CITIZEN SCIENCE:
THEORY AND PRACTICE

Bridging Knowledge Creation and Conservation Practice through Participatory Action Research on Private Lands

CASE STUDIES

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ABSTRACT

Ongoing failure to resolve how wildlife and people can co-exist on private land contributes to the global decline of wildlife populations. Experience in Tasmania, Australia suggests a disconnect between wildlife researchers, environmental agencies, and private landholders that prevents new scientific insights from translating into improved wildlife management practices. This case study based on a participatory action research model, describes a wildlife conservation initiative called WildTracker. WildTracker created hands-on collaborations among private landholders, university researchers, and the Tasmanian Land Conservancy (TLC). Landholders from 3 regions (total area 9977 km^2) participated in an iterative 2-year research process involving problem-framing workshops, data collection (mammals, birds, and habitat) using wildlife cameras and sound recorders, data analysis, and discussion of results. Participants contributed more than 2,000 hours to the project, resulting in more than 500,000 wildlife observations, with many landholders now implementing research findings, guided by locality-specific data on wildlife populations, feral animals, and habitat condition. WildTracker has evolved from a short-term participatory research project into an ongoing collaborative citizen science program that is documenting and contributing to on-the-ground and evolving wildlife conservation outcomes.

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KEYWORDS:
citizen science; wildlife monitoring; participatory action research; nature conservation; socio-ecological systems; private lands

TO CITE THIS ARTICLE:
Taylor, M, Davison, A and Harwood, A. 2023. Bridging Knowledge Creation and Conservation Practice through Participatory Action Research on Private Lands. *Citizen Science: Theory and Practice,* 8(1): 6, pp. 1–13. DOI: https://doi.org/10.5334/cstp.428

INTRODUCTION

The early Anthropocene is witnessing a global mass-extinction event, driven by human activities. Vertebrate species such as mammals and birds are especially at risk, with populations of most species declining rapidly in almost every terrestrial ecoregion (Ceballos et al. 2015) owing to pressures such as habitat loss, invasive species, and climate change (Almond et al. 2020). Productive landscapes in wealthy countries are mostly privately owned and have historically been the focus of human activities because they provide abundant natural resources (Henle et al. 2008). This has created a conflict between the interests of people and those of wildlife. Private land nevertheless continues to support rich assemblages of native wildlife, including many threatened species (Rayner et al. 2014). In contrast, public lands including protected areas occur disproportionately on marginal land that supports a lower density of wildlife (Jenkins 2015). At a time of rapid social and ecological change, engaging landholders in wildlife conservation activities on private land is therefore critical to addressing ongoing decline in wildlife populations. The biophysical causes of wildlife decline have been well researched, and effective ecological approaches to wildlife conservation have been developed (Lindenmayer, Franklin, and Fischer 2006; Lindenmayer, Morton, and Dovers 2014; Tilman et al. 2017). The challenge of implementing effective conservation on private land does not lie primarily with understanding of wildlife ecology, but with the need to integrate human and non-human needs in the context of the ecological characteristics of landscapes and the social practices associated with private land (Toomey, Knight, and Barlow 2017).

Efforts to conserve wildlife on private land need to recognise that landholders are as diverse in their motivations, values, and practices as the landscapes they inhabit and the ecosystems and species that share those spaces (Agnoletti and Rotherham 2015; Maffi 2012). This diversity presents challenges to the types of collective, coordinated, and ongoing actions required to manage highly mobile wildlife at the landscape scale. What works in one situation may not translate to other places because each landscape has distinct social and ecological characteristics. In addition, increasing pressure on natural resources because of human development and associated processes of environmental and climate change mean that landscapes are undergoing rapid change, both social and biophysical (Pecl et al. 2017). Approaches to wildlife conservation in these landscapes must therefore integrate the interests of people and nature, which change depending on context and over time.

Wildlife conservation across private landscapes is therefore an example of a wicked problem that requires novel transdisciplinary solutions (DeFries and Nagendra 2017; Mason et al. 2018). Wicked problems involve multiple interacting systems, diverse stakeholders with diverse values, shifting contextual factors and challenges, and contested terms of problem definition (Rittel and Webber 1973). The challenge of responding to such problems is often compounded by the simultaneously fragmented and universalised basis of much modern knowledge that produces siloed disciplines and understanding removed from context (Head and Xiang 2016).

Translating expert-driven ecological research into on-the-ground land management practice is a significant challenge in wildlife conservation. There is a well-documented disconnect between conservation science and the practical delivery of conservation actions by land managers, including private landholders (Arlettaz et al. 2010; Toomey, Knight, and Barlow 2017). The communication of conservation science is impeded by publication of research findings in specialist subscription-only journals not widely available to landholders, land managers, or conservation practitioners. Scientific terminology and complex statistical analyses are often inaccessible to the land managers who could find that knowledge useful for decision making. Where research findings are made available to stakeholders, it is often through linear, one-way communications that reinforce a separation between research producers and potential consumers' thereby failing to capitalise on and benefit from avenues for pluralistic and dialogical communication and knowledge generation (Leith et al. 2018; Wallis et al. 2017). While there are welcome efforts to make scientific findings more accessible, these efforts are not always successful or made widely available (Safford et al. 2017). It is thus difficult for non-expert landholders to interpret research findings and translate knowledge into something meaningful to them or useful for their circumstance. One outcome of this disconnection between conservation science and conservation practice has been that the forms of knowledge produced by researchers may not provide answers to the questions that land managers are asking.

Transdisciplinary research seeks to avoid the disconnection of knowledge and practice through collaborative methodologies that enable academic disciplines to coproduce knowledge with each other and with practitioners outside of the academy (Chettiparamb 2007). Examples of collaborative approaches to conservation include frameworks such as Alternative Futures (Baker et al 2004), citizen science co-design projects (Shirk et al 2012), and participatory action research (Milich et al 2021). Participatory action research methods,

in particular, help address wicked problems in conservation by involving people who are embedded in those problems within the research process, particularly in relation to problem-framing and tailoring practical responses to specific settings (Laurance et al. 2012). Co-creating wildlife conservation research allows land managers to help set the research agenda, ensuring that the questions that are being asked by researchers reflect the issues, contexts, and knowledge shortfalls of the people who can respond to that new knowledge (Fortmann 2009). Through capacity building of participants and interpersonal bonds created among researchers, conservation organisations, and land managers, these methods also have potential to translate research projects into collaborative on-the-ground conservation programs.

Wildlife in Australia face a range of well understood threats including habitat loss, habitat degradation, invasive species, feral animals, and climate change (Dickman 2018). These factors are leading to significant declines in iconic species such as the koala (*Phascolarctos cinereus*) and the Tasmanian devil (*Sarcophilus harrisii*), and they are placing entire ecosystems in peril (Tilman et al. 2017). The emergence of conservation efforts to tackle these problems on private land since the 1980s in Australia has attracted significant research into the opportunities for private land conservation (Figgis 2004, Fitzsimons and Westcott 2007; Iftekhar et al. 2014). These studies highlight some of the challenges of engaging with landholders and identify potential benefits from participatory and collaborative approaches to conservation. To address conservation challenges on private land, it is essential that sufficient landholders are engaged at a scale that is ecologically appropriate. It is also essential that landholders have easy access to the knowledge and skills held by researchers and professional land managers. Finally, landholders need information that is appropriate to local contexts and relevant to their specific circumstances (Hilty and Merenlender 2003; Pannell et al 2006). There are no one-size-fits-all solutions to wildlife conservation in private landscapes.

In this context, we offer a methodological reflection and assessment on the citizen science project WildTracker as an example of how participatory action research can bridge the gap between researchers and practitioners and build capacity for ongoing collaborative conservation programs. WildTracker involved 160 private landholders in Tasmania, Australia over 2 years in research that aimed to identify the key socioecological drivers of conservation outcomes for populations of mammals and birds on private land. The project was transdisciplinary, delivered as a partnership between an academic institution (University of Tasmania), a not-for-profit environmental organisation (Tasmanian Land Conservancy), and three geographical communities of private landholders (Derwent Valley, Huon Valley, and Bruny Island).

This paper presents our findings regarding the co-benefits of a participatory action research conservation project, in terms of engagement and empowerment of research participants and partners. Participants collected data and contributed to analysis about habitat quality, distribution, and relative abundance of native mammals, birds, and feral animals, derived from more than 500,000 property-based observations. This significant ecological dataset was complemented by socioeconomic data on land management practices derived from interviews and surveys. This dataset is being analysed to identify socio-ecological drivers of wildlife conservation outcomes at a range of spatial scales and will be the subject of subsequent publications. Preliminary findings indicate that both local and neighbourhood factors are significant influences on native mammal and bird populations, with implications for local collaboration and coordination of conservation efforts for wildlife across property boundaries. However, detailed discussion of substantive research results is outside the scope of this methodological case-study, which focuses instead on findings relating to the benefits and challenges of our participatory methodology.

METHODOLOGY

PARTICIPATORY ACTION RESEARCH APPROACH

Participatory action research has a broader set of objectives than conventional research approaches that focus on academic knowledge creation. These broader objectives include community engagement, local empowerment, building trust in findings, and implementing solutions (Chevalier and Buckles 2019; Fortmann 2009; Strasser et al. 2019). While the overarching research aim of WildTracker was to identify social and ecological drivers of wildlife conservation outcomes in Tasmania, we also had a set of long-term conservation objectives: to provide each landholder with an opportunity to learn about their own property and region; for landholders to build their land management capability; and to grow a community of practice (Wenger 2000) that could contribute towards enduring outcomes for wildlife conservation. Research questions at the outset of this project were deliberately open and generative. Our intention was to give space for the research questions, agenda, and process to shift and adapt in response to landholder participation in interviews and workshops, enabling landholders to develop tailored research models and identify contextual factors that they felt were important in understanding wildlife conservation.

Given these desired outcomes, the research team trialled a participatory action research approach that could evolve into an ongoing community-based model of ecological monitoring and wildlife conservation. The research started with field-based ecological data collection using standard methods. These methods were then refined based on input from both researchers and landholders at multiple stages, in an iterative and reflexive research process (Figure 1). The research involved private landholders in three regions in southeast Tasmania in a pilot program to test methods for wildlife and vegetation monitoring and to solicit feedback on those methods. By engaging private landholders as citizen scientists, we aimed to leverage project resources to gather a richer ecological dataset than would otherwise be possible. By involving participants in the scoping and design of the research questions, it was also hoped that they would become more embedded and invested in the research process and gain greater insights about conservation matters that were of specific interest and relevance to their own context. Equally, the detailed, embodied, and tacit knowledge that many landholders have of their property was valuable in helping translate conservation science expertise into on-the-ground applications.

This research was a collaboration between conservation managers from the Tasmanian Land Conservancy (TLC), ecological and social science researchers from the University of Tasmania (UTAS), and a diverse mix of private landholders based in three rural regions in southern Tasmania. Those regions were selected because of their contrasting ecological and socio-economic characteristics, allowing for cross-regional comparison across these three sub-samples within the larger study. The collaboration was named WildTracker to help define, identify, and promote the project. During initial scoping for WildTracker,

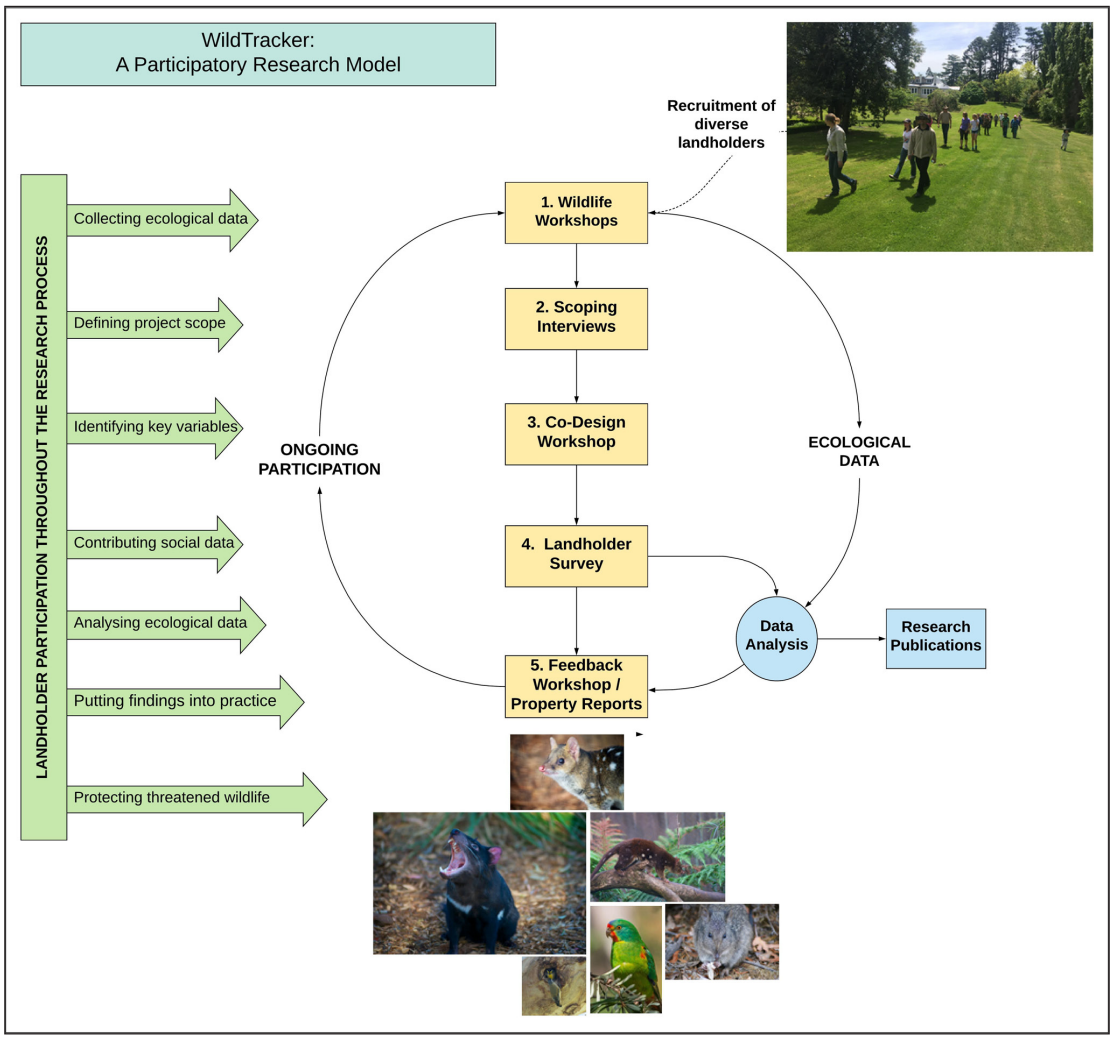

Figure 1 The WildTracker model involved landholders in each stage of the research process and has led to positive outcomes for participants, researchers, and native wildlife. This process of inquiry and feedback has continued beyond the life of the research project, evolving into an embedded conservation project, WildTracker, that continues to engage landholders in the trial regions and is being rolled out into other Tasmanian landscapes.

significant thought and planning was put into designing a framework that could deliver research outcomes as well as provide a practical model that would benefit landholders and continue to be applied as an ongoing conservation program, incorporating and building on the findings of the research. The overarching research aims were to identify key socio-ecological drivers of wildlife conservation on private land and to understand how issues of spatial scale in land management affect populations of mammals and birds, as well as the condition of their habitat. The practical outcomes that we hoped to achieve included testing novel methods for ecological data collection using a citizen-science model designed to inform landholders and conservation agencies in the task of improving wildlife management practices.

THE ROLE OF THE RESEARCH TEAM

One of the features of participatory action research is that the traditional boundaries between researchers and participants become fuzzy. The lead author is a landholder living on a 20-hectare farming property in the Huon Valley study region, an ecologist employed with the Tasmanian Land Conservancy, and a PhD candidate in socioecology at the University of Tasmania. The research team realised that having a member who was simultaneously a landholder, professional conservation practitioner, and researcher, while potentially a cause of bias, also provided a unique opportunity for facilitating research that could bridge the gap between scientific enquiry and conservation practice. Our participatory research model provided opportunities for researchers to engage in the research process in a more holistic way, with the lead researcher able to identify with the circumstances of the landholders, while also understanding the potential practical conservation benefits that could be realised from an interactive and engaging research process. This big-umbrella approach, in which many organisational and private stakeholders are invited to participate, has been advocated for as an engagement technique by participatory action researchers (Chevalier and Buckles 2019), and in the applied context of bridging the gap between knowledge generation and conservation practice (Cook et al. 2013). The positioning of the lead author with insider understanding of the three tribes of researchers, conservation practitioners, and private landholders facilitated recruitment of a diverse cohort of landholders.

STUDY REGION

The project was based in three regions in southeast Tasmania characterised by contrasting and distinctive ecological and socio-economic conditions (Figure 2). The Derwent Valley is a highly modified landscape where

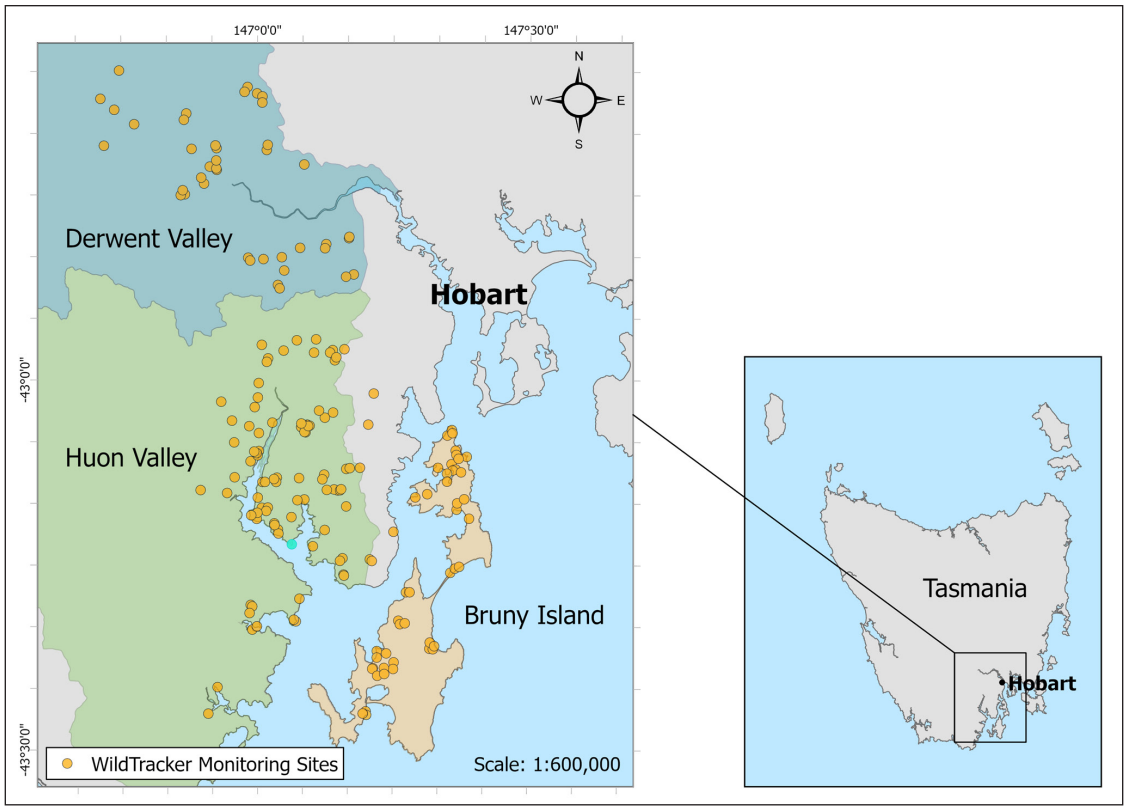

Figure 2 Map of the study region in southeast Tasmania, showing approximate location of properties involved in the research.

native vegetation has been extensively cleared, and the land tenure is dominated by large farming enterprises (>1000 hectares), with numerous smaller rural holdings in side-valleys. The Huon Valley has extensive areas of intact native vegetation on public land, surrounding a narrow, productive, privately owned, fertile valley where horticulture, aquaculture and tourism are the main industries. Bruny Island has transitioned from a natural-resource-based community to one based on tourism and recreation, with many absentee landholders ("shack" or holiday homeowners).

PARTICIPANTS

Over a 20-year history of delivering environmental programs on private land, the Tasmanian Land Conservancy has developed extensive professional and interpersonal networks amongst rural landholders. Landholders were recruited primarily through these networks, but also through advertising in local media and distribution of flyers on community noticeboards. The project was presented as offering landholders an opportunity to discover the mammals (which in Tasmania are mostly cryptic and nocturnal) and birds that live on their property, and thereby contribute towards a research project and ongoing conservation efforts (Figure 3). This pitch was crafted to have as broad an attraction as possible, with images of iconic mammal and bird species with wide appeal amongst the Tasmanian community. A deliberate effort was made to recruit owners of commercial farming enterprises through direct approaches via established networks. This was done to involve a more representative cross-section of the community, while also acknowledging that large-

Figure 3 An example of workshop flyer used to promote the WildTracker citizen science research program.

scale commercial farming enterprises can, through their decision making, have major influences on the wider social and ecological landscape. The wildlife conservation co-design workshops also involved a group of Tasmanian environmental researchers and conservation practitioners.

WILDTRACKER RESEARCH MODEL

The research developed iteratively through five discrete stages: scoping, preliminary data collection, co-design, secondary data collection and feedback (Figure 1). Following the data collection, findings specific to each property were collated into conservation action plans for each of the 160 participating landholders, enabling participants to put the findings specific to their property into practice (see Figure 2 for distribution of properties). The co-design, data collection, and implementation elements of the WildTracker model conform to the core elements of participatory action research identified by Buckles (2013). The research process was flexible and designed to accommodate landholders with different levels of availability and interest. While some landholders engaged in only one or two stages of the research, a significant cohort participated in every stage, from initial scoping and research question framing, through to data collection and analysis, and culminating in on-the-ground implementation of findings. The five stages of the WildTracker participatory action research model are presented in detail as supplemental material (Appendix 4).

RESULTS

ENGAGING DIVERSE STAKEHOLDERS

There was a much higher level of participation in and enthusiasm for the research and ongoing conservation program than the research team had anticipated and that had occurred previously when non-participatory approaches have been tried by the TLC. For example, at the Huon Valley citizen science wildlife workshop, where the flyer had advertised a free barbeque as an enticement, a hectic day of food preparation ensued when an expected group of 25 turned into a gathering of more than 80 landholders! This high response rate was mirrored in both Bruny Island and the Derwent Valley, where a diverse cross-section of the community attended, ranging from commercial operators of large farms to smaller non-commercial, environmentally focused landholders. The landholder survey similarly engaged a diverse range of landholders who participated in the project, including conservation landholders, tourism and hospitality business operators, and graziers and horticulturalists with enterprises ranging from small-scale to multi-million-dollar businesses.

PEOPLE LIKE TO BE ABLE TO CHOOSE THEIR LEVEL OF PARTICIPATION IN RESEARCH

The research program provided opportunities for landholders to participate to varying degrees in terms of time commitment and activities involved. At the lowest level of engagement, participants provided their property as a venue for ecological research and may have completed a survey (24% of participants). At the other end of the spectrum of engagement, there were landholders who attended workshops, collected data from multiple sites on their properties, attended wildlife identification and analysis workshops, analysed the data from their property and others, were interviewed, attended co-design workshops, completed a social survey, and attended feedback workshops (8% of participants). The ability to participate to varying degrees was identified by participants at all three feedback-feedforward workshops as a valuable aspect of the program and has been shown in other citizen science projects to aid recruitment and retention (Maund et al. 2020; Seymour and Haklay 2017).

LANDHOLDERS WERE EXCITED TO LEARN ABOUT WILDLIFE ON THEIR PROPERTY IN A HANDS-ON WAY

At feedback-feedforward workshops, through informal discussions with researchers, participants expressed their satisfaction with the hands-on citizen science approach, in which they were actively involved in several sensory-based forms of data collection (cameras, sound recorders). They also expressed a sense of reward gained from learning about wildlife, including species on their properties of which they were unaware. We found that soliciting ongoing feedback from participants is an important element of participatory action research and citizen science that ensures that research remains relevant to stakeholders, a finding supported by the literature (Becker-Klein, Peterman and Stylinski 2016; Buckles 2013). Many participants took the initiative of contacting researchers regularly with questions or to resolve issues, highlighting the flexible, pluralistic nature of communications that can evolve through participatory research approaches.

CO-DESIGN BRINGS PEOPLE TOGETHER, SHARES LEARNINGS, AND CREATES NETWORKS

The co-design workshop provided landholders, practitioners, and researchers with opportunities to interact and solve problems in an authentic, fluid, and semi-structured way that facilitated an open exchange of ideas, learning together, and trust building. Participants and researchers alike came from diverse backgrounds and occupations, with different degrees of knowledge

about wildlife management, and different perspectives on environmental issues. This was an opportunity for groups of people to interact beyond their usual peer groups with other groups with the same interest but different approaches to knowledge and practice. Participants were empowered to shape the direction of research, increasing the relevance of findings to their context and needs. For example, once neighbourhood effects were identified as highly important during scoping interviews, this factor was incorporated into both the subsequent workshop phase of the research and the landholder questionnaire sent to properties neighbouring ecological monitoring sites. Participant involvement also cultivated enthusiasm for the research process that resulted in some participants providing higher levels of engagement in terms of time and effort.

RESEARCHERS, PROFESSIONALS, AND LANDHOLDERS SEE THE WORLD DIFFERENTLY

The co-design workshop produced social-ecological systems models, prepared by the researchers, practitioners, and landholders working in three separate groups. We were interested in seeing if the perspectives of these groups differed and whether these perspectives could be meaningfully synthesized in a combined model. A synthesis model was developed based on mutual feedback provided by each group on the other groups' models. While there were some similarities in conceptual diagrams produced by each group, there were also clear distinctions. Landholders created a non-hierarchical model, with each variable node linking directly to other nodes in a flat web. The researchers and to a lesser degree the conservation practitioners introduced additional layers of hierarchy to their models to express groupings of concepts or collections of related variables (Figure 4). These contrasting approaches could reflect a greater degree of structured, conceptual thinking inherent in the research profession (Moon et al. 2019). However, this doesn't necessarily imply greater accuracy in their representation of ecological and social phenomena and interrelations. Landholders may have greater degree of experiential knowledge, but less familiarity with processes of conceptualisation, synthesis, and generalisation of ecological phenomena (Jones et al. 2011). This divergence of perspective across practice groups also provides an opportunity for triangulation and the bringing together of contrasting and complementary perspectives and experiences (Mertens 2015). This may provide opportunities for integration of understandings through direct personal interaction, where people have an opportunity to compare and contrast ideas and to learn from each other. For example, the workshops saw a shift in focus of the project from the individual property to the landscape scale, based on complementary feedback from the landscape ecology perspectives of researchers and the tacit experience of landholders living alongside neighbours and witnessing neighbourhood effects on the wildlife on their properties.

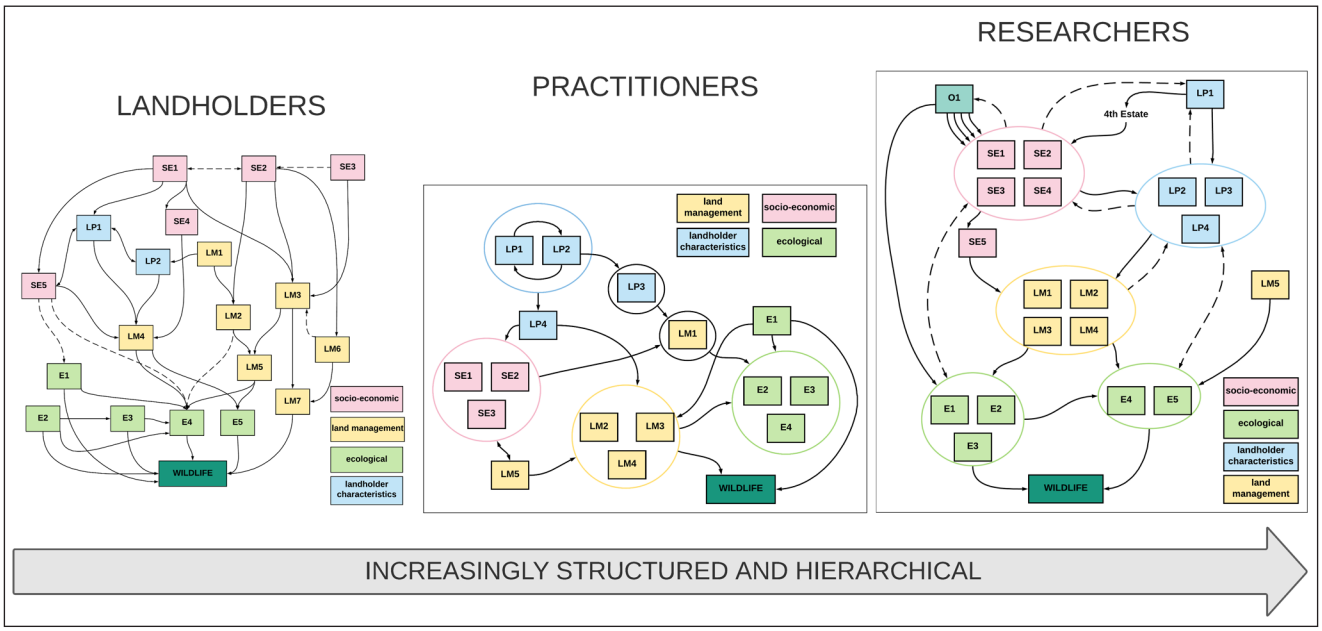

Figure 4 Social-ecological systems models developed by landholders, conservation practitioners, and academics, display increasing levels of conceptualisation. These differences in perspectives regarding the same system of interest reflect the difference in research approach that might occur with a researcher-led process of inquiry in comparison with a participatory model.

ON-THE-GROUND OUTCOMES

Landholders reported at feedback workshops and in direct communications with researchers an increased awareness of their properties and, to a lesser degree, changes to their land management practices. This gap between increased awareness and changed practices may be because there are additional factors that limit peoples' capacity to manage environmental issues, such as time or financial constraints (Greiner and Gregg 2011). There were, however, many encouraging examples of on-the-ground implementation of evidence-based wildlife conservation practices. For example, the discovery of wildlife species that are susceptible to predation by cats and dogs lead in many cases to landholders being more mindful and proactive in terms of control of their pets. Some landholders discovered that they had infestations of weeds and were able to use that information and their connection with TLC and local Natural Resource Management groups to secure funding for weed management.

EVOLUTION INTO AN ONGOING CONSERVATION PROGRAM

One of the most important outcomes of this research is the successful transitioning of this project from knowledge generation into ongoing conservation practice. Since the conclusion of the participatory action research project, WildTracker has become an ongoing conservation initiative of TLC, demonstrating the management potential of research partnerships that involve environmental organisations with on-the-ground program delivery capacity. The WildTracker program has taken methods refined from the research and adapted them in response to the feedback from landholders and continues to engage with many of those landholders in an ongoing relationship around ecological monitoring and conservation management. An existing community group on Bruny Island that included research participants and a new community group formed by participants in the Huon Valley have both secured funding to purchase wildlife cameras and run additional workshops on a range of conservation topics including wildlife management. These groups are using the WildTracker methods and have generated valuable ecological data over several years, even extending the scope of their endeavours to bat monitoring. These data are now being used to target recovery actions of a threatened species and have detected declines in several others, demonstrating the usefulness of WildTracker to inform conservation management at a range of scales. An example of practice changes reported via the WildTracker program include restoration of habitat for endangered species such as eastern barred bandicoots (*Perameles gunnii*), through replanting or stock exclusion from sensitive areas.

DISCUSSION

Participatory action research initiatives such as WildTracker can effectively address wicked problems such as wildlife conservation on private land by creating a foundation for ongoing collaboration, capability building, knowledge translation, and practical application, thereby extending the impact of research findings. A strength of the participatory action approach documented here is that research findings are generated by citizen scientists who, as landholders, can practically apply these findings. In this citizen science case study, the research process has delivered a range of benefits to researchers, practitioners, and landholders beyond scientific results. A longer-term collaboration has formed as the project has transitioned from research into an ongoing conservation program. While the participatory approach created logistical challenges and was relatively resource intensive, it also generated significant benefits to participants and has resulted in direct conservation outcomes for threatened wildlife species.

There are several aspects of the WildTracker model that contributed to the successful implementation of this novel research design. The project was highly inclusive, involving diverse stakeholders including conservation researchers, practitioners, and landholders across three socially and ecologically distinct regions. This diversity may reflect the project's focus on wildlife management rather than land conservation as nature-conservation focused research in Tasmania and elsewhere typically attracts participants who identify as conservation minded and often misses representation from a wider cross-section of the community (Langpap 2006; Nuno and St. John 2014; Wossink and Van Wenum 2003).

One of the most rewarding aspects of the project, reported by both researchers and landholders, was the excitement involved in making an unexpected discovery of a rare animal or other aspect of the ecological character of a property. This element of the research was enhanced by the data collection methods, which facilitated an experiential approach based on sensory data: photography of both vegetation and wildlife, and acoustic recordings of birds and other ambient noises. These sensory methods lessen the abstraction of gathering data in the form of numbers and technical terminology. Citizen scientists in the project could clearly see and hear what constitutes the raw data they were collecting. There is a common language to images and sounds that transcends narrow expertise, jargon, and technical concepts and that can facilitate participatory conservation (Pijanowski et al 2011; Krause 2016). As a result, these data came in a format that landholders are used to interpreting, and this process

of self-interpretation can dissolve some of the barriers to communication we noted in the Introduction and provide an engaging basis for further skill development.

The wide base of participation brought many people with an interest in wildlife conservation together to provide input and share perspectives on conservation practice. This approach drew upon and fostered networks within communities, and between researchers and land managers, that have the potential for long-term social and conservation benefits. The involvement of an environmental NGO allowed our original research model to swiftly be adapted into WildTracker a collaborative program that continues to involve landholders in wildlife monitoring and conservation action. The advantage of this partnership is that it brought different skill sets together. TLC was able to assist with recruitment through its broad network of landholder contacts and was able to provide ongoing support to landholders as the research phase evolved into an ongoing conservation program. The role of the primary researcher, with connections as a fellow landholder, researcher, and conservation practitioner, proved useful in both recruitment and maintaining ongoing relationships between participants. Broad participation and lasting relationships are essential if the types of wildlife conservation knowledge generated by research are to be implemented at sufficient spatial and temporal scales to be meaningful for wide-ranging wildlife species and to lead to real outcomes.

The WildTracker citizen science model provided multiple opportunities for landholders, conservation practitioners and researchers to participate at different phases of the research process, including research design, data collection and analysis, interpretation, and subsequently implementation. This created many logistical challenges in terms of planning, communication, and coordination, but also meant that the project was flexible, adaptive, and iterative. This enabled landholders to steer the research focus toward topics relevant to their circumstances, thereby generating knowledge that is useful and can inform their approach to wildlife conservation and land management. Those who were interested in the research but had insufficient time or confidence to undertake some or all data collection tasks felt that they could still be involved and rewarded by information about their property and region. The downside of this flexible approach was that it created logistical complexity that stretched the resources of the research team and volunteers. The communication between researchers and 160 landholders alone presented a major challenge and the logistical challenges of active participation should never be underestimated (Conrad and Hilchey 2011; Pecl et al. 2019). For example, the preparation of 160 individual property reports took many months. Technology can be a way to overcome some of these logistical challenges. For example, to manage the logistical challenges of data collection, analysis, and data management, the WildTracker team is now developing and trialling a website and mobile app, which will facilitate future data collection and automatically complete much of the analysis and reporting.

CONCLUSION

If we are to address wicked problems like wildlife conservation on private land, it is essential that those in a position to make a practical difference are able to make informed decisions appropriate to local contexts. Our research has shown that collaborative approaches are highly effective at generating locally relevant ecological knowledge. However, it is the research process of WildTracker that has most directly addressed the wicked problem of wildlife conservation on private land, rather than the research findings. Since the initial research and co-design trial phase, WildTracker has evolved into an ongoing engagement and conservation initiative that has connected hundreds of landholders to researchers and conservation practitioners across Tasmania. We advocate for the creation of similar ongoing collaborative citizen science initiatives that build community capacity to address environmental problems, by creating durable connections between diverse groups of people and facilitating knowledge creation and information flow. Over the medium to long term this will help those communities to adapt and respond to increasing environmental threats and implement practices that are effective at conserving local wildlife populations.

SUPPLEMENTARY FILES

The supplementary Files for this article can be found as follows:

- **Appendix 1.** Scoping Interview Questions. DOI: https://doi.org/10.5334/cstp.428.s1
- **Appendix 2.** Landholder Survey Questions. DOI: https://doi.org/10.5334/cstp.428.s2
- **Appendix 3.** Social Ecological Systems Models. DOI: https://doi.org/10.5334/cstp.428.s3
- **Appendix 4.** WildTracker Participatory Research Model. DOI: https://doi.org/10.5334/cstp.428.s4

ETHICS AND CONSENT

This project has received human and animal ethics permits from the University of Tasmania's Human Research and Animal Ethics Research Committees (refs. H0016014 and A0015788). All research participants have provided written consent to participate and for their data to be used for this publication.

ACKNOWLEDGEMENTS

The research team wishes to acknowledge the invaluable contribution of our research partner the Tasmanian Land Conservancy, which provided major financial, logistical, and technical assistance with this project. Dr Michael Lockwood was the initial supervisor of this research project and contributed substantially to research design. Professor Chris Johnson and Professor Barry Brook are part of the research team and have contributed substantial ecological knowledge to the design of the project. We would also like to thank the many participating landholders who contributed their time, ideas and enthusiasm that made this research possible. Finally, we'd like to thank NRM South and the Land for Wildlife Program, which provided funding and assistance with recruitment of participants.

COMPETING INTERESTS

The authors have no competing interests to declare.

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TO CITE THIS ARTICLE:
Taylor, M, Davison, A and Harwood, A. 2023. Bridging Knowledge Creation and Conservation Practice through Participatory Action Research on Private Lands. *Citizen Science: Theory and Practice*, 8(1): 6, pp. 1–13. DOI: https://doi.org/10.5334/cstp.428

Submitted: 13 April 2021 **Accepted:** 11 December 2022 **Published:** 08 February 2023