



HAL
open science

Living with rodent pests: Unifying stakeholder interests to prioritise pest management in rural Madagascar

Kathryn Scobie, Xavier Lambin, Sandra Telfer, Mendrika Fenohasina Rasahivelo, Rova Nandrianina Raheliarison, Minoarisoa Rajerison, Juliette Young

► To cite this version:

Kathryn Scobie, Xavier Lambin, Sandra Telfer, Mendrika Fenohasina Rasahivelo, Rova Nandrianina Raheliarison, et al.. Living with rodent pests: Unifying stakeholder interests to prioritise pest management in rural Madagascar. *People and Nature*, 2023, 5 (2), pp.713-725. 10.1002/pan3.10438 . hal-04087209

HAL Id: hal-04087209

<https://hal.inrae.fr/hal-04087209v1>

Submitted on 3 May 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Living with rodent pests: Unifying stakeholder interests to prioritise pest management in rural Madagascar

Kathryn Scobie¹  | Xavier Lambin¹  | Sandra Telfer¹  |
 Mendrika Fenohasina Rasahivelo² | Rova Nandrianina Raheliarison² |
 Minoarisoa Rajerison³ | Juliette Young⁴ 

¹University of Aberdeen, Aberdeen, UK

²Université d'Antananarivo, Antananarivo, Madagascar

³Plague Unit, Institut Pasteur de Madagascar, Antananarivo, Madagascar

⁴Agroécologie, INRAE, Institut Agro, Université de Bourgogne Franche-Comté, Dijon, France

Correspondence

Kathryn Scobie
 Email: kascobie@gmail.com

Funding information

Biotechnology and Biological Sciences Research Council, Grant/Award Number: BB/M010996/1; Medical Research Council, Grant/Award Number: MR/T029862/1; National Institute for Health Research, Grant/Award Number: 219532/Z/19/Z; Wellcome Trust, Grant/Award Number: 095171/Z/10/Z

Handling Editor: Darryl Jones

Abstract

1. Rodent pests can have major social, economic, and environmental impacts. Their management, therefore, represents a complex socio-ecological problem involving a network of stakeholders from across different sectors, with diverging and sometimes competing interests. Failure to incorporate stakeholder interests can result in ineffective or unsustainable management programmes, with unintended negative consequences for people and nature.
2. Participatory approaches to decision-making have been proposed as suitable strategies to tackle complex problems, yet, these processes are often considered too difficult, costly, or time-consuming to implement.
3. To facilitate a participatory approach to rodent control in Madagascar, we identified and mapped key stakeholders and developed a multisector framework for guiding rodent management programmes based on current literature and expert recommendations. We then carried out interviews and focus groups with stakeholders and end-users to validate the final framework.
4. The final framework unifies stakeholder interests around the dimensions of People, Resources, Knowledge and Power. Combined application of the stakeholder map and framework provides decision-makers with the tools to identify stakeholder interests; to explore areas of conflict, as well as areas of agreement; and to ensure that these are addressed within the design of control programmes. As an assessment tool, the framework can also be used to evaluate the responsiveness of programmes to the needs of different stakeholders and assess whether objectives are being reached.
5. We recommend the application of the stakeholder map and framework to encourage and strengthen participatory approaches aimed at rodent pest control. Due to the inclusive and interdisciplinary nature of the framework, it can be applied to address numerous complex social, environmental, and economic issues across scales, sectors, and systems.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2023 The Authors. *People and Nature* published by John Wiley & Sons Ltd on behalf of British Ecological Society.

KEYWORDS

stakeholder engagement, community-based intervention, Madagascar, agriculture, rodent control, public health, management actions

1 | INTRODUCTION

Worldwide, the proliferation of invasive rodents has severe implications for public health, food security and biodiversity loss. Pre- and post-harvest losses to rodent pests contribute to malnutrition and global food insecurity (Meerburg, Singleton, et al., 2009). Rodents also contaminate stored food, attack livestock, and damage infrastructure (Constant et al., 2020; Stenseth et al., 2003). Furthermore, rodents are reservoirs for over 60 zoonotic diseases transmissible to humans and animals, with catastrophic implications for the most vulnerable communities (Meerburg, Singleton, et al., 2009).

Due to their significant and widespread impacts, rodent pest management represents a complex socio-ecological problem involving stakeholders from across different sectors (Huan et al., 2010; Makundi et al., 1999; Palis et al., 2010). A major challenge in addressing complex problems is the need to incorporate the diverse and sometimes competing interests of different stakeholders (Parrott, 2017). By establishing multi-stakeholder relationships and actively engaging with end-users, participatory approaches have helped to tackle complex problems within the fields of public health (e.g. van Limburg et al., 2015; van Woezik et al., 2016; Wentzel et al., 2012) and invasive species management (e.g. Crowley et al., 2017; García-Llorente et al., 2008; Novoa et al., 2018; Shackleton et al., 2015). In rodent management, there is a need for approaches which integrate the complexity of rodent pest issues whilst being inclusive of the diverse interests of multi-sectoral and multi-scale stakeholders (Constant et al., 2020; Makundi & Massawe, 2011; Palis et al., 2011; Singleton et al., 2004; Swanepoel et al., 2017; Taylor et al., 2008).

In Madagascar, rodent pests are primarily perceived as a public health concern due to endemic plague (Andrianaivoarimanana et al., 2013; Constant et al., 2020). Madagascar's Ministry of Health thus makes recommendations for rodent pest control following advice from partners including the World Health Organization and the Pasteur Institute. Their interest centres on reducing plague risk, particularly through minimizing contact between humans and plague vectors (i.e. rodents and their fleas). Indeed, following a particularly severe plague outbreak in 2017, there has been renewed interest in understanding the role of rodent control in plague prevention strategies (Belmain et al., 2018; Vallès et al., 2020).

However, rodent pests also threaten food security in the country (Harvey et al., 2014). Rats in particular are estimated to have caused pre-harvest losses of over 100,000 tonnes of paddy rice in 2021 (Duplantier & Rakotondravony, 1999; FAO (Food and Agriculture Organization of the United Nations), 2021). Madagascar's Ministry of Agriculture, therefore, has an interest in rodent control; they make management recommendations based on research conducted at the National Centre of Applied Research for Rural Development (FOFIFA) and have traditionally advocated the use of lethal methods (Direction de la Protection des Végétaux, Antananarivo, pers. commun.).

Despite their impact, effective rodent pest management has not been established in Madagascar. Control programmes have involved little collaboration between different stakeholders and typically focus on managing plague outbreaks rather than prevention. There is also continued dependence on non-selective methods, such as lethal traps and poisons, which impact non-target species and the environment. Both Ministries are hindered by a lack of resources and the Malagasy government is highly dependent on financial and technical support from donors (Ravaoarisoa et al., 2020).

Failure to integrate local perspectives has also hampered ministry-level decisions on health- and agriculture-related policies. For example, a poor understanding of plague transmission, combined with the spread of misinformation through informal channels, contributed to an overall distrust of health authorities and further stigmatization of the plague during Madagascar's 2017 plague outbreak (Mattern et al., 2019; Ramaroson et al., 2019). This resulted in widespread resistance to safeguarding measures (e.g. safe burials) and reluctance to seek medical help. In rodent pest control, social taboos can influence the local acceptability of control measures. For example, in some Malagasy communities, indigenous predators such as owls or snakes are associated with occult practices such as witchcraft (Constant et al., 2020); these communities may resist strategies that encourage these 'taboo species' as a means of rodent control.

In light of the above, there is a clear need to better understand the perspectives of different stakeholders towards rodents and their control; to identify appropriate rodent management goals and to facilitate the integration of multi-sectoral and multi-scale stakeholder interests within clearly defined decision-making processes. In this paper, we outline the framework for guiding the design, implementation, and evaluation of community-based interventions, taking rodent control in Madagascar as a model. Drawing on current literature and expert recommendations, we validate the framework through interviews and discussions with stakeholders and end-users following a structured and replicable process to identify relevant stakeholders existing at the national, regional, district and village levels. We then present the final framework before reflecting on its application within Madagascar's health and agriculture sectors, as well as its potential for addressing a broad range of complex social and ecological problems.

2 | METHODS

2.1 | Designing the preliminary framework

To identify common factors linking successful community-based interventions, we conducted a literature review in Scopus using the search term: TITLE-ABS-KEY (Madagascar AND community AND (evaluat* OR assess*) AND (management OR intervention)). Subject areas included agriculture, biological science, environmental

science, medicine, and social science. Results ($n = 119$) were manually screened based on titles and abstracts, retaining articles or reviews which evaluated the efficacy of community-based interventions in Madagascar ($n = 16$).

The literature review had three objectives to identify: (1) common intervention approaches, (2) emergent concepts linking successful interventions and (3) existing frameworks. To extract the relevant information, we conducted a series of coding iterations. First, we identified the type of intervention and method of evaluation. We then extracted information on the strengths and weaknesses of each intervention and the lessons learned, as well as information from existing relevant frameworks (e.g. Raik & Decker, 2007), to create a list of attributes (Appendix S1). Similar attributes were grouped to create a smaller set of categories or themes around which a preliminary framework was constructed (Table 1).

To supplement the literature review, we interviewed key informants representing researchers, technicians, and government officials from the agriculture, environment, and public health sectors ($n = 6$). Interviews were unstructured and any predetermined questions were open-ended. All factors identified as important in the design, implementation and evaluation of rodent-control programmes were, thus, included within the resulting preliminary framework presented in Table 1.

2.2 | Testing the preliminary framework

To test the assumptions of the preliminary framework and identify additional themes or concepts, stakeholder interviews and focus groups were conducted. Questions were designed around the framework and aimed to examine the knowledge, attitudes, and practices of stakeholders with regards to rodent pests and their control. Data collection spanned the 2019–2021 COVID-19 pandemic; our methodologies were necessarily amended throughout, as detailed below.

2.2.1 | Ethics statement

This research was approved by the ethics committee of the Schools of Psychology and Physical Sciences and Engineering, University of Aberdeen. We obtained the informed consent of each participant prior to their participation. The study objectives were explained to participants verbally and in writing, and participants were provided

with the contact details of the lead researcher. In most cases, written consent was obtained; however, due to high levels of illiteracy amongst Madagascar's rural population, we also accepted verbal consent for participation in focus groups. In this case, only once both the facilitators and the partner organisation representative were confident that the participant understood the information was verbal consent accepted.

2.2.2 | Focus groups

Focus groups were conducted with farmers between November 2019 and February 2020. In light of the COVID-19 pandemic, no focus groups were conducted after March 2020. Our objective was to test whether the assumptions of the preliminary framework represented the needs and perspectives of farmers and to explore, in broad terms, local attitudes towards rodent pests.

We conducted focus groups in two communes within the Haute Matsiatra, Vatovavy and Fitovinany regions (Figure 1). Communes are the lowest administrative level with government representation (below districts and regions) and are comprised of multiple villages. Within each commune, we conducted focus groups in 3–5 villages. The two communes belonged to districts that had reported cases of bubonic plague during the 2017 plague outbreak, but no cases had been reported from the villages that we visited. So that participants felt able to give their opinions freely, focus groups were arranged and co-facilitated by representatives of local NGOs with strong existing ties with local communities. Site selection was therefore not random but depended on the presence of a partner organization willing to participate in the project.

Fourteen focus groups were conducted across eight villages, generating 5.5 hours of discussion with farmers on the topic of rodent pests. Eight focus groups were conducted with female participants, and six with male participants. Group size ranged from 5 to 11 participants (median = 8, total = 118). Discussions lasted from 11 to 47 minutes (median = 21 minutes).

Men and women over 18 years old were invited to participate. Malagasy society is traditionally patriarchal, and in a mixed male-female group the discourse will typically be led by men; therefore, focus groups were restricted to male- or female-only participants.

During focus groups, one moderator directed questions to the group whilst a second moderator took notes. Also present during focus groups was one representative from the partner organisation,

TABLE 1 The preliminary framework (People, Resources, Power) based on a literature review and expert recommendation.

Theme	Inputs	Outputs
People	Health; Communication; Culture/tradition	Reduced disease risk; Cultural values maintained; Collaboration between and within sectors
Resources	Time; Money; Labour; Knowledge	Reduced agricultural losses; Increased access to knowledge
Power	Policy; Decision-making; Land-tenure	Standardization of policy targets which reflect the needs of end-users



FIGURE 1 Geographical location of the two communes within which focus groups were conducted (indicated by ♦). The two communes are located in the Haute Matsiatra and Vatovavy Fitovinany regions (highlighted in green and yellow).

and the lead investigator (KS). Discussions began with a broad question on the types of agriculture practiced within the community, followed by a question on the challenges faced by farmers, and ended with a question on the participants' opinions on rats. The focus group schedule is provided in Appendix S2.

2.2.3 | Interviews

Semi-structured interviews were conducted with stakeholders representing the Malagasy government, academia, industry, and NGOs. Our objective was to examine the knowledge, attitudes, and practices of these stakeholders with regards to rodent pests and their control. Interviews also provided an opportunity to identify the most important stakeholders and to map connections between them.

We initially identified stakeholders, defined as 'any group or organization that could affect or is affected by rodent control in Madagascar', through a review of the literature available on agriculture, rodent pest control and zoonotic disease in Madagascar and through consultation with experts ($n = 7$) from Madagascar's agriculture and health sectors. Interview participants were selected through key informant sampling (whereby interviewees were selected from the initial stakeholder list) and snowball sampling.

Prior to the COVID-19 outbreak, interviews were conducted face-to-face. After March 2020, interviews were conducted by telephone. We stopped identifying new interviewees when no new themes were emerging in the data analysis (described below).

Interviews were arranged in four parts beginning with open-ended questions on the role of the interviewee and their organisation, followed by questions on the problems faced by rural Malagasy communities (see Appendix S3). We then asked about rodent pest control in Madagascar and the key stakeholders involved. All questions were piloted with the survey team.

Interviews lasted 15–120 min. Six interviews were conducted face-to-face and 14 by telephone. One interview was conducted in English (by KS) and the remainder ($n = 19$) in Malagasy (by MFR and RNR). We interviewed 26 stakeholders representing government ($n = 11$) and NGOs ($n = 15$) within the public health ($n = 10$), agriculture ($n = 11$) and environment ($n = 3$) sectors. Two NGO stakeholders represented both the public health and agriculture sectors.

2.3 | Analysis

Focus group discussions and interviews were audio-recorded, transcribed verbatim, and translated from Malagasy to English. Transcripts were uploaded to NVivo 12 (QSR International Pty Ltd, 2020). Responses were coded following the pre-selected pattern of the preliminary framework but with the flexibility to add codes as necessary. To check for consistency, a second member of the research team (JY) double-coded two of the transcripts.

The coded responses were reviewed to confirm the relevance of existing themes within the preliminary framework, identify areas of ambiguity or potential for misinterpretation, and identify any additional relevant themes not yet included. We then refined the framework based on these findings.

Finally, based on interviewee recommendations, we identified key stakeholders (i.e. those with the most influence on, or most influenced by, current or future rodent control programmes). Communication pathways linking key stakeholders were also incorporated into a stakeholder map (Figure S1). The final map was validated by key informants representing the public health and agriculture sectors ($n = 5$).

3 | RESULTS

Below, we detail the findings which led to the final framework presented in Figure 2. Key themes are illustrated using verbatim quotes from the translated transcripts. Interview quotes are anonymised as follows: government (GOV), NGO—public health (PH), agriculture (AG) environment (ENV)—participant number.

Quotes from focus group discussions are coded as follows: HM (commune Haute Matsiatra), VF (commune Vatovavy-Fitovinany)—village number—M (men), F (women). Having compared responses given by men and women during focus groups, we found that the

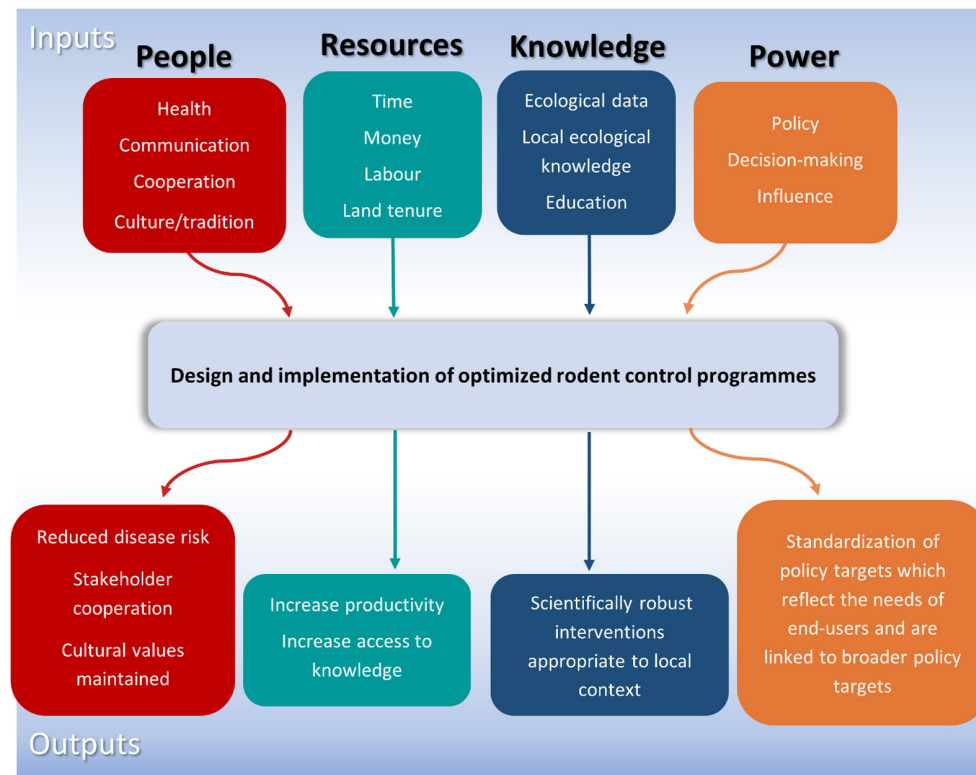


FIGURE 2 Framework focussed on the dimensions of People, Knowledge, Resources, and Power around which rodent management programmes can be designed and implemented.

same themes were identified by both groups and that perspectives given by men and women were consistent.

3.1 | People

Within the broader theme of People, interviewees highlighted the need to respect local culture: ‘taboos and customs of the place need always to be respected...you have to know the custom of a place before you do anything’ [NGO-AG-3]. Another stakeholder connected culture with agricultural practices: ‘In [northern Madagascar], slash-and-burn agriculture for maintaining cattle pasture is a cultural, social, political, everything issue’ [NGO-AG-6]. Understanding culture was also suggested to improve communication: ‘If you don’t have a relationship then people will just say ‘yeah, that’s great’—but it doesn’t mean anything. [In Malagasy] culture there’s an element of non-confrontation’ [NGO-PH-1].

Communication was confirmed to be an important theme in discussions around rodent control. Communication of research findings was seen as necessary to inform government policy; for example, one stakeholder was responsible for delivering research recommendations from scientists to policymakers at the Ministry of Agriculture. Communication with end-users was also highlighted as necessary to inform policy makers of situations on-the-ground. For example, local community health centres are responsible for reporting plague cases to the central government via district and regional health authorities. Moving in the opposite

direction, top-down communication was seen as necessary to notify local communities of government directives. One government stakeholder highlighted that, during the 2017 plague outbreak, instructions to reduce the spread of disease were sent from the central government to doctors in community health centres, who would disseminate information to local communities via community health workers (CHWs).

Two non-government stakeholders described how communication between end-users could facilitate behavioural change. For example, new agricultural techniques can be demonstrated on ‘model plots’; when farmers see the technique working well, they are encouraged to try it for themselves. This was echoed by farmers during focus group discussions.

Stakeholders from both the health and agriculture sectors identified human health as an important consideration within rodent control programmes. The primary concern relating to ill health was the impact on productivity and livelihoods: ‘The aim is to keep [people] healthy so that they are productive’ [NGO-AG-1]. Access to health-care was also an important concern: ‘We don’t have enough doctors here—we have one doctor, but they don’t take care of adults, just children’ [VF-02-M].

Cooperation emerged as a new category within the broader theme of People. NGOs are required to cooperate with government agencies, for example, to obtain work permits or other authorisations. Cooperating with government agencies can also be perceived by local communities to provide NGOs with legitimacy: ‘[the government] have the authority to motivate and to initiate the programme

in general within the community, it's why cooperating with them is good in fulfilling an endeavour' [NGO-PH-3]. Cooperation across different sectors also allowed groups to benefit from each other's expertise: 'Rodent eradication may have an ecological cost and so requires consultation with ecology experts' [NGO-AG-6].

Different ministries were described as having a shared interest in rodent control and their cooperation was often perceived as fundamental. Several stakeholders criticised ministries for their failure to cooperate, with one non-government stakeholder accusing them of 'passing responsibility to each other' [NGO-ENV-1]. Notably, a lack of cooperation between the public health and agriculture sectors is suggested by the absence of communication pathways linking these sectors in the final stakeholder map (Figure S1). Additionally, two non-government stakeholders identified government instability as a barrier to effective cooperation.

Cooperation with local communities was also identified as important. Two stakeholders explained that participatory approaches were needed to identify issues, which are of concern to local people and to ensure that these issues are addressed appropriately. Cooperation with the local community was also perceived as allowing organisations to benefit from local knowledge, and could facilitate the eventual transfer of responsibility to end-users: '[local people] need to be taught, motivated and given all the necessary things to enable them to execute the work' [NGO-PH-3]. Finally, one stakeholder highlighted that rodent control required a collaborative effort by members of a community: 'Rats won't disappear if the whole community does not combine their effort' [NGO-ENV-2].

3.2 | Resources

Financial cost was confirmed by interviewees as an important consideration in rodent management interventions. For example, one stakeholder told us that the government had previously distributed rodenticides and trained farmers in their correct use but that this was scrapped in favour of cheaper rat traps. Several interviewees stated that interventions needed a long-term commitment: '[Programmes] become punctuated or temporary...but such effort should go uninterrupted' [GOV-AG-2]. Stakeholders, therefore, needed to consider the long-term implications of their programme: 'If [the programme] was for a short-term, the rats would diminish for a while and then flourish again little by little' [GOV-PH-1].

The resources available to the local population were another important consideration, which we found to be often overlooked. For instance, one government stakeholder described an initiative that taught farmers to fertilise their crops with cow manure, but which failed to account for the fact that the farmers did not own any cows. In the case of rodent control, communities can be reluctant to use rodenticides mixed with human food: 'In places where they could afford it, they were willing, but in [other places] they were very reluctant in giving bait since they themselves don't have enough to eat' [GOV AG 2].

End-users may also lack the resources to cope with shocks to their livelihoods. This can create a barrier to agricultural change, as subsistence farmers may be opposed to changes that risk reducing their agricultural productivity ('If they have a season where they don't grow enough, their kids don't eat' [NGO-PH-1]).

Several references were made to the land as a resource. In six of the focus group (two with men and four with women), participants spoke of having insufficient land on which to grow crops to feed and provide for their families. One stakeholder described a cycle of poverty whereby farmers borrow from wealthier neighbours but, without money to repay the loan, are later forced to give up their land, leading to tensions within the community: 'so it happens that the little they have - such as rice fields - is taken from them' [NGO-PH/AG-2].

3.3 | Knowledge

In the preliminary framework, we included knowledge as an important concept within the broader theme of Resources. However, discussions with stakeholders and end-users indicated that the concept of knowledge was too complex to be considered under one heading. Therefore, in our final framework, we distinguish between ecological data, local ecological knowledge and education within the broader theme of Knowledge.

Four of the interviewees agreed that ecological data is needed to inform effective rodent management policies. Interviews and focus groups also highlighted the depth of local knowledge on rodents. During focus groups, participants described the different rodent species present as well as where they live, what they eat and what damage they cause, and shared information about different control methods ('we often use pineapple leave and nothing else, not even [poison]' [HM-01-F]). Local ecological knowledge may also provide relevant insights into the interactions between rodent pests and other factors. For example, several farmers linked rodent movements with agricultural activities ('when the crops come up, [the rats] follow behind' [HM-02-M]) and with deforestation ('when there is [slash-and-burn] then it's always the house rats that come' [VF-01-M]).

Several stakeholders indicated that community-based interventions benefitted from a strong education component. This included practical education on how to implement specific technologies; for example, agricultural technicians can provide farmers with training in the use of improved farming techniques (e.g. the System of Rice Intensification) or developing alternative livelihoods (e.g. aquaculture, apiculture). In public health, large-scale educational campaigns can raise awareness of specific health issues ('every year, during plague season, "health motivators" go around villages giving awareness talks' [NGO-PH-3]). Education also had long-term implications (e.g. 'there might be a pump project [to provide clean water], but what if the pump breaks? It's more about sensitization about the importance of clean water, or how you can clean water based on

your situation' [NGO-PH-1]). Another stakeholder felt that education made people more receptive to new ideas: 'if you open yourself up to education then you are open to new thought' [NGO-AG-4]. Conversely, several stakeholders indicated that low literacy levels could hinder behavioural change: 'due to illiteracy it is very difficult to teach the farmers, it is difficult to convince them' [GOV-AG-2].

3.4 | Power

Several stakeholders felt that the central government should be responsible for making and coordinating decisions about rodent control ('[rodent control] will involve a large number of ministerial entities and so it is good for those at a higher level to coordinate it' [NGO-PH-2]). Another stakeholder emphasized the role of local government: 'as soon as the district speaks, every commune, every village, every community, every household should obey since it's the voice of the parents, of the elders in the government, and the communities must somehow obey it' [GOV-PH-5]. Several stakeholders, however, described the conflicting advice previously given by the Ministry of Health and Ministry of Agriculture regarding rodent control, and their failure to incorporate the needs of end-users. Specifically, whilst the Ministry of Agriculture promoted lethal rodent controls, an outbreak of plague led the Ministry of Health to forbid the killing of rats due to the potential risk of plague transmission. One stakeholder told us that, as a result, farmers outside of the plague zone suffered substantial crop losses whilst laws prevented them from using lethal rodent control.

Decentralisation of power was seen as potentially helpful to ensure that decisions were appropriate within the local social, environmental and economic context: 'instructions come from down from the central level, but community agents know the situation in the villages and so people are taught according to the local situation and not theory parachuted from above' [GOV-PH-2].

In addition, a number of stakeholders suggested that bottom-up approaches are useful in identifying locally-appropriate strategies: 'the local community should be the first in charge because they see and interact with the rats' [GOV-PH-1]. However, inefficient communication pathways could lead to delays in action: 'we sent a request to the ministry asking for any action to help us fight against the rats. Unfortunately, there was no response' [GOV-PH-3].

Finally, discussions around power highlighted that those with influence were not necessarily the decision-makers and that those with power were not necessarily able to affect behavioural change. One non-government stakeholder described the frustration of working within the scope of programmes determined by international funders rather than according to the needs of the local community. Another stakeholder commented that programmes needed support from someone in local government to have influence within local communities: 'you always look for someone who could collaborate with you, someone from the governing body who could help, otherwise people won't listen to you' [NGO-PH-2]. Importantly, authority figures were not necessarily those with the most power;

for example, unofficial leaders (e.g. village elders) were often highly influential within their communities ('the population work with obedience when the elders and *tangalamena* [traditional leaders] talk' [GOV-PH-5]). One stakeholder emphasized the role of women ('when you can get buy-in from women I think that's a force to be reckoned with' [NGO-PH-1]) whilst another emphasized the value of young people as 'ambassadors of change' [NGO-AG-3] who—when empowered through education – could educate others within their community.

4 | DISCUSSION

Rodent control is a complex socio-ecological problem, involving a network of stakeholders from across multiple sectors and hierarchies. Using qualitative data from stakeholder interviews and focus groups, we propose a framework centred around the dimensions of People, Resources, Knowledge and Power around which community-based rodent management interventions can be designed and implemented. We believe that unifying stakeholder interests within the same framework could encourage and strengthen a multisector and participatory approach to tackling this and other complex social, economic and environmental issues.

4.1 | The People, Resources, Knowledge and Power framework

Communication and cooperation were identified as important considerations in rodent control programmes, which we group in the final framework within the broader theme of People. Developing interventions in collaboration with end-users can increase engagement and help to identify local needs (Cochrane et al., 2019; Douthwaite et al., 2002; Kuntosch & König, 2018; Rasolofoson et al., 2018; Singleton et al., 2004; Waeber et al., 2017). Transparent communication with local authorities and communities can increase compliance (Ramanantsoa et al., 2017), whilst communication between end-users can strengthen interventions and catalyse behavioural change (Asaaga et al., 2021; Barnes-Mauthe et al., 2015).

Existing research has identified a need to support cooperation across Madagascar's different sectors and administrative levels, as well as improve communication between local authorities, researchers, and end-users (Cinner et al., 2009; Raik & Decker, 2007). We note, however, that the transfer of information between stakeholders does not of itself guarantee the transformation of knowledge into action (Ferré et al., 2022). Likewise, implementation through farmers' groups is often said to enhance adoption but may nonetheless require additional support to create a substantial impact (Kuntosch & König, 2018). One approach may be to increase support for extension services (i.e. communication and learning activities provided for rural communities by educators from the health and agriculture sectors). For example, Madagascar's network of CHWs provides a vital link between the formal health system and local communities,

improving access to information and health services particularly in underserved areas. The CHW programme relies on foreign aid and is frequently hampered by interrupted or expired funding (Gilmartin & Saya, 2015), but reliable funding to exploit this resource could enhance stakeholder communication, facilitate education and awareness raising, and engage and empower local communities.

An awareness of local values is needed to ensure that interventions are appropriate to local socio-cultural contexts and to help decision-makers identify potential barriers to change (e.g. Hume, 2009; Vallès et al., 2020). Cultural factors can also be employed to increase compliance. For example, Westerman and Gardner (2013) used ancestral ceremonies as a novel approach to increase respect for marine protected areas. In the case of rodent pests, our research supports the view that management programmes are more effective if they are appropriate to the specific local context and designed in cooperation with end-users (Brown & Khamphoukeo, 2010; Makundi & Massawe, 2011; Palis et al., 2007, 2011; Singleton et al., 1999, 2004).

The impact on human health is a fundamental consideration within rodent pest control. In particular, we found that many stakeholders were concerned about the impact of poor health on productivity (e.g. in terms of lost labour or earnings). This link could provide a useful tool for gaining buy-in from both local communities and institutional stakeholders for whom access to resources, or resource availability, was an additional important concern.

Alongside People, we include Resources as an important theme within the final framework. In community-based interventions, economic incentives can increase compliance (Aymoz et al., 2013; Waeber et al., 2017) and catalyse behavioural change (Long, 2017). However, as we and others have found (e.g. McClanahan & Abunge, 2016; McClanahan et al., 2014; Rasolofoson et al., 2018), unequal resource distribution and failure to meet expectations can undermine trust and risks disrupting social cohesion. Financial cost can also determine whether a site receives support at all; this can exacerbate geographic inequalities if more remote sites are deemed too difficult or costly to reach (e.g. Poudyal et al., 2016).

The final framework also includes land tenure as an important consideration within the theme of Resources, though with additional implications for power dynamics. Without the security of land ownership, rural farmers are placed in a subordinate economic position. Land tenure security can strengthen individuals' economic and decision-making power (e.g. Allendorf, 2007; Asaaga et al., 2020; Widman, 2014; World Bank, 2008).

Ultimately, decision-makers must consider whether interventions are economically feasible, considering both the financial costs as well as the time and labour requirements, and whether the resources are available to end-users (Constant et al., 2020; Moser & Barrett, 2003; Palis et al., 2003; Stoop et al., 2002). Good quality rodent traps and poisons may be unaffordable or locally unavailable, whilst the clearing of fields or hedges requires additional labour (Belmain et al., 2018; Soarimalala et al., 2019). Transparent cost-benefit analysis of interventions is recommended to manage expectations, increase compliance, and improve decision-making

(MacKinnon et al., 2018; McClanahan & Abunge, 2016; Swanepoel et al., 2017).

To further support decision-making, it is widely accepted that designing effective rodent control programmes requires knowledge of both the target species' ecology and the local agricultural and ecological context (Singleton et al., 1999). This data can be collected through rigorous scientific exploration, experimentation, and observation; however, our results also demonstrate that local ecological knowledge could be an important information resource. Whilst the accuracy of local ecological knowledge may be a limitation (e.g. Propper et al., 2020), it nonetheless has the potential to supplement ecological data to develop site-specific interventions. In the final framework, we, therefore, distinguish between ecological data and local ecological knowledge within the broader theme of Knowledge.

Alongside these, we acknowledge the importance of education. By establishing a scientific foundation, educational components can build awareness and empower local communities to make informed decisions (Cochrane et al., 2019). Additionally, contextualised learning enables local people to construct meaning based on their own experiences and can enhance the uptake of community-based interventions (Aymoz et al., 2013; Cochrane et al., 2019; Uphoff & Langholz, 1998; Waeber et al., 2017).

Within the broader theme of Power, we include policy, decision-making, and influence as important considerations within rodent control programmes. In Madagascar, community-based interventions benefit from policies that respond to local needs (MacKinnon et al., 2018; Raik & Decker, 2007). In rodent management, conflicting policies have created confusion and frustration amongst end-users and local authorities. Ministries from different sectors should therefore collaborate on developing unified policies which respect local values and protect the needs of end-users.

During the last two decades, Madagascar's government-wide move towards decentralisation has afforded greater decision-making power to regional and district-level authorities. However, local authorities often lack the capacity to enforce regulations and locally made decisions have weak links to those made higher up (Cinner et al., 2009; Dhital et al., 2015; Raik & Decker, 2007). This can generate tension between central, regional and local government (Burnod et al., 2013) while a lack of transparency and high rates of corruption prevent decentralised agencies from functioning correctly (Holloway & Short, 2014; Raik & Decker, 2007).

In line with existing research, we argue that greater involvement of diverse stakeholders and end-users in decision-making, together with structured and transparent decision-making approaches (e.g. documented approaches that follow a structured and evidence-based framework), could help to build trust, enhance compliance and ensure that decisions are locally appropriate. Additionally, local involvement in decision-making can strengthen interventions by increasing engagement and social cohesion (Barnes-Mauthe et al., 2015; Cochrane et al., 2019; Waeber et al., 2017), whilst empowering community associations can contribute to more stable behavioural change (Sommerville et al., 2010). Application of the multisector framework could support decision-making by providing

a structure around which discussions are organised; for example, following a decision matrix approach, the framework could be used to determine the criteria on which different management approaches are evaluated. Whilst it is beyond the scope of our work to pinpoint appropriate rodent management activities, García-Díaz et al. (2022) recommend a procedure intended to facilitate multi-stakeholder collaboration when formulating priorities, targets and management actions related to invasive non-native species management.

Finally, seeking the support of those with influence was recommended to increase local support for community-based interventions. Whilst the direction of influence may be clear within social or political structures (e.g. a government hierarchy), an awareness of how complex social, historical, cultural and political conditions shape behaviours is also needed. Indeed, our results demonstrate that power and influence cannot be assumed to lie solely with the decision-makers or with those 'at the top'. Instead, intervention programmes should identify individuals or groups who hold influence at the community level, including unelected leaders (e.g. village elders, see Westerman & Gardner, 2013), young people and women.

4.2 | Application of the stakeholder map and framework

Initiatives aimed at developing rodent management have acknowledged the complex multi-level and multi-sectoral nature of the rodent pest problem (e.g. FAO, UNEP, WHO, and WOA, 2022; WHO, 2019). These aspects underlie the need for a framework that can strengthen and support cross-level and cross-sector collaboration. To help support such initiatives, the combined application of the stakeholder map and framework provides decision-makers with the tools for identifying key stakeholders and their relationships; understanding the varied needs and objectives of different stakeholders and ensuring that these are addressed within decision-making processes.

To ensure that the framework reflects the interests of all stakeholders, we used a structured and replicable process for identifying stakeholders. However, the stakeholder map is not exhaustive and should be adapted to reflect changes in the network over time and to identify any additional stakeholders within specific localities. For instance, local NGOs were not included in the stakeholder map but could play a valuable role in scaling-up rodent management programmes. We therefore recommend that future work investigates the role of local NGOs as important intermediaries between end-users and stakeholder groups operating at national or international levels. Additionally, whilst we consider our sample size to be adequate for framework analysis, a number of stakeholder groups were under-represented during interviews (e.g. international organisations, regional-level government stakeholders and those representing the environment sector). The framework should thus be adapted should additional themes emerge during future discussions around rodent control.

Application of the framework also requires an awareness of the connections between themes. In particular, the concept of Power is pervasive within the wider framework. For example, whilst rodent management actions may be determined under seemingly neutral conditions based on rodent ecology, in reality, those actions are implemented within complex and dynamic social, cultural and political conditions. Additionally, the imposition of rules or policy by external stakeholders can weaken existing and traditional management systems (Jones et al., 2008). Informal social structures and local power relations may also complicate collaborative decision-making and contribute to the unequal distribution of resources, which risks increasing inequality within and between communities (e.g. Lammers et al., 2017). Moreover, the participatory approach may, in itself, be an attempt to neutralize power asymmetries among stakeholders and foster more equitable governance (Apgar et al., 2017).

Critical reflection of how power is exercised and its role in community-based rodent management programmes may provide insights that can be used to equalize power asymmetries (Raik et al., 2008). This can be supported through application of the stakeholder map and framework, which provide structures around which decision-making processes (e.g. decision matrices, discrete choice experiments) can be designed. If a structured process is followed during decision-making, then exclusion of any of the stakeholders identified in the stakeholder map, or the omission of any of the themes identified in the framework, should be evident. Documenting decision-making processes will help provide transparency and make it possible to identify such absences (such as the exclusion of key stakeholders from decision-making) and question why they exist.

4.3 | Future research and practice directions

Rodent management programmes are confronted with the need to bring about a change in the behaviour of end-users (Makundi & Massawe, 2011). We often encountered defeatist attitudes towards rodent pests—that rats are cunning, able to outsmart humans, and impossible to control. This can decrease farmers' motivation to participate in control activities (Belmain, 2010). Programmes will therefore likely benefit from an adaptive management approach, whereby farmers and other stakeholders have flexibility to modify their management approach through interactive experiential learning (Douthwaite et al., 2002). For example, positive experiential learning and active involvement in decision-making was found to strengthen the motivation of farmers in Vietnam to participate in rodent management (Palis et al., 2011).

Another concept which was raised during discussions, but which fell outside the scope of the framework, was the link between rodents and poverty. Globally, impoverished communities are disproportionately impacted by rodent pests (Bonwitt et al., 2017; de Klerk et al., 2016; Duplantier et al., 2005; Himsworth et al., 2013). Malnutrition, poor sanitation, absence of schooling, insecurity, and inadequate health services were issues highlighted by our study participants. This is concerning of itself but may also have implications

for the success of interventions which fail to address the underlying drivers of poverty. To manage expectations, researchers must be explicit with communities about the scope of interventions. Furthermore, in poor communities, even low external-input technologies may fall outside the reach of the poorest households (Moser & Barrett, 2003). In our study, farmers without enough food to feed their families were unwilling to invest in rodent control, despite potential long-term benefits. This indicates a limitation of the framework but also raises the question of whether the framework can be used to help strengthen the systems to which it applies.

Finally, we hope that application of the framework will help to reduce conflicts, particularly through the collaborative development of interventions, increased transparency and enhanced communication between stakeholders. Nonetheless, stakeholders will require support in managing conflicts where they do arise. Whilst there is a growing literature on approaches to conflict resolution and management in invasive species management (e.g. Crowley et al., 2017; Estévez et al., 2014; García-Díaz et al., 2022), research is needed to identify suitable approaches within the specific social and political context. For example, in light of complex power imbalances across Madagascar's social and political hierarchies, different decision-making approaches may be appropriate at different scales.

5 | CONCLUSIONS

In Madagascar, rodent pest control represents a complex socio-ecological problem which different government and non-government organisations have so far struggled to address. In this study, we have organised key themes relevant to community-based interventions in a cohesive multisector framework, using a multi-method approach which draws upon current literature and is supported by discussions with key stakeholders. The resulting People, Resources, Knowledge and Power framework can be used to guide the design, implementation, and evaluation of community-based interventions. By addressing the interests of all stakeholders, we hope that application of the framework will contribute to the development of effective and sustainable control strategies. Additionally, due to the inclusive and interdisciplinary nature of the framework, we believe that its potential applications are wide reaching and may help in addressing complex social, economic and environmental issues across scales, sectors and systems.

AUTHOR CONTRIBUTIONS

Kathryn Scobie and Juliette Young conceived the ideas and designed methodology; Minoarisoa Rajerison, Sandra Telfer and Xavier Lambin contributed critically to the design of the methodology; Kathryn Scobie, Mendrika Fenohasina Rasahivelo and Rova Nandrianina Rahelison collected the data and Minoarisoa Rajerison provided logistical support for fieldwork; Kathryn Scobie performed the analysis of data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

ACKNOWLEDGEMENTS

We thank all those who took part in interviews and focus groups, as well the partner organisations (IMPACT Madagascar, Feedback Madagascar and Ny Tanintsika) who generously facilitated and supported focus groups. KS was supported by the Biotechnology and Biological Sciences Research Council (BBSRC) under the EastBio DTP [grant number BB/M010996/1]. This work was also supported by the Wellcome Trust [095171/Z/10/Z]; the Medical Research Council [MR/T029862/1]; and by the National Institute for Health Research (NIHR) (using the UK's Official Development Assistance (ODA) Funding) and Wellcome [219532/Z/19/Z] under the NIHR-Wellcome Partnership for Global Health Research. The views expressed are those of the authors and not necessarily those of Wellcome, the NIHR or the Department of Health and Social Care. For the purpose of Open Access, the authors have applied a CC BY license to any Author Accepted Manuscript version arising.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest in preparing this article. One of the authors (MR) was interviewed during the data collection in light of their institutional knowledge.

DATA AVAILABILITY STATEMENT

The data on which this research is based are archived on secure servers at the corresponding author's institution. In order to preserve confidentiality and the anonymity of research participants, the data are not made publicly available.

ORCID

Kathryn Scobie  <https://orcid.org/0000-0001-6619-220X>

Xavier Lambin  <https://orcid.org/0000-0003-4643-2653>

Sandra Telfer  <https://orcid.org/0000-0002-9596-0711>

Juliette Young  <https://orcid.org/0000-0002-8522-0883>

REFERENCES

- Allendorf, K. (2007). Do women's land rights promote empowerment and child health in Nepal? *World Development*, 35, 1975–1988. <https://doi.org/10.1016/j.worlddev.2006.12.005>
- Andrianaivoarimanana, V., Kreppel, K., Elissa, N., Duplantier, J. M., Carniel, E., Rajerison, M., & Jambou, R. (2013). Understanding the persistence of plague foci in Madagascar. *PLoS Neglected Tropical Diseases*, 7, 1–8. <https://doi.org/10.1371/journal.pntd.0002382>
- Apgar, J. M., Cohen, P. J., Ratner, B. D., de Silva, S., Buisson, M. C., Longley, C., Bastakoti, R. C., & Mapedza, E. (2017). Identifying opportunities to improve governance of aquatic agricultural systems through participatory action research. *Ecology and Society*, 22, 9. <https://doi.org/10.5751/ES-08929-220109>
- Asaaga, F. A., Hiron, M. A., & Malhi, Y. (2020). Questioning the link between tenure security and sustainable land management in cocoa landscapes in Ghana. *World Development*, 130, 104913. <https://doi.org/10.1016/j.worlddev.2020.104913>
- Asaaga, F. A., Rahman, M., Kalegowda, S. D., Mathapati, J., Savanur, I., Srinivas, P. N., Seshadri, T., Narayanswamy, D., Kiran, S. K., Oommen, M. A., Young, J. C., & Purse, B. V. (2021). 'None of my ancestors ever discussed this disease before!' How disease

- information shapes adaptive capacity of marginalised rural populations in India. *PLoS Neglected Tropical Diseases*, 15, e0009265. <https://doi.org/10.1371/journal.pntd.0009265>
- Aymoz, B. G. P., Randrianjafy, V. R., Randrianjafy, Z. J. N., & Khasa, D. P. (2013). Community management of natural resources: A case study from Ankarafantsika National Park, Madagascar. *Ambio*, 42, 767–775. <https://doi.org/10.1007/s13280-013-0391-9>
- Barnes-Mauthe, M., Oleson, K. L. L., Brander, L. M., Zafindrasilivonona, B., Oliver, T. A., & van Beukering, P. (2015). Social capital as an ecosystem service: Evidence from a locally managed marine area. *Ecosystem Services*, 16, 283–293. <https://doi.org/10.1016/j.ecoser.2014.10.009>
- Belmain, S. (2010). Developing pesticide-free rodent control in Africa. *Pesticides News*, 87, 9–13.
- Belmain, S. R., Ndiaye, C. F., Diallo, B., Rakotonjanabelo, L. A., Anoko, J. N., Rakotondrazafy, S., Forbin, E. E., & Chêne, S. (2018). *A new rat control strategy for Madagascar to Prevent Plague Outbreaks* (p. 23). Organisation Mondiale de la Santé.
- Bonwitt, J., Sáez, A. M., Lamin, J., Ansumana, R., Dawson, M., Buanie, J., Lamin, J., Sondufu, D., Borchert, M., Sahr, F., Fichet-Calvet, E., & Brown, H. (2017). At home with *Mastomys* and *Rattus*: Human-rodent interactions and potential for primary transmission of lassa virus in domestic spaces. *American Journal of Tropical Medicine and Hygiene*, 96(4), 935–943. <https://doi.org/10.4269/ajtmh.16-0675>
- Brown, P. R., & Khamphoukeo, K. (2010). Changes in farmers' knowledge, attitudes and practices after implementation of ecologically-based rodent management in the uplands of Lao PDR. *Crop Protection*, 29, 577–582. <https://doi.org/10.1016/j.cropro.2009.12.025>
- Burnod, P., Gingembre, M., & Ratsialonana, R. A. (2013). Competition over authority and access: International land deals in Madagascar. *Development and Change*, 44, 357–379. <https://doi.org/10.1111/dech.12015>
- Cinner, J., Fuentes, M. M. P. B., & Randriamahazo, H. (2009). Exploring social resilience in Madagascar's marine protected areas. *Ecology and Society*, 14, 41.
- Cochrane, K. L., Rakotondrazafy, H., Aswani, S., Chaigneau, T., Downey-Breedt, N., Lemahieu, A., Paytan, A., Pecl, G., Plagányi, E., Popova, E., van Putten, E. I., Sauer, W. H. H., Byfield, V., Gasalla, M. A., van Gennip, S. J., Malherbe, W., Rabary, A., Rabearisoa, A., Ramarason, N., ... Tsimanaoraty, P. M. (2019). Tools to enrich vulnerability assessment and adaptation planning for coastal communities in data-poor regions: Application to a case study in Madagascar. *Frontiers in Marine Science*, 5, 505. <https://doi.org/10.3389/fmars.2018.00505>
- Constant, N. L., Swanepoel, L. H., Williams, S. T., Soarimalala, V., Goodman, S. M., Massawe, A. T., Mulungu, L. S., Makundi, R. H., Mdangi, M. E., Taylor, P. J., & Belmain, S. R. (2020). Comparative assessment on rodent impacts and cultural perceptions of ecologically based rodent management in 3 Afro-Malagasy farming regions. *Integrative Zoology*, 15, 578–594. <https://doi.org/10.1111/1749-4877.12447>
- Crowley, S. L., Hinchliffe, S., & McDonald, R. A. (2017). Invasive species management will benefit from social impact assessment. *Journal of Applied Ecology*, 54, 351–357.
- de Klerk, P., van Dijk, M., & van As, A. B. (2016). Treatment and outcome of unusual animal bite injuries in young children. *South African Medical Journal*, 106(2), 206–209. <https://doi.org/10.7196/SAMJ.2016.v106i2.10106>
- Dhital, N., Vololomboahangy, R. R., & Khasa, D. P. (2015). Issues and challenges of forest governance in Madagascar. *Canadian Journal of Development Studies*, 36, 38–56. <https://doi.org/10.1080/02255189.2015.989197>
- Douthwaite, B., Manyong, V. M., Keatinge, J. D. H., & Chianu, J. (2002). The adoption of alley farming and *Mucuna*: Lessons for research, development and extension. *Agroforestry Systems*, 56, 193–202. <https://doi.org/10.1023/A:1021319028117>
- Duplantier, J.-M., Duchemin, J.-B., Chanteau, S., & Carniel, E. (2005). From the recent lessons of the Malagasy foci towards a global understanding of the factors involved in plague reemergence. *Veterinary Research*, 36, 437–453. <https://doi.org/10.1051/vetres>
- Duplantier, J.-M., & Rakotondravony, D. (1999). The Rodent problem in Madagascar: Agricultural pest and threat to human health. In G. R. Singleton, L. A. Hinds, H. Leirs, & Z. Zhang (Eds.), *Ecologically-based management of rodent pests*. ACIAR Monograph No. 59. (pp. 441–457). Australian Centre for International Agricultural Research.
- Estévez, R. A., Anderson, C. B., Pizarro, J. C., & Burgman, M. A. (2014). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology*, 29, 19–30. <https://doi.org/10.1111/cobi.12359>
- FAO (Food and Agriculture Organization of the United Nations). (2021). *GIEWS - Global information and early warning system*. Country Brief Madagascar <https://www.fao.org/giews/countrybrief/country.jsp?code=MDG>
- FAO, UNEP, WHO, and WOA. (2022). One Health Joint Plan of Action (2022-2026). Working together for the health of humans, animals, plants and the environment. <https://doi.org/10.4060/cc2289en>
- Ferré, M., Martín-Ortega, J., Di Gregorio, M., & Dallimer, M. (2022). How do information flows affect impact from environmental research? - An analysis of a science-policy network. *Journal of Environmental Management*, 321, 115828. <https://doi.org/10.1016/j.jenvman.2022.115828>
- García-Díaz, P., Montti, L., Powell, P. A., Phimister, E., Pizarro, J. C., Fasola, L., Langdon, B., Pauchard, A., Raffo, E., Bastias, J., Damasceno, G., Fidelis, A., Huerta, M. F., Linardaki, E., Moyano, J., Núñez, M. A., Ortiz, M. I., Rodríguez-Jorquera, I., Roesler, I., ... Lambin, X. (2022). Identifying priorities, targets, and actions for the long-term social and ecological management of invasive non-native species. *Environmental Management*, 69, 140–153. <https://doi.org/10.1007/s00267-021-01541-3>
- García-Llorente, M., Martín-López, B., González, J. A., Alcorlo, P., & Montes, C. (2008). Social perceptions of the impacts and benefits of invasive alien species: Implications for management. *Biological Conservation*, 141, 2969–2983.
- Gilmartin, C., & Saya, U. (2015). *Community health worker incentives: Lessons learned and best practices from Madagascar*. African Strategies for Health (ASH).
- Harvey, C. A., Rakotobe, Z. L., Rao, N. S., Dave, R., Razafimahatratra, H., Rabarijoh, R. H., Rajaofara, H., & Mackinnon, J. L. (2014). Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 369, 20130089. <https://doi.org/10.1098/rstb.2013.0089>
- Himsworth, C. G., Parsons, K. L., Jardine, C., & Patrick, D. M. (2013). Rats, cities, people, and pathogens: A systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. *Vector-Borne and Zoonotic Diseases*, 13(6), 349–359. <https://doi.org/10.1089/vbz.2012.1195>
- Holloway, G., & Short, S. (2014). Towards a more adaptive co-management of natural resources - increasing social-ecological resilience in southeast Madagascar. *Madagascar Conservation & Development*, 9, 36. <https://doi.org/10.4314/mcd.v9i1.7>
- Huan, N. H., Nga, V. T. Q., Brown, P. R., Phung, M. T. M., & Singleton, G. R. (2010). Rodent impacts in lowland irrigated intensive rice systems in Vietnam. In G. R. Singleton, S. R. Belmain, P. R. Brown, & B. Hardy (Eds.), *Rodent outbreaks: Ecology and impacts* (pp. 139–152). International Rice Research Institute.
- Hume, D. W. (2009). Vary gasy: Folk models of rice and implications for agricultural development in eastern Madagascar. *Études Océan Indien*, 42–43, 243–256. <https://doi.org/10.4000/oceanindien.812>
- Jones, J. P. G., Andriamarivololona, M. M., & Hockley, N. (2008). The importance of taboos and social norms to conservation

- in Madagascar. *Conservation Biology*, 22, 976–986. <https://doi.org/10.1111/j.1523-1739.2008.00970.x>
- Kuntosch, A., & König, B. (2018). Linking system perspectives with user perspectives to identify adoption barriers to food security innovations for smallholder farmers – evidence from rural Tanzania. *Food Security*, 10, 881–896. <https://doi.org/10.1007/s12571-018-0821-4>
- Lammers, P. L., Richter, T., Lux, M., Ratsimbazafy, J., & Mantilla-Contreras, J. (2017). The challenges of community-based conservation in developing countries—A case study from Lake Alaotra, Madagascar. *Journal for Nature Conservation*, 40, 100–112. <https://doi.org/10.1016/j.jnc.2017.08.003>
- Long, S. (2017). Short-term impacts and value of a periodic no take zone (NTZ) in a community-managed small-scale lobster fishery, Madagascar. *PLoS ONE*, 12, 1–23. <https://doi.org/10.1371/journal.pone.0177858>
- MacKinnon, J. L., Andriamaro, L., Rambeloson, A., Razafindrazakaso, M., & Harvey, C. A. (2018). Costs of delivery approaches for providing livelihood projects to local communities as part of REDD+ programmes: An analysis from Madagascar. *Environmental Conservation*, 45, 315–323. <https://doi.org/10.1017/S0376892917000571>
- Makundi, R. H., Makundi, R. H., Oguge, N., Oguge, N., Mwanjabe, P. S., & Mwanjabe, P. S. (1999). Rodent pest management in East Africa—an ecological approach. In G. R. Singleton, L. A. Hinds, H. Leirs, & Z. Zhang (Eds.), *Ecologically based management of rodent pests* (pp. 460–476). ACIAR.
- Makundi, R. H., & Massawe, A. W. (2011). Ecologically based rodent management in Africa: Potential and challenges. *Wildlife Research*, 38, 588–595. <https://doi.org/10.1071/WR10147>
- Mattern, C., Chevallier, E., & Ramaroson, H. J. V. (2019). Contribution of anthropology to awareness message: Lessons learned from the 2017 pulmonary plague epidemic. Paper presented at the *Yersinia 13th International Symposium*, Antananarivo, Madagascar, 16–19 September 2019. p 23.
- McClanahan, T. R., & Abunge, C. A. (2016). Perceptions of fishing access restrictions and the disparity of benefits among stakeholder communities and nations of south-eastern Africa. *Fish and Fisheries*, 17, 417–437. <https://doi.org/10.1111/faf.12118>
- McClanahan, T. R., Cinner, J. E., Abunge, C., Rabearisoa, A., Mahatante, P., Ramahatratra, F., & Andrianarivelo, N. (2014). Perceived benefits of fisheries management restrictions in Madagascar. *Ecology and Society*, 19, 5. <https://doi.org/10.5751/ES-06080-190105>
- Meerburg, B. G., Singleton, G. R., & Kijlstra, A. (2009). Rodent-borne diseases and their risks for public health. *Critical Reviews in Microbiology*, 35, 221–270.
- Meerburg, B. G., Singleton, G. R., & Leirs, H. (2009). The year of the rat ends - time to fight hunger! *Pest Management Science*, 65, 351–352.
- Moser, C. M., & Barrett, C. B. (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: The case of SRI in Madagascar. *Agricultural Systems*, 76, 1085–1100. [https://doi.org/10.1016/S0308-521X\(02\)00041-0](https://doi.org/10.1016/S0308-521X(02)00041-0)
- Novoa, A., Shackleton, R., Canavan, S., Cybèle, C., Davies, S. J., Dehnen-Schmutz, K., Fried, J., Gaertner, M., Geerts, S., Griffiths, C. L., Kaplan, H., Kumschick, S., Le Maitre, D. C., Measey, G. J., Nunes, A. L., Richardson, D. M., Robinson, T. B., Touza, J., & Wilson, J. R. U. (2018). A framework for engaging stakeholders on the management of alien species. *Journal of Environmental Management*, 205(January), 286–297. <https://doi.org/10.1016/j.jenvman.2017.09.059>
- Palis, F. G., Morin, S., Van Chien, H., & Chi, T. N. (2003). Socio-cultural and economic assessment of community trap-barrier system adoption in southern Vietnam. *Acia Monograph Series*, 96(January), 422–425.
- Palis, F. G., Singleton, G. R., Brown, P. R., Huan, N. H., & Nga, N. T. D. (2010). Socio-cultural factors influencing the adoption of ecologically based rodent pest management. In G. R. Singleton, S. R. Belmain, P. R. Brown, & B. Hardy (Eds.), *Rodent outbreaks: Ecology and impacts* (pp. 153–169). International Rice Research Institute.
- Palis, F. G., Singleton, G. R., Brown, P. R., Huan, N. H., Umali, C., & Nga, N. T. D. (2011). Can humans outsmart rodents? Learning to work collectively and strategically. *Wildlife Research*, 38, 568–578. <https://doi.org/10.1071/WR10226>
- Palis, F. G., Singleton, G. R., Sumalde, Z., & Hossain, M. (2007). Social and cultural dimensions of rodent pest management. *Integrative Zoology*, 2, 174–183. <https://doi.org/10.1111/j.1749-4877.2007.00057.x>
- Parrott, L. (2017). The modelling spiral for solving ‘wicked’ environmental problems: Guidance for stakeholder involvement and collaborative model development. *Methods in Ecology and Evolution*, 8, 1005–1011. <https://doi.org/10.1111/2041-210X.12757>
- Poudyal, M., Ramamonjisoa, B. S., Hockley, N., Rakotonarivo, O. S., Gibbons, J. M., Mandimbiniaina, R., Rasoamanana, A., & Jones, J. P. G. (2016). Can REDD+ social safeguards reach the ‘right’ people? Lessons from Madagascar. *Global Environmental Change*, 37, 31–42. <https://doi.org/10.1016/j.gloenvcha.2016.01.004>
- Propper, C. R., Hardy, L. J., Howard, B. D., Flor, R. J. B., & Singleton, G. R. (2020). Role of farmer knowledge in agro-ecosystem science: Rice farming and amphibians in the Philippines. *Human-Wildlife Interactions*, 14(2), 273–286.
- QSR International Pty Ltd. (2020). NVivo (released in March 2020). <https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home>
- Raik, D. B., & Decker, D. J. (2007). A multisector framework for assessing community-based forest management: Lessons from Madagascar. *Ecology and Society*, 12, 14. <http://www.jstor.org/stable/26267846>
- Raik, D. B., Wilson, A. L., & Decker, D. J. (2008). Power in natural resources management: An application of theory. *Society & Natural Resources*, 21, 729–739. <https://doi.org/10.1080/08941920801905195>
- Ramanantsoa, A., Wilson-Barthes, M., Rahenintsoa, R., Hoibak, S., Ranaivoharimina, H., Rahelimalala, M. D., Rakotomanga, A., Finlay, A., Muela Ribera, J., & Peeters Grietens, K. (2017). Can the collection of expired long-lasting insecticidal nets reduce their coverage and use? Sociocultural aspects related to LLIN life cycle management and use in four districts in Madagascar. *Malaria Journal*, 16(1), 1–9. <https://doi.org/10.1186/s12936-017-2053-z>
- Ramaroson, H. J. V., Mattern, C., Rakotomanana, E., Rakotosamimanana, S., Raboanary, E., & Chevallier, E. (2019). Perception of plague in Madagascar: From historical heritage to the present day. Paper presented at the *Yersinia 13th International Symposium*, Antananarivo, Madagascar, 16–19 September 2019. p 33.
- Rasolofoson, R. A., Nielsen, M. R., & Jones, J. P. G. (2018). The potential of the Global Person Generated Index for evaluating the perceived impacts of conservation interventions on subjective well-being. *World Development*, 105, 107–118. <https://doi.org/10.1016/j.worlddev.2017.12.032>
- Ravaoarisoa, L., Razafimahatratra, M. J. J., Rakotondratsara, M. A., Gaspard, N., Rolland Ratsimbazafy, M., Rafamantanantsoa, J. F., Ramanantsoa, V., Schaaf, M., Midy, A.-C., & Casey, S. E. (2020). Slowing progress: The US Global Gag Rule undermines access to contraception in Madagascar. *Sexual and Reproductive Health Matters*, 28, 39–53. <https://doi.org/10.1080/26410397.2020.1838053>
- Shackleton, R. T., Le Maitre, D. C., & Richardson, D. M. (2015). Stakeholder perceptions and practices regarding Prosopis (mesquite) invasions and management in South Africa. *Ambio*, 44, 569–581. <https://doi.org/10.1007/s13280-014-0597-5>
- Singleton, G. R., Brown, P. R., & Jacob, J. (2004). Ecologically-based rodent management: Its effectiveness in cropping systems in South-East Asia. *NJAS - Wageningen Journal of Life Sciences*, 52, 163–171. [https://doi.org/10.1016/S1573-5214\(04\)80011-3](https://doi.org/10.1016/S1573-5214(04)80011-3)
- Singleton, G. R., Leirs, H., Hinds, L. a., & Zhang, Z. B. (1999). Ecologically-based management of rodent pests- Re-evaluating our approach to an old problem. In G. R. Singleton, L. A. Hinds, H. Leirs, & Z. Zhang

- (Eds.), *Ecologically-based management of rodent pests*, Monograph No. 59 (pp. 1–50). Australian Centre for International Agricultural Research (ACIAR).
- Soarimalala, V., Jean, P., & Rakotovao, F. (2019). Les rats dans le monde rural du Centre-est et du Centre-sud de Madagascar: Dommages causés et systèmes de contrôle. *Malagasy Nature*, 13, 125–151.
- Sommerville, M., Milner-Gulland, E. J., Rahajarahison, M., & Jones, J. P. G. (2010). Impact of a community-based payment for environmental services intervention on forest use in Menabe, Madagascar. *Conservation Biology*, 24, 1488–1498. <https://doi.org/10.1111/j.1523-1739.2010.01526.x>
- Stenseth, N. C., Leirs, H., Skonhoff, A., Davis, S. A., Pech, R. P., Andreassen, H. P., Singleton, G. R., Lima, M., Machang'u, R. S., Makundi, R. H., Zhang, Z., Brown, P. R., Shi, D., & Wan, X. (2003). Mice, rats, and people: The bio-economics of agricultural rodent pests. *Frontiers in Ecology and the Environment*, 1, 367–375. [https://doi.org/10.1890/1540-9295\(2003\)001\[0367:MRAPT BJ2.0.CO;2](https://doi.org/10.1890/1540-9295(2003)001[0367:MRAPT BJ2.0.CO;2)
- Stoop, W. A., Uphoff, N., & Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource-poor farmers. *Agricultural Systems*, 71, 249–274. [https://doi.org/10.1016/S0308-521X\(01\)00070-1](https://doi.org/10.1016/S0308-521X(01)00070-1)
- Swanepoel, L. H., Swanepoel, C. M., Brown, P. R., Eiseb, S. J., Goodman, S. M., Keith, M., Kirsten, F., Leirs, H., Mahlaba, T. A. M., Makundi, R. H., Malebane, P., von Maltitz, E. F., Massawe, A. W., Monadjem, A., Mulungu, L. S., Singleton, G. R., Taylor, P. J., Soarimalala, V., & Belmain, S. R. (2017). A systematic review of rodent pest research in Afro-Malagasy small-holder farming systems: Are we asking the right questions? *PLoS ONE*, 12, e0174554. <https://doi.org/10.1371/journal.pone.0174554>
- Taylor, P. J., Arntzen, L., Hayter, M., Iles, M., Frea, J., & Belmain, S. R. (2008). Understanding and managing sanitary risks due to rodent zoonoses in an African city: Beyond the Boston Model. *Integrative Zoology*, 3, 38–50. <https://doi.org/10.1111/j.1749-4877.2008.00072.x>
- Uphoff, N., & Langholz, J. (1998). Incentives for avoiding the tragedy of the commons. *Environmental Conservation*, 25, 251–261. <https://doi.org/10.1017/S0376892998000319>
- Vallès, X., Stenseth, N. C., Demeure, C., Horby, P., Mead, P. S., Cabanillas, O., Ratsitorahina, M., Rajerison, M., Andrianaivoarimanana, V., Ramasindrazana, B., Pizarro-Cerda, J., Scholz, H. C., Girod, R., Hinnebusch, B. J., Vigan-Womas, I., Fontanet, A., Wagner, D. M., Telfer, S., Yazdanpanah, Y., ... Baril, L. (2020). Human plague: An old scourge that needs new answers. *PLoS Neglected Tropical Diseases*, 14, e0008251. <https://doi.org/10.1371/journal.pntd.0008251>
- van Limburg, M., Wentzel, J., Sanderman, R., & van Gemert-Pijnen, L. (2015). Business modeling to implement an eHealth portal for infection control: A reflection on co-creation with stakeholders. *JMIR Research Protocols*, 4, e104. <https://doi.org/10.2196/resp.4.4519>
- van Woezik, A. F. G., Braakman-Jansen, L. M. A., Kulyk, O., Siemons, L., & van Gemert-Pijnen, J. E. W. C. (2016). Tackling wicked problems in infection prevention and control: A guideline for co-creation with stakeholders. *Antimicrobial Resistance & Infection Control*, 5, 20. <https://doi.org/10.1186/s13756-016-0119-2>
- Waeber, P. O., Reibelt, L. M., Randriamalala, I. H., Moser, G., Raveloarimalala, L. M., Ralainasolo, F. B., Ratsimbazafy, J., & Woolaver, L. (2017). Local awareness and perceptions: Consequences for conservation of marsh habitat at Lake Alaotra for one of the world's rarest lemurs. *Oryx*, 52, 677–686. <https://doi.org/10.1017/S0030605316001198>
- Wentzel, J., van Limburg, M., Karreman, J., Hendrix, R., & van Gemert-Pijnen, L. (2012). Co-creation with stakeholders: A web 2.0 antibiotic stewardship program. The Fourth International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED); Jan 30-Feb 4, 2012; Valencia, Spain.
- Westerman, K., & Gardner, C. J. (2013). Adoption of socio-cultural norms to increase community compliance in permanent marine reserves in southwest Madagascar. *Conservation Evidence*, 10, 4–9.
- WHO. (2019). A new approach to rodent control to better protect human health: First international meeting of experts under the auspices of WHO and the Pan American Health Organization. *Weekly Epidemiological Record*, 17, 197–203.
- Widman, M. (2014). Land tenure insecurity and formalizing land rights in Madagascar: A gender perspective on the certification program. *Feminist Economics*, 20, 130–154. <https://doi.org/10.1080/13545701.2013.873136>
- World Bank. (2008). *Analysis of the impact of land tenure certificates with both the names of wife and husband in Vietnam*. World Bank <https://openknowledge.worldbank.org/handle/10986/7810>

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1. Table S1. Results of literature review. Number in left column (No.) corresponds to articles listed below (n = 16). A number of different community-based interventions were evaluated. During the review, we identified positive and negative outcomes associated with each approach. Themes (or concepts) evident within the literature are also listed.

Appendix S2. Focus Group Schedule.

Appendix S3. Interview Guide – NGOs.

Figure S1. Key stakeholder map. Includes stakeholders identified as most important in current or future rodent control programmes in Madagascar but excludes those operating only at specific locations (i.e. local non-government organisations). The public health (red) and agriculture and environment sectors (green) are represented, as well as international organisations (yellow), local government and end-users (black). The Bureau National de Gestion des Risques et des Catastrophes (National Office for Risk and Disaster Management) is within the Ministry of the Interior. Stakeholders are organised by administrative level (Central, Regional, District, Local). Solid lines join stakeholders who communicate frequently; dotted lines join those who communicate only sometimes. OMS = Organisation Mondiale pour la Santé (World Health Organisation); USAID = United States Agency for International Development; CIRAD = Centre de Coopération Internationale en Recherche Agronomique pour le Développement (French Agricultural Research Centre for International Development).

How to cite this article: Scobie, K., Lambin, X., Telfer, S., Rasahivelo, M. F., Rahelirison, R. N., Rajerison, M., & Young, J. (2023). Living with rodent pests: Unifying stakeholder interests to prioritise pest management in rural Madagascar. *People and Nature*, 5, 713–725. <https://doi.org/10.1002/pan3.10438>