Chapter 1: Management, Research and Experimental Design

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✉ — Correspondence possible via GitHub Issues

Introduction

What is wildlife science and management?

Seeking truth

Uncertainty

Environmental variation

Linguistic uncertainty

Partial observability

Partial controllability

Structural uncertainty

Opening the Gates of Management and Science

Openness to diversity of knowledge

Wildlife research and management are closely entwined fields with a large number of different stakeholders. Not only that, but the stakeholders typically represent a highly diverse group of actors with complimentary knowledge and expertise relevant to the wildlife systems and/or management challenges at hand [drescher2013]. This diversity of knowledge can be illustrated through the – admittedly very vague – concept of "expert knowledge".
In the eyes of the general public it may be the **researchers** that come to mind first when thinking about "experts" [dommett2019; funk2019]. Researchers collect and analyze data in order to provide a (quantitative) knowledge base for decision-making. Modern science is becoming increasingly more collaborative and typically involves teams of researchers with different and complimentary skills and backgrounds [**carpenter2006?**,**goring2004?**,**cheruvelil2014?**]. At the same time, there is a growing awareness in the scientific community of the need for interdisciplinary work that also makes use of what is often termed "expert knowledge" in scientific work [gosselin2018; [**rubert2021?**]].
When used by a researcher, the term "expert" often refers to any non-researcher who possesses valuable knowledge (in the context of a study/problem). In wildlife research, this typically encompasses managers and citizen scientists, and sometimes also includes indigenous people. **Wildlife managers**, occasionally also referred to as "end users", "decision makers", or "policy makers", are aware of the practical contexts framing wildlife research and often have a good grasp of both logistical and financial implications of different types of monitoring and management strategies and interventions [gosselin2018]. They may also possess a wealth of (qualitative) knowledge about focal species and ecosystems, as well as about motivations and interests of various other stakeholders in a system [drescher2013; gosselin2018].

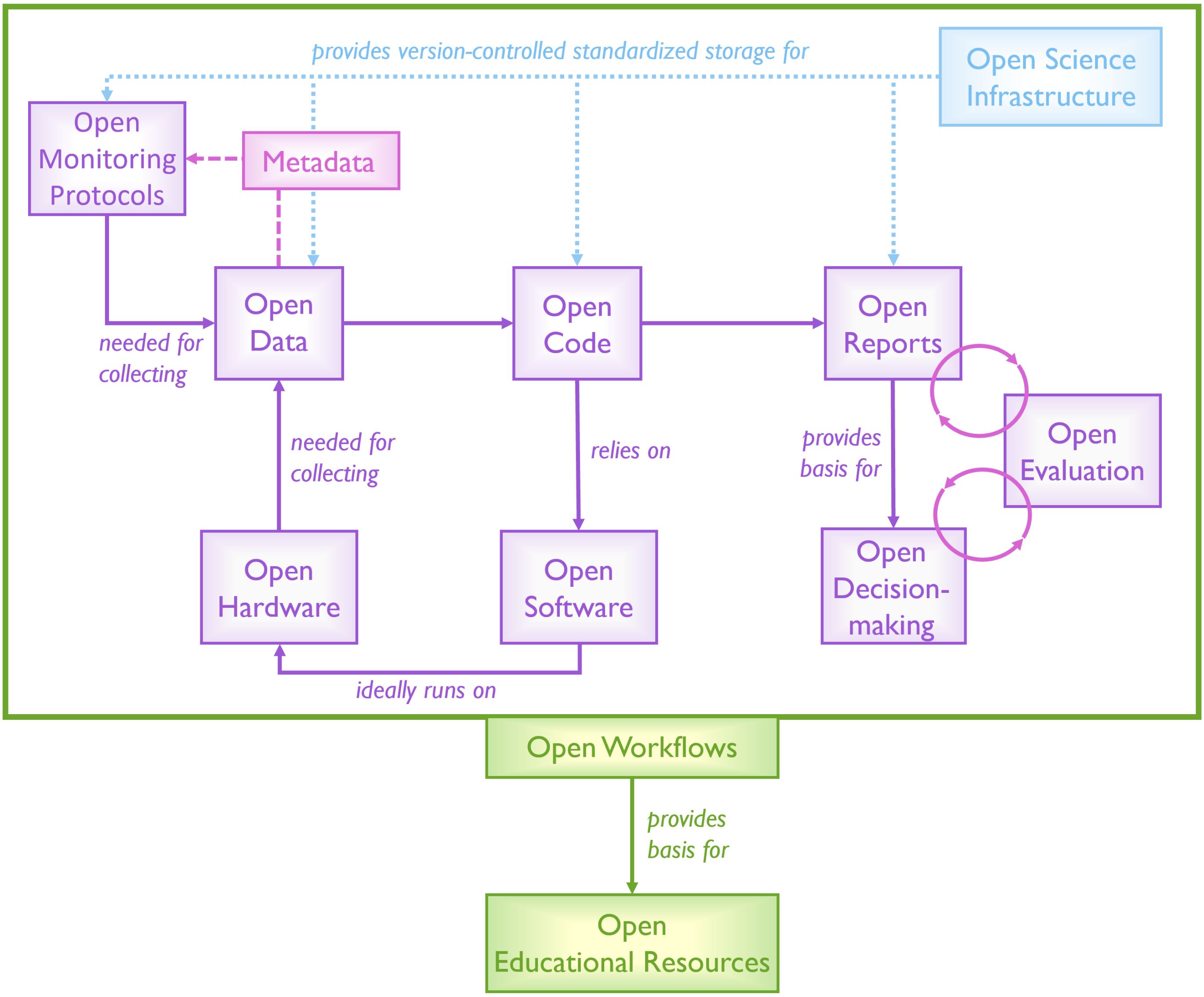
Some **citizen scientists** (sometimes also called "community scientists") may possess similar knowledge, at least about the former, based on experiences from their extensive time spent observing, enjoying, and collecting data on species [**miller2012?**,**mckinley2017?**]. They may also have a good understanding of potential issues and challenges with data collection in the field [**miller2012?**]. Last but not least, citizen scientists represent a portion of the general public, and may contribute to debates and decision-making with viewpoints, priorities, and values that are central to a large number of people [[**mckinley2017?**]; binley2021].
Indigenous people have been living as part of and interacting with the natural environment since long before scientific research as we know it today was conducted [berkes2017]. As a consequence, indigenous communities hold intricate knowledge about their lands and waters which is tightly linked to their culture [jessen2022] and which often covers time spans necessary for understanding long-term ecological changes [e.g. savo2016]. Indigenous knowledge is, in many ways, complementary to ecological science and the involvement of indigenous people can lead to more impactful, effective, and just research and management [ban2018].
Notably, individuals may also belong to several of the categories introduced above. Wildlife managers, for example, may be actively doing research (or have done so in the past) and may also be collecting citizen science data in their free time. Indigenous people may hold central roles in conservation decision making. Some researchers may have indigenous backgrounds, etc. If anything, that only further enhances the diversity of knowledge surrounding wildlife research and management.

Engagement of diverse stakeholders

Harnessing and making optimal use of the diversity of available knowledge surrounding wildlife and wildlife management requires broad involvement of different stakeholder groups [e.g. **rubert2021?**]. Collaboration is key, and this necessitates that the entire process – from data collection to policy implementation – is inclusive. Four principles form the basis of inclusivity in this context: openness, accessbility, transparency, and reproducibility. These principles are also the corner stones of open science [**hampton2015?**,**powers2019?**,**vincente2020?**]. **Open** processes are clearly visible and offer opportunities for anyone to engage with them and contribute. **Accessible** processes are set up and documented in a way that allows everyone to obtain information relevant to them and be able to understand both the information itself and the way it was generated. **Transparent** processes feature complete documentation of every step of the workflow (this includes data collection, analysis, and presentation but also resulting decision-making) and provide all materials that informed and are produced by them. Finally, the mark of **reproducible** processes is that they are provided as complete workflows and based on tools that everyone can access, meaning that anyone (possessing relevant knowledge) can re-run the workflow and arrive at the same conclusions. Robust decision-making based on diverse knowledge thus requires workflows that are open, accessible, transparent, and reproducible and the next section provides and overview over the components of such workflows (Figure X).

Open and accessible workflows

When considering research workflows, we often only think of the steps connecting data and results. However, complete workflows in wildife research and management begin with planning and implementation of monitoring and end with reporting, decision making, and evaluation. Knowledge is built incrementally, and workflows should therefore also be thought of as cycles where newly gained information and results from evaluation feed back into earlier steps (e.g. sensu adaptive management, [**williams2011?**]; [**nichols2015?**]).



Schematic overview of the components of open and accessible workflows for wildlife research and decision-making.

?? gives an overview over the main components of open and accessible workflows.

It starts with data collection and hence with **monitoring protocols**, which should be openly accessible and documented in a way that they can be understood and – in theory – re-produced/re-implemented by independent parties.
The outcome of monitoring is recorded **raw data**, which should be made available publicly if possible and ideally adhere to FAIR (*F*indabilty, *A*ccessibility, *I*nteroperability, *R*eusability) and/or CARE (*C*ollective benefit, *A*uthority to control, *R*esponsibility, and *E*thics) data principles [wilkinson2016?,carroll2020?,carroll2021?]. Data needs to be supplemented with appropriate and standardized **metadata** to communicate both the structure and content of the data itself, and how it has been generated (i.e. how it is linked to the monitoring protocol).
The process to get from raw data to results typically consists of several steps, e.g. data cleaning, data wrangling/reformatting, data analysis, visualization of results, etc. These steps are implemented using some sort of **code** (manual steps, such as data editing/reformatting in Excel, are best avoided). All code should be well documented, reproducible, and version controlled [see cooper2017? for a guide] and made available via an appropriate repository such as GitHub, GitLab, etc. Formal code review, as is common in e.g. software development, is also a great tool to enhance reproducibility and overall quality of code [ivimey2023?].
Under ideal circumstances, both the **software** used for running code (analyses) and the **hardware** on which it is run should be open. For software, this means that the underlying code is open-source and that the program is – ideally – free to use. Defining openness for hardware is trickier, not least because the term spans a large variety of tech ranging from simple field loggers to sophisticated super-computers. These are typically not “publicly available”, but what is crucial in the context of open and transparent workflows is that it is clearly stated what hardware was used and – if applicable – how one may get access to it.
The results from data analysis, their interpretation, and potentially recommendations resulting thereof are presented in **reports**. Whether these take the shape of institutional written reports, scientific articles, oral presentations for different interest groups or any combination of them: they hold important information that should be accessible to anyone interested.
While a majority of written reports nowadays are open access and dissemination presentations often are public events, the same cannot be said of most **decision making** processes. It is not rare for decisions in wildlife management to be made by a small number of individuals behind closed doors. That in itself does not need to be problematic, and may, in many cases, be the most efficient approach to reaching a conclusion and deciding on action. What is important for openness of and trust in wildlife management, however, is that there is an accessible record documenting the decision-making process. That way, anyone interested may gain insights into how and based on what evidence and factors decisions were made.
This is also crucial for the final step of the workflow: **evaluation**. Thoroughly evaluating the different steps of the workflow, from the design of the monitoring to the implementation of management actions and policy, is crucial for improving outcomes and maximizing value for money in the long run.
Finally, it is important to be aware that open scientific and management practices require appropriate **infrastructure**. This includes – but is not limited

to – databases and repositories for storing and sharing data, code, and documents. Relevant infrastructure may be institutional or global, as long as it is accessible, endorses standardized formats, and provides both permanent identifiers and version control.

Wildlife research and management need to be open and accessible to harness the diversity of knowledge available, which in term is crucial to tackle current and future challenges. Open and accessible workflows, from planning of monitoring to evaluation of decisions and actions (Figure X), are key to achieving that. Changing practices towards that goal will happen both through adaptation by current researchers and managers, and by teaching the next generation. Successes and failures in setting up and operating with open workflows provide examples that can be used in **education** and help equipping tomorrow's researchers and managers with the skills they need for successful wildlife management and conservation in a rapidly changing world.

Basics of Management/Decision Science

Value of Information

Evidence

PrOACT

Management Strategy Evaluation

Adaptive Resource Management

Causation and Inference

Asking the right questions in the right way

Estimation questions

Hypothesis driven research

Exploratory research

Causation and correlation

Sufficient causation

Necessary causation

Manipulative Experiments

Observational Studies

Directed Acyclic Graphs (DAGs)

Confounding variables

Mediator and moderating variables

Basics of Robust Experimental Design

Repetition

Replication

Randomization

Controls

Blocking

Response variables (i.e., performance measures in a decision context)

Basics of Sampling

Probability vs. Non-probability sampling

Defining the population, sampling frame, sampling unit, etc.

Simple random sampling

Stratified random sampling

Systematic sampling

The Publication and Peer Review Process

Determining coauthorship

Choosing the best outlet

Who should review your manuscript?

How to constructively provide feedback as a reviewer?

Responding to reviews

Marketing your manuscript after acceptance

Figures

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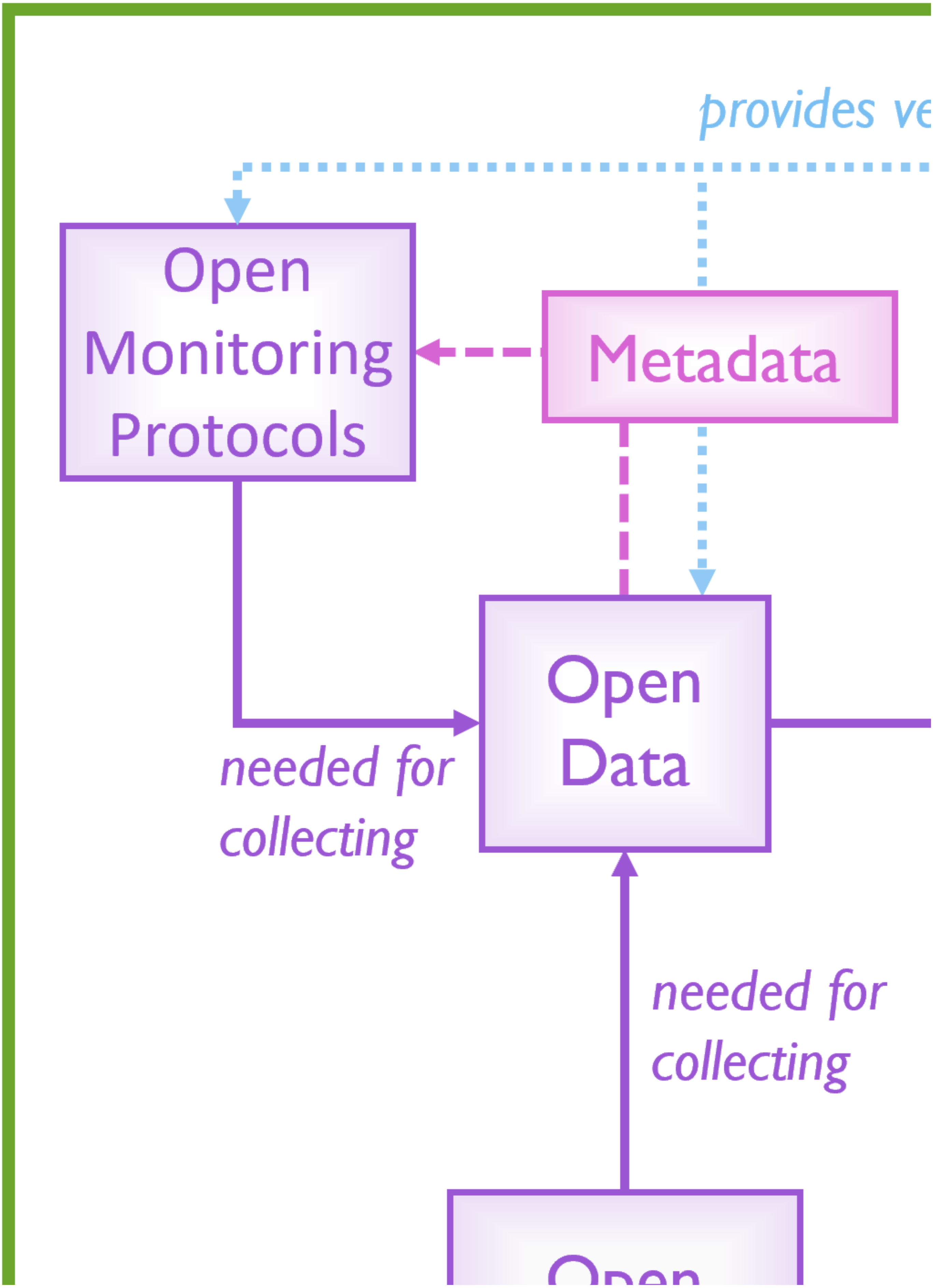

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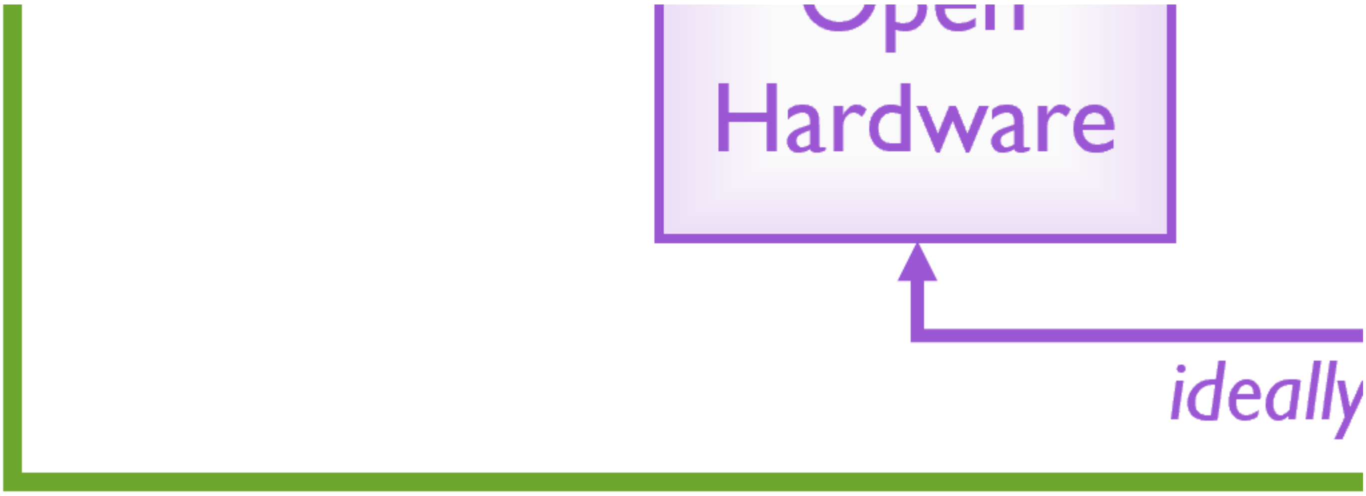
Open Monitoring Protocols
Metadata
Open Data
needed for collecting
needed for collecting
Open



Tables

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