IMPROVING THE EFFECTIVENESS AND EFFICIENCY OF MONITORING FOR ENVIRONMENTAL FLOWS

XIAOYAN (DIANA) DAI

University of Melbourne, Australia

Abstract

In response to the urgent global need to stop biodiversity loss, environmental flow (e-flow) programs have gained prominence as a means to sustain ecosystems and livelihoods. E-flow represents water releasing from a dam or weir to maintain downstream river health, and the health of the environment. However, decisions about environmental management are driven predominantly by the people's perspectives and values, and effective monitoring of these programs often hindered by resource limitations and complex human factors. Past research has indicated that scientists, managers, and other individuals tend to approach things with different perspectives. Capturing this knowledge using methods like interviews, discussions, and participatory observation can yield invaluable insights into project performance and opportunities for enhancement.

This study focuses on the Murray-Darling Basin's Flow Monitoring, Evaluation, and Research program (Flow-MER) as a case study. Through semi-structured interviews with and a subsequent survey, the research uncovers stakeholders' perspectives on monitoring design, and to evalute the projects' effectiveness. Moreover, by comparing perception differences between scientists and managers, the research enhances the understanding of e-flow monitoring and its challenges. Ultimately, this research contributes to the development of efficient e-flow strategies, fostering both biodiversity conservation and sustainable water resource management.

Introduction

Around the world, the rapid decline in biodiversity has sparked a global effort to address this issue (Tickner et al. 2020). One popular approach to combat this decline is the development of environmental flow (e-flow) programs. These programs focus on determining the right quantity, timing, and quality of water flows necessary to support both sustainable ecological systems and the livelihoods of people who depend on them, as described by Arthington et al. in 2018. To establish e-flow requirements, it is essential to have a certain level of understanding regarding how different aspects of water flow are connected to various environmental characteristics. This understanding is crucial because it helps guide decisions about how water resources should be allocated, addresses uncertainties about how ecosystems function (which, in turn, leads to better decision-making), and assesses the effectiveness of interventions aimed at regulating water flow (Yoccoz et al. 2001, Nichols and Williams 2006, Field et al. 2007, Bonney 2019). However, it's worth noting that monitoring efforts are frequently criticized for their inefficiency, particularly when resources are limited.

While there is extensive research on modelling ecological responses to help planning and management, developing effective and efficient monitoring program for e-flow projects is intricately connected to human behaviour, values, attitudes, and decision-making processes (Mussehl et al., 2023). Previous studies have demonstrated the difference between conceptual mindsets of scientists, managers, and other collaborating stakeholders in e-flows management (Robelia and Murphy, 2012; Poff et al., 2003; White and Hall, 2006; Taylor et al., 2012). These knowledge systems and values might not be codified or articulated, and are often gained through personal experience, intuition, and difficult to communicate explicitly (Robelia and Murphy, 2012; Taylor et al., 2012), and these differences and barriers might hinder the decision-making process, and thus overall effectiveness of the project implementation.

In this study, we explore the perspectives of different monitoring-related groups during the decision-making process. Specifically, by incorporating semi-structured interview and survey studies, we aim to (1) gain a deeper understanding of people's perspectives on monitoring design, and (2) assess whether a significant perception difference exists between different stakeholders within a collaborative monitoring program.

Method

This research will use the World's largest e-flows monitoring program – the Flow Monitoring, Evaluation and Research program (Flow-MER) in the Murray-Darling Basin, Australia to draw out lessons for future monitoring design. This program is funded by the Commonwealth Environmental Water Holder (CEWH) to understand how fish, birds, vegetation, and river ecosystems are responding to the delivery of environmental water.

Semi-structured interviews (n=16) were conducted to determine broad principles regarding attitudes to monitoring design. Participants were selected carefully to represent each group within the Flow-MER: Managers; Selected area Leads, and Theme Leads. The interview lasted from 30 to 50 minutes and followed a topic guide, allowing for a consistent framework but flexible follow-up questions (Flick et al., 2004). Interview transcripts were analyzed through NVivo qualitative analysis software (NVivo 12 Pro, 2020) using a combination of deductive and inductive coding. Codes were combined or re-grouped to connect emergent patterns and themes

Based on the interview results, a more general online survey (n=60) was developed to validate the patterns identified during the interview phrase. Participants were recruited through email distribution lists with a response rate of approximately 46%, and anonymous QR code distribution during a scientific conference (the international Freshwater Science meeting in June 2023 in Brisbane, Australia). Recruitment targeted people experienced with environmental monitoring projects or monitoring data. We used exploratory data analysis of the survey data to examine the relationships and characteristics of respondent perception. To evaluate the effectiveness of Flow-MER and support next iteration decision-making, we would like to identify the most primary advantages and most critical and pressing areas that need improvement

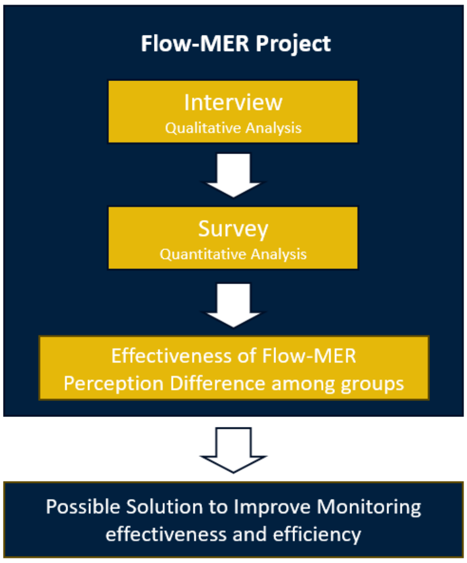

Figure 1: Workflow outlining the interview and survey within the Flow-MER program. This research aimed to investigate the perception difference between different stakeholder groups and thereby propose a solution to improve monitoring.

Interview and Survey Result and Discussion

Characteristics of Successful monitoring design

The clearest result is that "Clear objectives" received the largest number of mentions across all interviewees (Table 1). In addition, this criterion was commonly mentioned as the first criteria (12 out of 14 interviewees).

"It's about being very clear on what you what questions you're asking, what hypothesis you're testing" By SAL 1

"The design needs to appropriately reflect the questions that you're asking." By Social scientists 2

"I think poor monitoring is, is where the question is either poorly defined, or is the wrong question." By Manager 4

Table 1: Characteristics for successful monitoring design by coding reference. Interview participants were asked "what are some characteristics of good monitoring design criteria?" (Dai et al., in progress)

	No. Management Sector	No. Selected Area Leads	No. Themes Leads	No. Social Scientists	Total
Clear objectives	6	3	2	3	14 (88%)
Transferable	4	2	1	2	9 (56%)
Detectability	2	4	0	0	6 (38%)
Significance	2	2	1	1	6 (38%)
Adaptive	1	1	0	0	2 (13%)
Total number of Interviews in group	6	5	2	3	16

Survey respondents were asked to provide their level of importance for seven pre-determined criteria based on the interview results, choosing from "not at all important" to "extremely important" (Figure 2 and 3). Results show that biophysical scientists and managers share an overall similar perception in defining important features of monitoring programs. "Clear question and objective" is viewed as the most important characteristics for program success, followed by "Good communication among all relevant stakeholders". The only difference was that biophysical scientists prioritize enhanced system comprehension over adaptive monitoring design, while managers hold the opposite view. In addition, there are slight variations in the distribution of individuals between two groups. For example, while the two groups both emphasize the significance of communication among stakeholders, a large proportion of biophysical scientists (77%) regard this as extremely important, whereas opinion from managers range from very important (50%) to extremely important (50%).

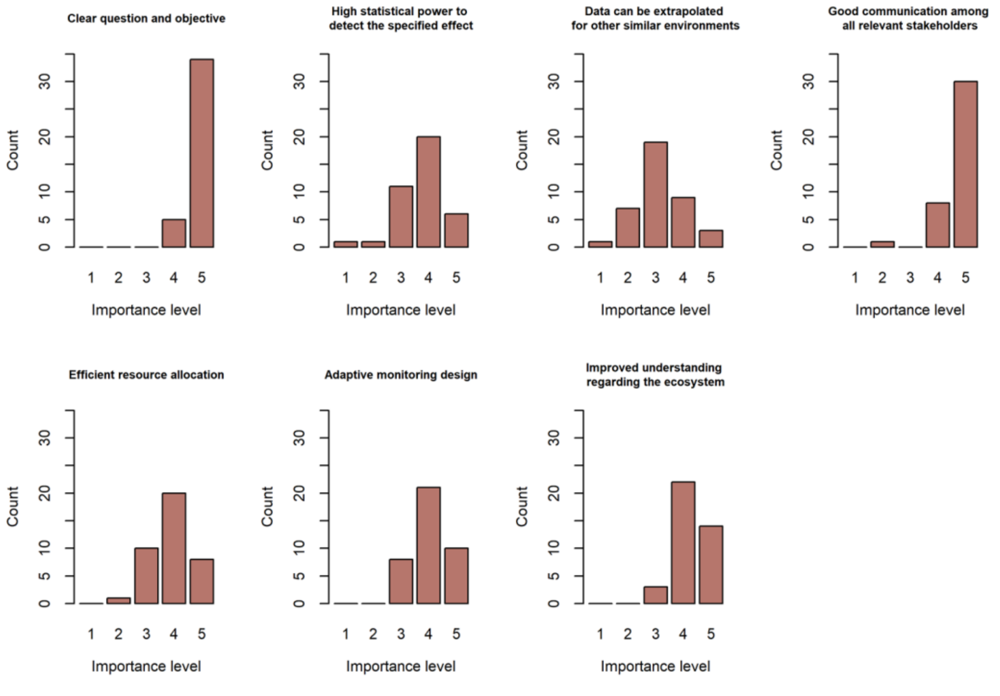

Figure 2: Importance level by biophysical scientists for each criterion that characterizes successful monitoring design

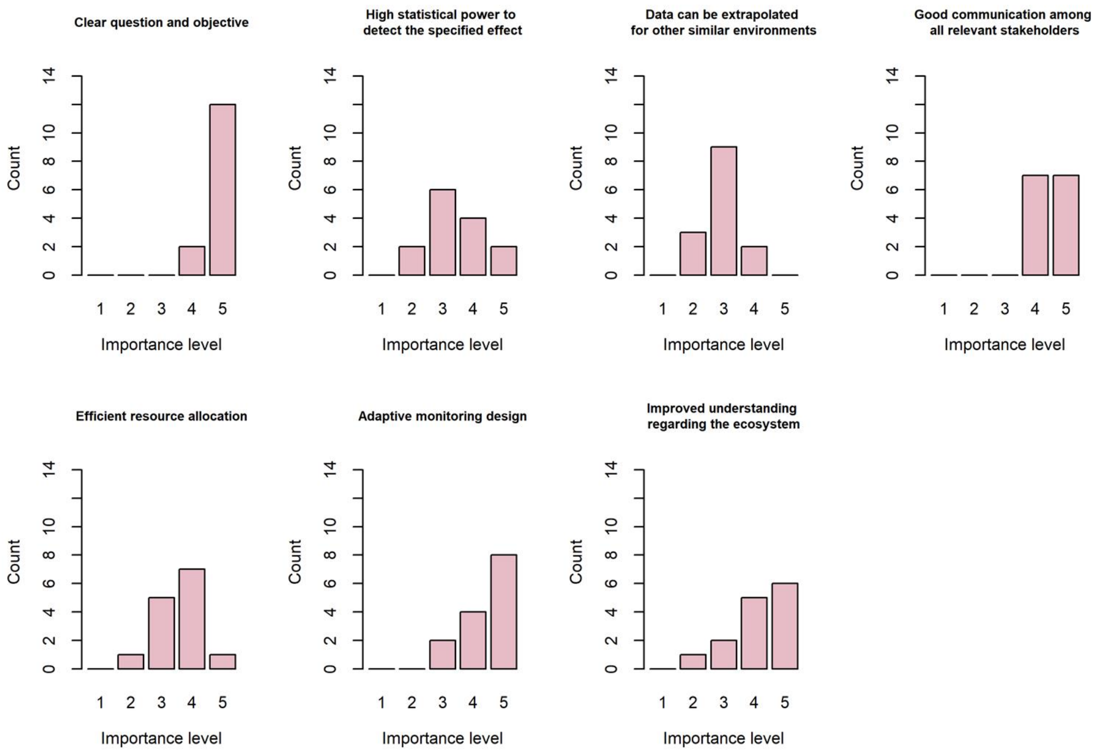

Figure 3: Importance level by managers for each criterion that characterizes successful monitoring design

Effectiveness of Flow-Monitoring, Evaluating, and Research (Flow-MER)

For those critical characteristics of successful monitoring design, participants expressed a positive attitude regarding Flow-MER's performance. Impressively, there were no negative opinions regarding the effectiveness of communication and the improved knowledge regarding the ecosystem. A great number of biophysical scientists and managers perceive that Flow-MER works extremely well in these two aspects.

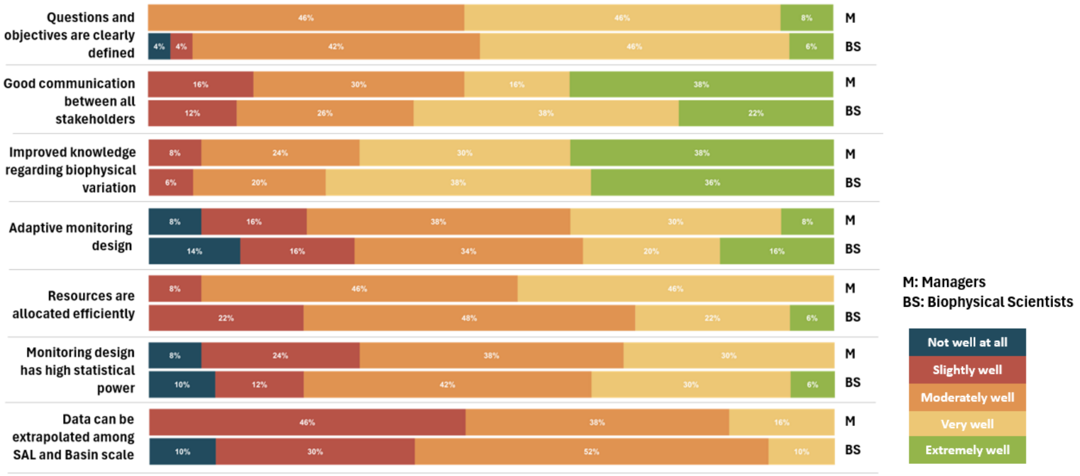

Figure 4: Distribution of performance rating for Flow-MER for managers and biophysical scientists. Y-axis outlines each characteristic of successful monitoring design, arranged in order from the most important to the least. (Dai et al., in progress)

Surprisingly, both biophysical scientists and managers exhibit a very similar attitude towards Flow-MER success across all criteria, with only minor differences in their perceptions. For example, while no managers claimed that resources have been allocated extremely efficiently, 6% biophysical scientists held this view.

In most surveys of this type, participants are conservative while choosing extremes in questions, “Extremely well” and “Not well at all” in this case (Moors 2008). Since each monitoring design criterion is ranked, it is necessary to closely examine these extreme outcomes. Therefore, while Clear questions and Objectives are the most important criteria determining program success, it should be noted that 4% of biophysical scientists find the questions and objectives in Flow-MER to be poorly defined.

As for “adaptive monitoring design”, it is worth noting that an important function of Flow-MER is to maintain the ongoing effort initiated by preceding Long-Term Intervention Monitoring (2014-2019, LTIM; Hale et al. 2020) Project and Environmental Water Knowledge and Research (EWKR; MDFRC 2016) Project. Those programs ran for 5 years, with only minor modifications in terms of overall objectives and management priorities. The feedback gathered from surveys and interviews consistently highlights the necessity for a project adaptation and transition, but this conflicts with the value of maintaining long-term data sets. Within the context of the CWEH, both managers and scientists are actively driving the advancement of the next project – Flow-MER 2.0, which will begin monitoring in June 2024. The design phase of this new project involves a comprehensive re-evaluation of historical monitoring data and the outcomes of management efforts.

One of the strengths of Flow-MER is its ability to monitor multiple objectives over time (Figure 5). Improved system understanding is being recognized as the second strongest feature, followed by the consistency of core measurements throughout the iterations. The importance of objectives has been consistently identified through both the survey and the interview process. It demonstrates a need to improve the alignment of objectives with the monitoring design more effectively and efficiently.

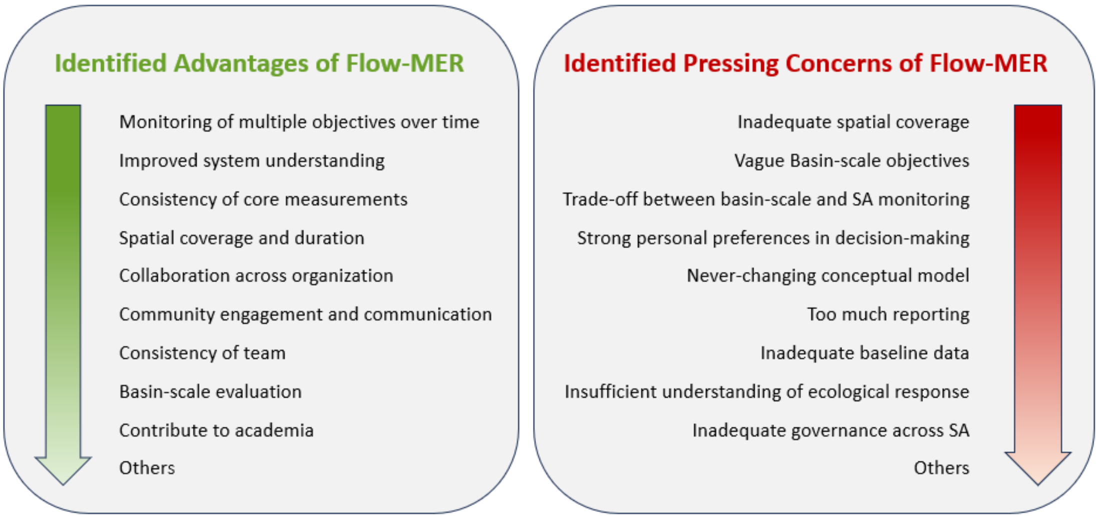

Figure 5: Identified advantages (ranging from the strongest feature to the weakest) and pressing concerns (ranging from the most pressing concerns to the least) of Flow-MER.

Regarding the pressing concerns for Flow-MER, survey findings were in line with the interview outcomes, with the internal contradictions consistently raised in both (Figure 5). The uniqueness of Flow-MER is also linked to its scale and significance. As a world leading project, its spatial coverage and duration are recognized as a particular highlight. Yet at the same time, inadequate spatial coverage has been identified as the most pressing problem for Flow-MER. In addition, the second most pressing concern pertains to the vague basin-scale objectives. This implied that while monitoring multiple objectives stands as a strong feature, there is not enough clarity as to how these relate to objectives.

Within the selected area scale, specific sites were carefully chosen. The problem is that these sites might not be representative of the entire selected area, as they may not fully capture the overall characteristics of the riverine ecosystem. Additionally, it is crucial to recognize that the monitoring at each selected area cannot adequately represent even that portion of the entire basin. This relates to the “trade-off between basin-scale and selected area scale monitoring” as well.

Implications for Management

Overall, a distinction in viewpoints between scientists and managers does exist, although it is much smaller than initially anticipated. This observation serves as compelling evidence of the effectiveness of past communication and collaboration efforts. These efforts have meant that scientists and managers have likely been able to exchange ideas, share information, and find common ground, resulting in a level of alignment that might not have been initially expected. This harmony between the two groups is indicative of a healthy working relationship and a shared understanding of the project's goals and objectives.

Given the importance of maintaining this positive dynamic, it is recommended that continuous and transparent communication practices be maintained moving forward. This involves keeping channels of communication open between scientists, managers, and other relevant parties. Regular updates, discussions, and knowledge-sharing sessions can help prevent potential misunderstandings, ensure that everyone remains on the same page, and foster an environment of collaboration.

However, as stated before, the importance of objective setting within the monitoring projects has emerged as a priority area. Objectives are specific indicators or measurement endpoints that guide decision-making and are used to evaluate success of actions (Lyons et al. 2008). Here, based on the interview and survey results, we have drawn on concepts from structured decision-making to define an Objective Hierarchy framework that distinguishes between the different types of objectives.

Structured decision making differentiates means objectives from fundamental objectives. Fundamental objectives represent the core values of different stakeholders and the ultimate aims of management, while means objective are the means to achieving those ends (Keeney and McDaniels 1992).

A fundamental objective may be able to be measured directly (i.e., a threatened species population), but it is common for the overarching aim of programs to be multifaceted (e.g., ecological resilience). These are used to directly assess the success of the e-flows program, and/or determine decisions about required flow regimes. The means objectives are associated indicators that are critical to understanding progress towards achieving the fundamental objectives (Reynolds et al. 2016, Horne et al. 2022). Means objectives are normally monitored as an intermediate indicator, and the monitoring data can inform managers and relevant stakeholders about the effectiveness of the intervention strategy (Hutto and Belote 2013, Horne et al. 2022). In this framework, we also use the term ‘drivers’. Drivers refers to the critical environmental attributes and processes that may be affected by a management intervention (e.g., river flow), but may also be used to represent environmental variables that cannot be controlled by management (e.g., rainfall). These drivers can be considered in the context of long-term non-stationarity and variability within adaptive management processes (Horne et al. 2022).

To establish the connection between drivers, means, and fundamental objectives, a conceptual model can be used to explicitly acknowledge their interrelationships. It can include all essential environmental attributes, including human threats, interventions, system drivers and their relationship to the objectives (Reynolds et al. 2016). A well-established conceptual model can differentiate fundamental from means objectives, help brainstorm and articulate the actions for managing different drivers, and finally, can help guide the manager about what to monitor (Reynolds et al. 2016).

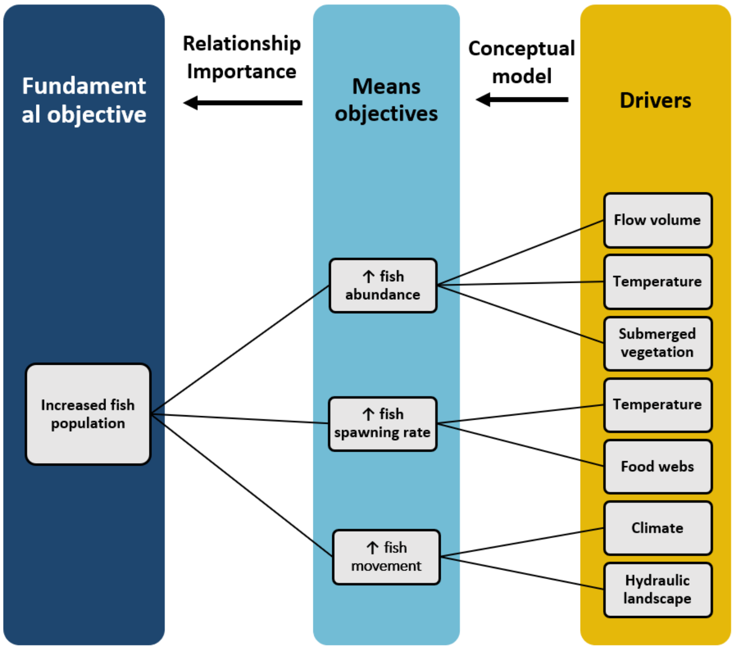

Figure 7: Objective Hierarchy consisting of 1) Drivers, 2) Means Objectives, 3) Fundamental objectives. As a simplified representation of an environmental program, this figure shows a management intervention that targets a driver, which in turn impacts a means objective and that over time leads to the realisation of a fundamental objective (e.g., increase in a fish population, as a fundamental objective). (Reproduced from Dai et al., under review)

Based on the hierarchical objectives, the roles of monitoring can also be clearly articulated and addressed because the strategies required to monitor different types of objectives (fundamental, means and drivers) are distinct. This type of clear articulation could reduce the unfortunately common outcome where monitoring programs fail to translate their data into effective management (Chadès et al. 2008, Lindenmayer et al. 2012, Horne et al. 2022). It also makes clear the challenge of the allocation of monitoring resources within programs (Field et al. 2007, Fuller and Martin 2010). Determining when to change or stop monitoring is a critical question for managers and funding agencies that is not currently adequately addressed (Chadès et al. 2008, Canessa et al. 2015, Wu et al. 2021).

Conclusion

Through the interview and survey qualitative analysis, the characteristics of successful monitoring programs for environmental flows have been outlined. The perception difference between the two key stakeholders groups of scientists and managers was small, suggesting positive outcomes from open communication in the Flow-MER program. Furthermore, it became evident that enhancing the clarity of project objectives is crucial. We believe that the objectives hierarchy framework could strengthen the distinction of means objectives from fundamental objectives, and thereby benefit the project resources allocation process as well.

References

Arthington AH, Bhaduri A, Bunn SE, Jackson SE, Tharme RE, Tickner D, Young B, Acreman M, Baker N, Capon S, Horne AC, Kendy E, McClain ME, Poff NLR, Richter BD, Ward S. 2018. The Brisbane Declaration and Global Action Agenda on Environmental Flows (2018). Frontiers in Environmental Science 6: 1–15.

Bonney P. 2019. Monitoring threatened species and ecological communities.

Canessa S, Guillera-Arroita G, Lahoz-Monfort JJ, Southwell DM, Armstrong DP, Chadès I, Lacy RC, Converse SJ. 2015. When do we need more data? A primer on calculating the value of information for applied ecologists. Methods in Ecology and Evolution 6: 1219–1228.

Chadès I, McDonald-Madden E, McCarthy MA, Wintle B, Linkie M, Possingham HP. 2008. When to stop managing or surveying cryptic threatened species. Proceedings of the National Academy of Sciences of the United States of America 105: 13936–13940.

Field SA, O'Connor PJ, Tyre AJ, Possingham HP. 2007. Making monitoring meaningful. Austral Ecology 32: 485–491.

Flick U. 2018. Introduction To Qualitative Research. 6th ed. Sage

Fuller R, Martin T. 2010. Monitoring does not always count.

Hale J, Bond N, Brooks S, Capon S, Grace M, Guarino F, James C, King A, McPhan L, Mynott J, Stewardson M, Thurgate N. 2020. Murray–Darling Basin Long Term Intervention Monitoring Project — Basin Synthesis Report.

Horne AC, Webb JA, Mussehl M, John A, Rumpff L, Fowler K, Lovell D, Poff LR. 2022. Not Just Another Assessment Method: Reimagining Environmental Flows Assessments in the Face of Uncertainty. Frontiers in Environmental Science 10: 1–17.

Hutto RL, Belote RT. 2013. Distinguishing four types of monitoring based on the questions they address. Forest Ecology and Management 289: 183–189.

Keeney RL, McDaniels TL. 1992. Value-Focused Thinking about Strategic Decisions at BC Hydro. Interfaces 22: 94–109.

Lindenmayer DB, Gibbons P, Bourke M, Burgman M, Dickman CR, Ferrier S, Fitzsimons J, Freudenberger D, Garnett ST, Groves C, Hobbs RJ, Kingsford RT, Krebs C, Legge S, Lowe AJ, Mclean R, Montambault J, Possingham H, Radford J, Robinson D, Smallbone L, Thomas D, Varcoe T, Vardon M, Wardle G, Woinarski J, Zerger A. 2012. Improving biodiversity monitoring. Austral Ecology 37: 285–294.

Lyons JE, Runge MC, Laskowski HP, Kendall WL. 2008. Monitoring in the Context of Structured Decision-Making and Adaptive Management. Journal of Wildlife Management 72: 1683–1692.

MDFRC. 2016. Murray–Darling Basin Environmental Water Knowledge and Research Project: Multi-Year Research Plan 2016–2019.

Moors G. 2008. Exploring the effect of a middle response category on response style in attitude measurement. Quality and Quantity 42: 779–794.

Mussehl M, Webb JA, Horne A, Rumpff L, Poff L. 2023. Applying and Assessing Participatory Approaches in an Environmental Flows Case Study. Environmental Management.

Nichols JD, Williams BK. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21: 668–673.

Poff NL, Allan JD, Palmer MA, Hart DD, Richter BD. 2003. River Flows and Water Wars : Emerging Science for Environmental Decision Making Let us know how access to this document benefits you .

Reynolds JH, Knutson MG, Newman KB, Silverman ED, Thompson WL. 2016. A road map for designing and implementing a biological monitoring program. Environmental Monitoring and Assessment 188.

Robelia B, Murphy T. 2012. What do people know about key environmental issues ? A review of environmental knowledge surveys. 4622.

Taylor B, de Loë RC. 2012. Conceptualizations of local knowledge in collaborative environmental governance. Geoforum 43: 1207–1217.

Tickner D, Opperman JJ, Abell R, Acreman M, Arthington AH, Bunn SE, Cooke SJ, Dalton J, Darwall W, Edwards G, Harrison I, Hughes K, Jones T, Leclère D, Lynch AJ, Leonard P, McClain ME, Muruven D, Olden JD, Ormerod SJ, Robinson J, Tharme RE, Thieme M, Tockner K, Wright M, Young L. 2020. Bending the Curve of Global Freshwater Biodiversity Loss: An Emergency Recovery Plan. BioScience 70: 330–342.

Wu CH, Dodd AJ, Hauser CE, McCarthy MA. 2021. Reallocating budgets among ongoing and emerging conservation projects. Conservation Biology 35: 955–966.

Yoccoz NG, Nichols JD, Boulinier T. 2001. Monitoring of biological diversity in space and time. Trends in Ecology and Evolution 16: 446–453.