/10.1016/j.gloenvcha.2016.02.004

Robinson CJ, Wallington TJ (2012) Boundary work: engaging knowledge systems in co-management of feral animals on Indigenous lands. Ecol Soc 17:16. https://doi.org/10.5751/ES-04836-170216

Scassa T, Taylor F (2017) Legal and ethical issues around incorporating traditional knowledge in polar data infrastructures. Data Sci J 16:1–14. https://doi.org/10.5334/dsj-2017-003

Sterling EJ, Filardi C, Toomey A, Sigouin A, Betley E, Gazit N et al. (2017) Biocultural approaches to well-being and sustainability indicators across scales. Nat Ecol Evolution 1:1798–1806. https://doi.org/10.1038/s41559-017-0349-6

Te Arawhiti (Office for Māori Crown Relations) (2019) Māori crown relations capability framework for the public service – organisational capability component. Te Arawhiti, Wellington

Tengö M, Hill R, Malmer P, Raymond CM, Spierenburg M, Danilsen F et al. (2017) Weaving knowledge systems in IPBES, CBD and beyond – lessons learned for sustainability. Curr Opin Environ Sustainability 26–27:17–25. https://doi.org/10.1016/j.cosust.2016.12.005

Verran H, Christie M (2007) Using/designing digital technologies of representation in Aboriginal Australian knowledge practices. Hum Technol 3:214–227

Walter M (2016) The voice of Indigenous data. Beyond the markers of disadvantage. Griffith Rev 60:256–263

Walter MM (2010) The politics of the data: how the Australian statistical indigene is constructed. Int J Crit Indigenous Stud 3:45–56

Walter M, Suina M (2018) Indigenous data, indigenous methodologies and Indigenous data sovereignty. Int J Soc Res Methodol 22(3):233–243

Walter M, Lovett R, Maher B, B Williamson, Prehn J, Bodkin-Andrews G, Lee V (2020) Indigenous Data Sovereignty in the Era of Big Data and Open Data. Australian Journal of Social Issues 1-14

Watson I, Chen C, Kong T, McConnell A, Pert P, Robinson C et al. (2020) Physical Environment Analysis Network (PEAN) – Indigenous environmental programs: socio-economic analysis – methods report supporting the key project insights. CSIRO, Canberra, https://www.pean.gov.au/

Whyte KP, Brewer JP, Johnson JT (2016) Weaving Indigenous science, protocols and sustainability science. Sustain Sci 11:25–32. https://doi.org/10.1007/s11625-015-0296-6

Wiseman ND, Bardsley DK (2016) Monitoring to learn, learning to monitor: a critical analysis of opportunities for Indigenous community-based monitoring of environmental change in Australian rangelands. Geographical Res 54:52–71. https://doi.org/10.1111/1745-5871.12150