Biol Invasions
https://doi.org/10.1007/s10530-024-03454-8

ORIGINAL PAPER

From planning to implementation: a multi-stakeholder partnership for managing plant invasions in tropical island ecosystems

Mathieu Rouget · Pauline Fenouillas · Emilie Cazal · Margot Caubit · Cédric Ajaguin Soleyen · Eve Balard · Antoine Becker-Scarpitta · Laurent Calichiama · Gael Karczewski · Christophe Lavergne · Benoît Lequette · Roxane L'Horset · Léa Marie · Guillaume Payet · Nicolas Payet · Frédéric Picot · Dominique Strasberg · Julien Triolo · Vincent Turquet · Jean-Philippe Delorme

Received: 31 May 2024 / Accepted: 16 September 2024

Abstract Effective management of invasive species within protected areas requires innovative solutions. In the Mascarene's archipelago, the national park of Reunion contains the largest area of intact vegetation, which faces alarming threats from invasive alien plant species. In response, the local government initiated an inclusive partnership in 2018 involving decision-makers, managers, and scientists to address the management of invasive alien plant species. An operational framework from planning to implementation has been established encompassing five key steps: (1) conduct a comprehensive site assessment, (2) model future threats, (3) prioritise interventions, (4) implement actions through a multi-stakeholder programme spanning multiple years, and (5) evaluate the effectiveness of implemented interventions. This study provides an in-depth examination of the research-action partnership and the operational framework, illustrating outputs for key priority sites. Our survey covered over 2500 ha, quantifying invasion degree in three vegetation strata at a fine-scale, and revealed significant areas within subalpine vegetation which remain remarkably pristine. By adapting participatory conservation planning approaches, we developed implementation-level outputs at a scale useful for managers which guided interventions on the ground. The partnership exemplifies a transdisciplinary approach with a broad array of stakeholders. Drawing from a checklist of essential components for successful partnerships, we highlight key insights from this initiative,

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10530-024-03454-8.

M. Rouget (✉) · P. Fenouillas · C. Ajaguin Soleyen · A. Becker-Scarpitta · R. L'Horset
CIRAD, UMR PVBMT, 97410 St Pierre, La Réunion, France
e-mail: mathieu.rouget@cirad.fr

E. Cazal · M. Caubit · G. Karczewski · B. Lequette · G. Payet · J.-P. Delorme
Parc national de La Réunion, La Plaine des Palmistes, La Réunion, France

E. Balard
DEAL, Saint-Denis, La Réunion, France

L. Calichiama
SPL-Edden, Saint-Pierre, La Réunion, France

C. Lavergne · F. Picot
CBNM, Saint-Leu, La Réunion, France

L. Marie · J. Triolo
ONF Réunion, Saint-Denis, La Réunion, France

N. Payet · V. Turquet
Département de La Réunion, Saint-Denis, La Réunion, France

D. Strasberg
Université de La Réunion, UMR PVBMT, Saint-Denis, La Réunion, France

providing valuable lessons for managing invasions in other regions. This framework holds promise for addressing several Global Biodiversity Framework Targets concerning plant invasions in island ecosystems or within landscapes characterised by multi-layered governance.

French abstract La gestion des invasions biologiques au sein des aires protégées nécessite des solutions innovantes. Dans l'archipel des Mascareignes, la plus grande zone de végétation intacte se trouve dans le parc national de l'île de La Réunion, qui fait face à des menaces alarmantes telles que les espèces végétales exotiques envahissantes. Pour y répondre, le gouvernement local a initié en 2018 un partenariat inclusif impliquant décideurs, gestionnaires et scientifiques pour aborder la question de la gestion des espèces végétales exotiques envahissantes sur l'île. Un cadre opérationnel allant de la planification à la mise en œuvre a été établi, englobant cinq étapes clés : (1) réaliser un diagnostic complet du site, (2) modéliser les menaces futures, (3) prioriser les interventions, (4) mettre en œuvre des actions à travers un programme multi-acteurs et pluriannuel, et (5) évaluer l'efficacité des interventions mises en œuvre. Cette étude offre un examen approfondi du partenariat recherche-action et du cadre opérationnel, illustrant les résultats pour deux sites prioritaires clés. Notre campagne de terrain a couvert plus de 2500 hectares, quantifiant le degré d'invasion dans trois strates de végétation à une échelle fine, indiquant des zones significatives de végétation subalpine qui restent remarquablement intactes. En adaptant des approches de planification de conservation participative, nous avons développé des outils utiles pour les gestionnaires qui ont permis la mise en place des interventions sur le terrain. Le partenariat illustre une approche transdisciplinaire avec un large éventail de parties prenantes. En nous appuyant sur une liste de facteurs de réussite, nous mettons en avant les leçons clés tirées de cette initiative pour la gestion des invasions dans d'autres régions. Cette approche offre des perspectives prometteuses pour répondre à plusieurs objectifs du Cadre mondial pour la biodiversité concernant les invasions végétales dans les écosystèmes insulaires ou dans des contextes caractérisés par une gouvernance à plusieurs niveaux.

Keywords Invasive species management · Restoration planning · Mascarenes · Reunion Island · Research-action partnership · GBF Targets

Keywords **Gestion** des espèces envahissantes · Planification de la restauration · Mascareignes · Ile de La Réunion · Partenariat recherche-action · Objectifs du cadre mondial pour la biodiversité (GBF Targets)

Introduction

Invasive alien species now exceed the number of native plants in more than 25% of the insular ecosystems, driving many recent extinctions (Bellard et al. 2016, 2017; IPBES 2023). To maximise the benefits of management actions, it is imperative to adopt strategies encompassing a comprehensive set of coordinated actions over a long period (García-Díaz et al. 2022). Strategies for managing invasive species to mitigate or reverse biodiversity decline remain a top priority at national and international scales; as highlighted by initiatives such as the "Global Biodiversity Framework" (CBD 2022) or the creation of intergovernmental platforms such as IPBES (2023). In particular, Target 6 of the Global Biodiversity Framework aims to reduce the introduction of invasive alien species by 50% and to minimize their impact (CBD 2022). One of the key steps of effective alien plant management strategies consists in prioritisation to support cost-effective allocation of resources (Krug et al. 2009; McGeoch et al. 2016). Invasive species policy and management should prioritise pathways, sites or species based on the invasion stage and the desired management objectives.

For science to provide the necessary answers to translate into effective actions and to meaningfully influence decision-making, a two-way transfer of knowledge along a continuum between science and management is necessary, often referred as the "knowing-doing continuum" (Foxcroft et al. 2020; see GBF Targets 20 & 21, CBD 2022). This connection between all the spheres of practice helps to close the "knowing-doing" or "Research-Implementation" gap (Knight et al. 2008; Pfeffer and Sutton 1999) which tends to generate a barrier between science and management actions (Cook et al. 2013). This gap is partly explained by the use of an inappropriate spatial scale. Scientists often focus on broad conceptual principles over large spatial scales, with an emphasis on methodological advances. However, managers usually encounter practical difficulties at more local and finer scales (Foxcroft et al. 2020; McIntosh et al. 2018). Published studies often lack fine-scale data such as invasion degree, implementation costs, operational factors, or restoration outcomes which are essential for informing prioritisation efforts. Although broad spatial scales are useful in providing general direction for management and monitoring efforts, strategies must be refined at finer scales. This facilitates effective implementation and establishes links between strategies and tangible actions on the field (Foxcroft et al. 2009). To maximise the relevance of scientific work to managers, it is also imperative to involve a wide range of stakeholders from the beginning of a project (Gonzalo-Turpin et al. 2008; Matzek et al. 2015). Managers and decision-makers must therefore be seen as active participants rather than passive recipients of information (Dubois et al. 2020).

Reunion Island, a French tropical oceanic island, is one of the world's biodiversity hotspots (Mittermeier et al. 2011). Although the destruction and transformation of habitats in Reunion following human activity is strongly marked, 25% of the original natural habitats remain preserved (Strasberg et al. 2005). In 2007, a national park was established to safeguard the rich biodiversity and high rate of endemism of La Reunion Island. Nevertheless, the island is faced with numerous threats, first and foremost the invasion of alien plant species (Baret et al. 2006; Cadet 1977; Macdonald et al. 1991; Lavergne 1978) which spread throughout all ecosystems across the entire altitudinal range (Fenouillas et al. 2021; Strasberg et al. 2005). In 2017, UNESCO called for action to address the spread of invasive plant species on the island, highlighting the inadequate resource allocation. They emphasised the necessity to strengthen governance and coordination among stakeholders involved in biodiversity management (Osipova et al. 2017). Following this alert, a collaborative approach has been developed bringing together managers, decision-makers, funders and scientists to deal with alien invasive plant management in Reunion Island. In this study, we aim to present an operational framework from planning to implementation for managing plant invasions in tropical island ecosystems. Based on a multi-stakeholder process, we illustrate key stages of the framework through the case of Reunion Island and outline the lessons-learned into key ingredients for success that can be applied elsewhere to deal with alien plant management.

A step-by-step operational programme

Managing invasive species requires the involvement of a wide range of stakeholders for various tasks which include funding, gathering data, making decisions, implementing actions and evaluating management success. Often these stakeholders are involved in only one or two tasks, lacking coordination among them. As a result, actions can become disconnected and ineffective. For example, decisions might not be made based on the best-available information (Cheney et al. 2018), management plans might not be implemented, or clearing operations might not be established in priority areas (van Wilgen et al. 2012, 2022). In this paper, we define clearing operations as all actions needed to remove an invasive alien plant species or reduce its abundance. These include: early detection and local eradication, and containment. Associated actions considered in this programme also include surveillance and restoration (by planting indigenous species).

Here we established an integrated research-action partnership connecting all these tasks together. An operational programme was co-constructed with all partners involved in invasive plant management including funders, decision-makers, scientists, and managers. Our operational programme consisted of seven key steps, from (1) establishing a formal partnership to (7) evaluating actions (Fig. 1). Below, we present a concise overview of each step, emphasising on the rationale and major outcomes. We then illustrate key steps (3–5) in two sites identified as priority areas for conservation and restoration.

Step 1: Establish a long-term partnership with formalised governance

In Reunion Island, the entire chain from knowledge to implementation for managing invasions was not well connected due to inadequate communication and integration among the wide range of stakeholders involved (Fig. 2). In 2018, the establishment of this formal partnership addressed this issue bringing

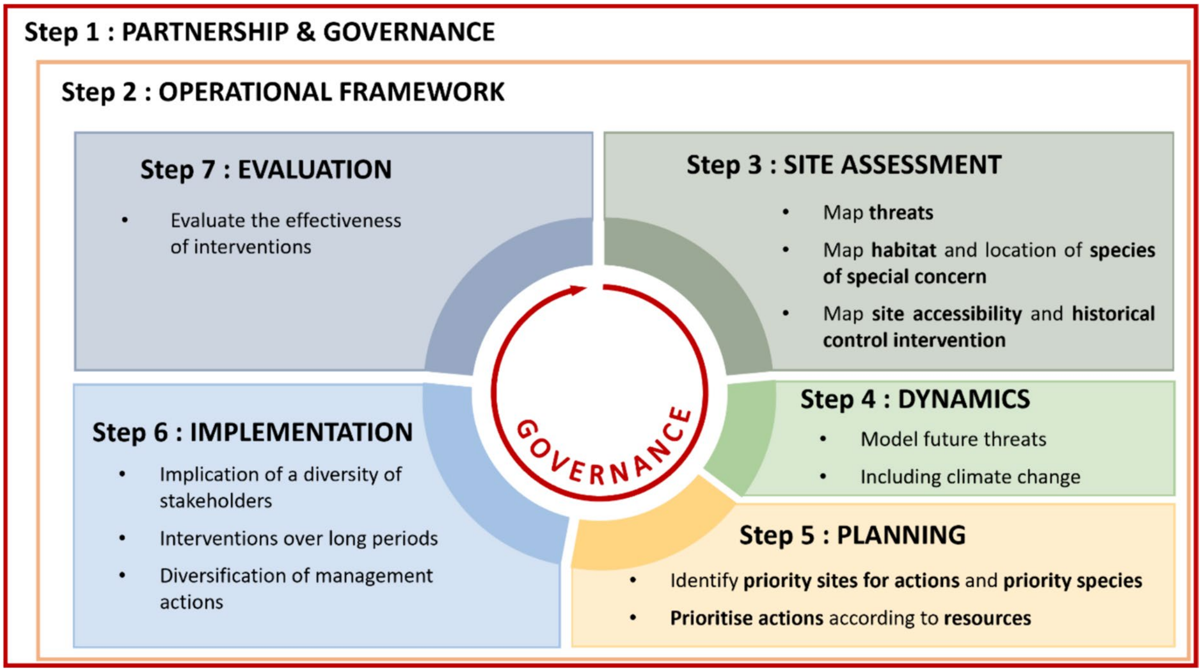


Fig. 1 Operational programme for managing plant invasions in Reunion Island. This framework is not restricted to managing invasions but can be applied to conservation programmes more generally

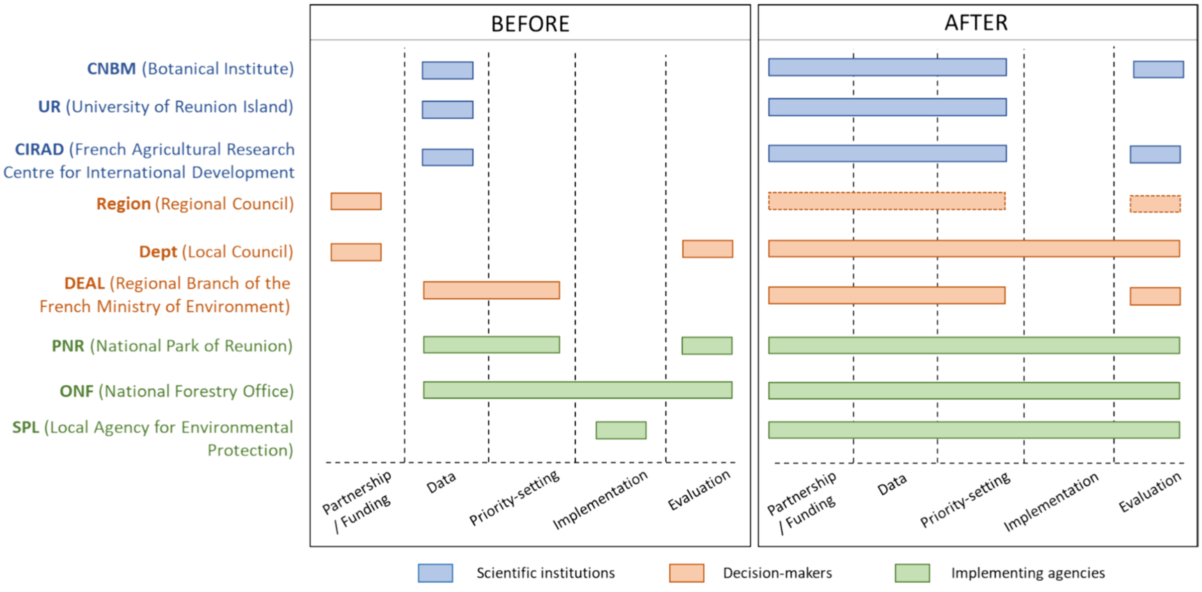


Fig. 2 Stakeholders' involvement in the management of invasive species before and after establishing the research-action partnership. This does not show the level of involvement of each institution but only their involvement in the operational programme

together all relevant stakeholders with a clear governance structure (García-Díaz et al. 2022). By strengthening technical and scientific cooperation at all levels, including at local level, this partnership is an example of how to achieve several targets from the Global Biodiversity Framework (CBD 2022), such as Target 14 "*Integrate Biodiversity in decision-making at every level*" and Target 20 "*Strengthen Capacity-Building, Technology Transfer, and Scientific and Technical Cooperation for Biodiversity*". Through the creation of this formal agreement, stakeholders were recognised and became actors in many tasks of the knowledge-implementation chain (Table 1, Fig. 2). Funders, scientists, decision-makers and managers were brought together in a working group to address the issue of managing plant invasions from funding, gathering data, decision-making, implementing and evaluating actions. Governance was a central issue to address from the start to clarify the role of each institution and how decisions were made (Conroy and Peterson 2013; García-Díaz et al. 2022). Within the working group, technical decisions were taken based on consensus. The working group was accountable to a steering committee comprising the directorates of each institution. The steering committee ensured that the different steps of the framework were well-connected and provided strategic guidance. The Local (Department) and the Regional Council provided political buy-in and ensured that this framework was part of a regional planning process. Importantly, this partnership was independent of specific project funding, leveraging internal resources from each institution to ensure long-term sustainability.

Step 2: Co-develop an operational framework

The first task of this working group was to co-develop an operational framework with shared objectives among stakeholders. This was critical to close the research-action gap, or the knowing-doing gap which is commonly found in invasive species management (Foxcroft et al. 2020; van Rees et al. 2022). The operational framework clarified right upfront the goals and objectives—collectively-identified,

Table 1 Stakeholders involved in the research-action partnership

Institution	URL	English name	Role
Scientific agencies			
CBNM	www.cbnm.org	Botanical Institute	Data provider, conceptual development of approach, decision-making
CIRAD	www.cirad.fr	French Agricultural Research Centre for International Development	Conceptual and technical development of approach, decision-making
UR	www.univ-reunion.fr	University of Reunion Island	Data provider, conceptual development of approach
Decision-makers			
DEAL	www.reunion.developpement-durable.gouv.fr/	Regional Branch of the French Ministry of Environment	Data provider, conceptual development of approach, decision-making
Department	www.departement974.fr/	Local Council	Data provider, conceptual development of approach, decision-making, funding, implementation
Region	www.regionreunion.com/	Regional Council	Conceptual development of approach, decision-making, funding
Implementing agencies			
ONF	www.onf.fr/la-reunion	National Forestry Office	Data provider, conceptual development of approach, decision-making, implementation
PNRun	www.reunion-parcnational.fr/fr	National Park of Reunion	Data provider, conceptual development of approach, decision-making, funding, implementation
SPL EDDEN	www.edden.re/	Local Agency for Environmental Protection	Data provider, conceptual development of approach, decision-making, implementation

and enabled scientists, decision-makers and managers to be involved in all the seven steps of the operational programme. Too often, key stakeholders, such as managers or implementing agencies are involved at the end of a linear chain of decision-making, which prevents uptake and implementation of the results (see Fig. 1 in van Rees et al. 2022). Critical components of a transdisciplinary process encompass collaboratively developing a shared conceptual framework, engaging in ongoing consultations, incorporating feedback loops at every stage, and generating knowledge that is valuable for users (Cockburn et al. 2016a; García-Díaz et al. 2022; Hirsch Hadorn et al. 2008).

To increase its likelihood of implementation, we co-developed by consensus the overall approach and the intended outcomes, to get acceptance by all stakeholders. This framework aimed to collect data to inform management decisions, prioritise actions for invasive plant management, coordinate the implementation effort among agencies, facilitate data sharing among stakeholders, monitor the effectiveness of actions, and adjust the processes if needed. To ensure the framework remained implementable, each step of the framework was downscaled to the appropriate implementation level, and user-friendly and user-useful outputs have been generated. Such framework ensures that the best available data, information and knowledge are accessible to decision makers and practitioners as suggested by the GBF Target 21.

2.3. Step 3: Conduct site assessment

To identify management priorities and the actions to implement, a preliminary phase of evidence-based assessment is necessary. The data collected in the field should be sufficient to quantify the biodiversity at a site (e.g., mapping of habitat and species of special concern), major threatening factors, and operational factors that will help with implementation (e.g. site accessibility and management history).

Mapping key features of biodiversity areas such as habitats and location of native species constituted the first part of the assessment. This enabled us to reflect accurately the biodiversity present on site and identify potential habitats and species of special concern. The second part consisted in the identification and mapping of threats; in our case we only considered invasion by alien plant species as threats to biodiversity. Depending on the threats facing the studied area, this could include fire risk (Mandle et al. 2011), habitat fragmentation (Honnay et al. 2002) or grazing caused by ungulates (Vavra et al. 2007). Detection and mapping of alien species is an important component of conservation and management efforts. Quantifying the invasion degree which indicates the extent of which a community has already been invaded (Catford et al. 2012; Guo et al. 2015) forms the basis of any invasive management strategy. To meet the needs, we developed a Rapid Assessment Method based on field-surveys quantifying invasion degree (see Online Resource 1). The key points of this protocol were that it considered strata differentiation (herbaceous including seedlings, shrub and tree) and was rapid, simple and replicable in different habitats (see Fenouillas et al. 2024 for more detail), while remaining statistically robust. These characteristics made our protocol easy to use. Assessments of seed bank longevity and germination rates of key invasive alien plant species could also be included depending on resource availability (here we only assessed the presence of invasive alien species seed banks). Standardised and systematic approaches for collecting data are key tenets of a well-designed long-term ecological management of invasive alien species (García-Díaz et al. 2022). Remote sensing, which allows large-scale mapping of the current distribution of invasive alien plant species, can also be used to complement field surveys. The process of data collection was conducted thoughtfully, ensuring that the gathered information could be translated in a manner that would facilitate meaningful and actionable outcomes. The site assessment should also consider operational criteria, such as site accessibility or the history of clearing operations, to guide the location of future clearing operations.

Step 4: Modelling future threats and intervention scenarios

Natural resource managers face an increasingly important challenge: how to manage ecosystems changing constantly under land use change, pollution, climate change, or invasive alien species impacts. These constant changes should be considered in long-term management strategies. Studies on alien plant invasions should include spatial and temporal dynamics as many alien species have largely extended their distribution range within the last century (Pyšek and

Hulme 2005). Ecological modelling and forecasting of the environmental niches are appropriate to study alien plant species spatio-temporal dynamics and to orient management decisions (see Geary et al. 2020; Baker and Bode 2021 for examples). These approaches could especially facilitate risk assessment, spatial prioritisation at early stages of invasion and ranking sites for management. As part of our operational framework, an ecological model has been developed to assess the future spatio-temporal spread of invasive alien plant species (Online Resource 2). It represents ecological processes and life cycle stages at both individual and patch levels, including seed bank dynamics and dispersal, of key invasive alien plant species. The model consists of six modules related to key ecological processes, which can be customised for different life-forms (herbs, grass, shrub, tree or vine). These processes include: vegetative reproduction, sexual reproduction, establishment, growth and patch creation. The model can be used to guide management decisions for key invasive alien plant species based on projected future spread into key biodiversity areas.

In addition, one can evaluate the optimal management strategy among a range of scenarios using cost–benefit analysis or multi-criteria decision analysis (Cullinane et al. 2019; Pouzols et al. 2012). Decisions about invasive species management are often complicated as they involved trade-offs and competing outcomes. For example, should managers focus on controlling large areas slightly invaded at a lower unit cost or fewer highly invaded areas at a much higher unit cost? Landscape simulation models, combined with economic tools, can inform invasive species control decisions (Cullinane et al. 2019) and become more efficient in the use of limited resources (Bennett et al. 2018).

Step 5: Spatial planning of clearing operations

Identifying priority species and sites for action is integral to enhancing spatial planning in the management of invasive alien plant species (McGeoch et al. 2016). Spatial planning involves the strategic allocation of resources and interventions across landscapes, considering the geographical distribution and ecological context of invasive alien species. By identifying priority sites for interventions, where the risk and impact of invasive alien plant species is the highest, managers can concentrate efforts where they are most needed. Targeting priority species is also essential because not all invasive alien species have the same ecological impact or spread rate. These targeted approaches ensure that resources are used efficiently to address areas that are most vulnerable or ecologically valuable and are tailored to the specific challenges posed by different invasive species.

To address the need for prioritisation, we draw on the considerable expertise of conservation planning (Groves 2013; Knight et al. 2006; Margules and Pressey 2000) and adapted it to fit our needs. When implementing Target 1 *"Plan and Manage all Areas To Reduce Biodiversity Loss"* of the GBF, spatial planning and conservation planning in particular can provide valuable insights. We combined all existing data on habitats, both threatened and endemic species, and the distribution of invasive alien plant species based on field data, modelled data and expert knowledge. We developed a participatory decision-making process using a conservation planning tool -Zonation to identify biodiversity conservation priorities (Fenouillas et al. 2023). We used Zonation version 4 (https://github.com/cbig/zonation-core/releases) to identify important areas to retain species of special concern and habitats taking into account invasion degree. These priority areas were selected to maximise biodiversity levels in areas slightly invaded. We combined key biodiversity areas with operational criteria to prioritise areas for invasive alien plant species clearing. These operational criteria included clearing costs, accessibility, and the history of previous management programmes (see Fig. 3). Future dynamics, such as climate change (Kumschick et al. this issue) and invasion debt (Rouget et al. 2016), could also inform key biodiversity areas and clearing priority areas.

In parallel, we developed an approach to prioritise alien plant species. It seemed essential to integrate both species-focused and habitat-based approaches to comprehensively address conservation needs. This is not commonly done, as most approaches focus either on species or specific areas for determining species spread and risk (see Foxcroft et al. (2007) for an example of combining species and landscape approaches). Our process of species prioritisation entails recognising high-impact species through frameworks such as EICAT and other impacts schemes (Hawkins et al. 2015). These species were prioritised according to distribution and abundance in

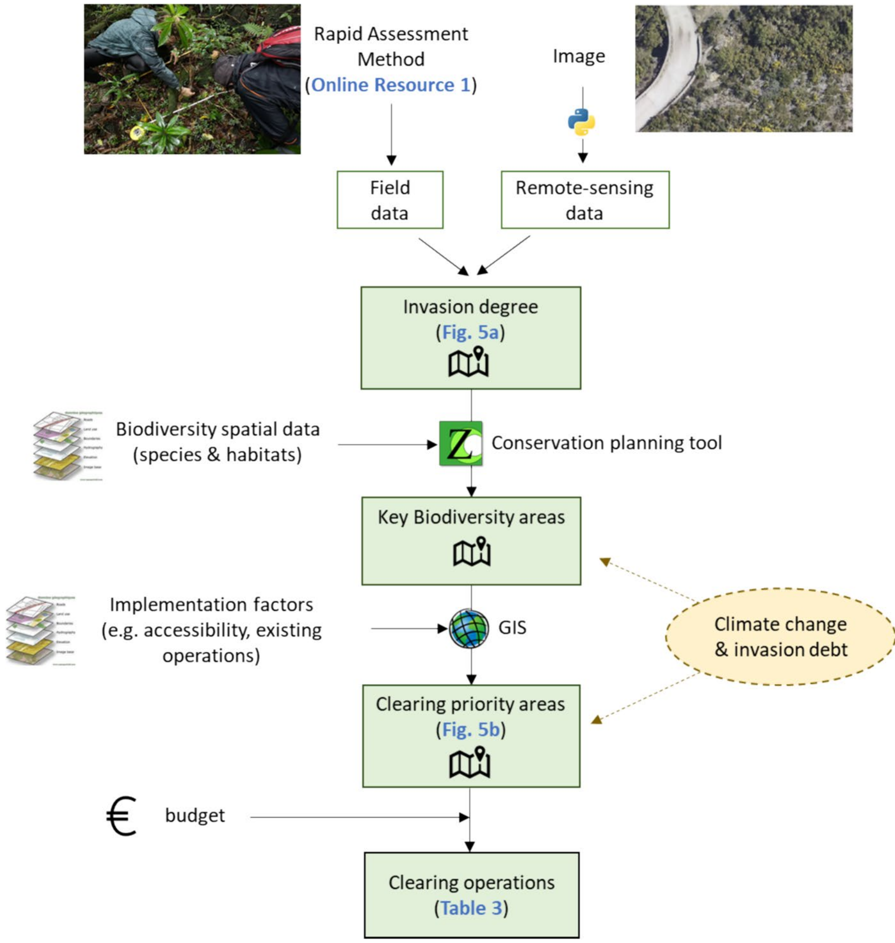


Fig. 3 Schematic illustrating the operation approach from field data to clearing operations. Field data and remote sensing analysis were combined to map invasion degree. Zonation, a conservation planning tool was used to identify key biodiversity areas. A map of clearing priority areas was produced which helped managers to select clearing operations for each site

biodiversity conservation priorities previously identified. We established two distinct priority lists: one for emerging species and another for widespread species; enabling targeted efforts for the management of both emerging and established species.

Step 6: Implement actions through a multi-stakeholders and multi-years implementation programme

This step aims at translating priority maps into implementation of clearing operations. We used a participatory approach to allocate clearing operations across implementation agencies. In doing this, we ensure to achieve a common goal while spreading the operations to be done across diverse stakeholders. Ensuring that operations on the ground are linked to an overall strategy is a difficult task as there are often gaps between assessment and implementation meaning that one is doing without the other (García-Díaz 2022; Knight et al. 2008). We considered the following criteria to allocate actions: priority areas and priority species from Step 5, annual budget, existing operations, intervention capabilities, implementation agency's experience, and site access. Most of our operations were planned only for the following year, but we identified the need to secure long-term funding and conduct long-term planning of clearing operations. Long-term management for invasive alien plant species is often overlooked as many operations are planned for short periods (1–3 years) whereas it takes much longer to control most populations of invasive alien plant species.

To maximise the net benefits of clearing efforts, it is important to diversify stakeholders and operations (Shackleton et al. 2019; García-Díaz 2022). In our plan we included different stakeholders (e.g. voluntary workers, forestry office, national park, job creation schemes) and a range of actions (e.g. surveillance, population eradication, containment, restoration by planting indigenous species). We developed fact sheets for managers to recommend clearing techniques of key invasive alien plant species (Online Resource 3). The frequency and timing of control efforts should be adjusted based on seed bank dynamics and dispersal patterns. It is also important to efficiently prioritise resources allocated to the range of actions identified. For example, the forestry office, given its experience and work force, was better suited to containing invasive species in relatively accessible sites. The national park team, smaller but more flexible, could target surveillance and population eradication in sites not easily accessible. Voluntary workers and participatory clearing operations were best suited to small, well-identified operations for invasive alien plant species that were easily identifiable.

In addition to mechanical and chemical clearing, biological control is an appropriate complementary clearing method to use, especially for widespread invasive species in remote areas. In Reunion Island, there has been one successful programme of biological control targeting *Rubus alceifolius*, a vine invading natural habitats from lowlands to tropical montane forests (Cybèle et al. 2021). While such method requires a long research phase to identify suitable agents, several research programmes are currently in place to establish biological control programmes for invasive alien plants (such as *Hiptage benghalensis*) and insects (such as *Acizzia uncatoides*) invading natural habitats of the island.

Step 7: Evaluate the effectiveness of clearing operations

This last step is a critical one, which is often not included or planned for in managing biological invasions (van Wilgen et al. 2022). This step however determines the overall success and the need for follow-up operations (Cheney et al. 2020). As part of an adaptive management strategy, it allows for redirecting operations which did not achieve expected outcomes. Few evaluation schemes are available and range from simple administrative checks to outcome-based evaluation (McConnachie et al. 2016).

In the past in Reunion Island, the forestry office (the main implementation agency) and the funding agency conducted their own evaluation (Rousse and Triolo 2016). For the funder, the focus was on project monitoring in terms of budget spent, species and sites targeted, and overall effectiveness. The forestry office focused on levels of objectives being achieved and capacity to manage the site. Here we developed a rapid assessment method, based on the initial assessment of invasion degree to evaluate several factors: the extent to which the abundance of invasive species has decreased, the extent to which indigenous species regenerate, and the extent to which the indigenous vegetation cover, structure and diversity has recovered (Online Resource 4). Our monitoring and evaluation protocol of clearing operations has been designed with three levels of complexity to measure from broad changes in alien and indigenous vegetation to fine-scale seed bank expression following clearing operation. We used a comparative approach with counterfactuals to evaluate sites with and without operations in similar conditions (habitat, invasion level) (McConnachie et al. 2016). Depending on the monitoring outcome, the clearing operation can be either considered as finalised, carried over to the next year or abandoned due to lack of success. Long-term monitoring and evaluation data is needed to assess the success of this operational framework.

Pilot sites: Plaine des Fougères and Grand Bénare

Here we illustrate key stages of the operational framework for two priority sites: Plaine des Fougères and Grand Bénare (Fig. 4).

Description of pilot sites

Plaine des Fougères is a mountain rainforest site, ranging from 900 to 1900 m a.s.l. on the north-eastern side of Reunion Island. It is relatively difficult to access, with rugged topography and dense vegetation. It is characterised by several habitats: *Acacia heterophylla* mountain rainforest, *Pandanus* wet thicket, and *Erica* shrublands on the higher parts, with varying degrees of invasion. Prior to this survey, it was thought to be relatively pristine due to its remoteness and was listed as a local key biodiversity area (Fenouillas et al. 2023).

Grand Bénare is a subalpine vegetation site, ranging from 2000 to 2800 m a.s.l. on the western side of the island. It is easier to access with gentle slope

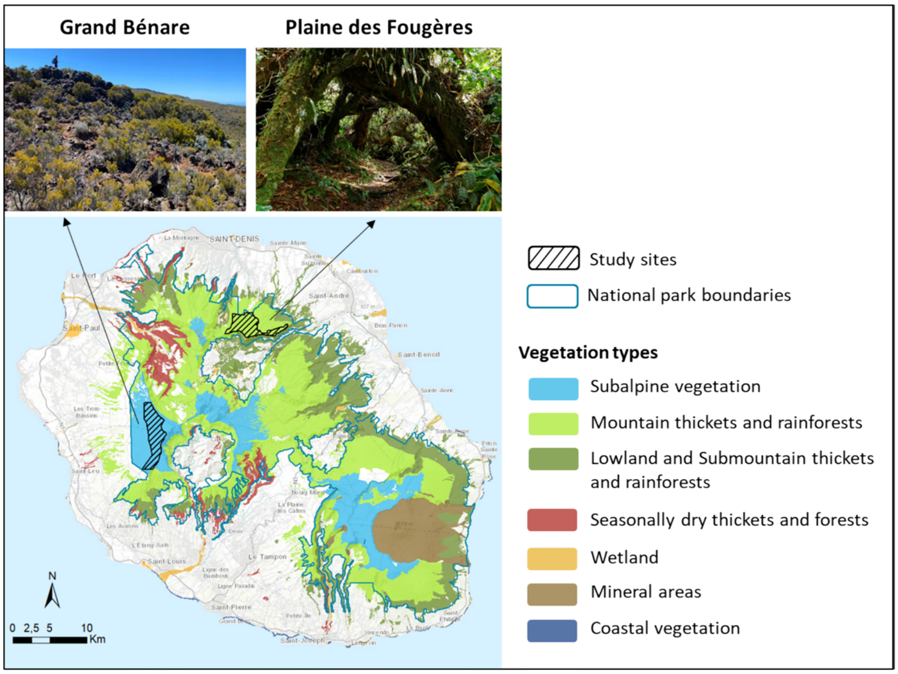


Fig. 4 Map of study area (including habitats) and pilot sites (Grand Bénare—1200 ha and Plaine des Fougères—900 ha)

and open vegetation in most areas. In 2000's it was subject to a series of intense wildfires which favored invasion by *Ulex europaeus*. It is characterised by several habitats: *Acacia heterophylla* mountain rainforest and thicket, *Erica* shrubland, and subalpine herblands with low levels of plant invasions. As this was the least invaded side on the western side, it was also considered as a key biodiversity area.

From field surveys to clearing operations

The importance of data on invasion degree (Step 3 site assessment)

Our rapid-assessment method of invasion degree could be implemented in diverse landscapes (ranging from 100 to 1000 s ha) in tropical forests and subalpine mountain habitats. It took one person one day to survey between 7.2 and 22.2 ha (Plaine des Fougères: 125 person-days for 900 ha, Grand Bénare: 54 person-days for 1200 ha), due to differences in site accessibility. The field-based evidence was essential to update our knowledge of invasion degree for both sites. In Plaine des Fougères, we found a much higher level of invasion than initially known (Online Resource 5) as only 9% of the area surveyed was free of invasive species. The field campaign was instrumental in refining priority areas for clearing and implementing key interventions for emerging species such as *Ligustrum robustum, Strobilanthes hamiltoniana* and *Cinchona officinalis* (see Table 2). Unexpectedly, the field assessment for Grand Bénare revealed a low level of invasion, with 87% of the area considered free of invasive species (Fig. 5A). However, we found a few alien species of major concern such as *Ulex europaeus*, *Acacia mearnsii* and *Pinus pinaster* (Table 2). Here, the evidence gathered during the field survey highlighted a much lower invasion level than previously known and emphasized the importance of this site as a key biodiversity area.

Using conservation planning approaches to prioritise clearing operations (Step 5)

The method developed in this study allowed the identification of key biodiversity areas and priority sites and species for actions. The Plaine des Fougères site was more invaded than Grand Bénare site, around 50% and 80% of the entire site have been identified by our analysis as key biodiversity areas for Plaine des Fougères and Grand Bénare respectively. The limited level of invasion in the Grand Bénare area implies several urgent priorities for actions (Fig. 5B). The primary focus remains on ongoing surveillance and

Table 2 Priority alien plant species for clearing

Species	Family	Biological type	Site	Number of records	Operations
Cinchona officinalis L., 1753	Rubiaceae	Shrub	Plaine des Fougères	9	Clear isolated individuals
Strobilanthes hamiltoniana (Steud.) Bosser & Heine, 1988	Acanthaceae	Herb	Plaine des Fougères	35	Control outermost populations
Ligustrum robustum (Roxb.) Blume, 1851	Oleaceae	Shrub	Plaine des Fougères	38	Monitor spread
Ulex europaeus L., 1753*	Fabaceae	Shrub	Grand Bénare	34	Clear outermost populations
Pinus pinaster Aiton, 1789	Pinaceae	Tree	Grand Bénare	3	Clear isolated individuals
Acacia mearnsii De Wild.*	Fabaceae	Tree	Grand Bénare	1	Clear isolated individuals

*Widespread species over the island but we focus on isolated populations in slightly invaded areas

Only emerging species are targeted here

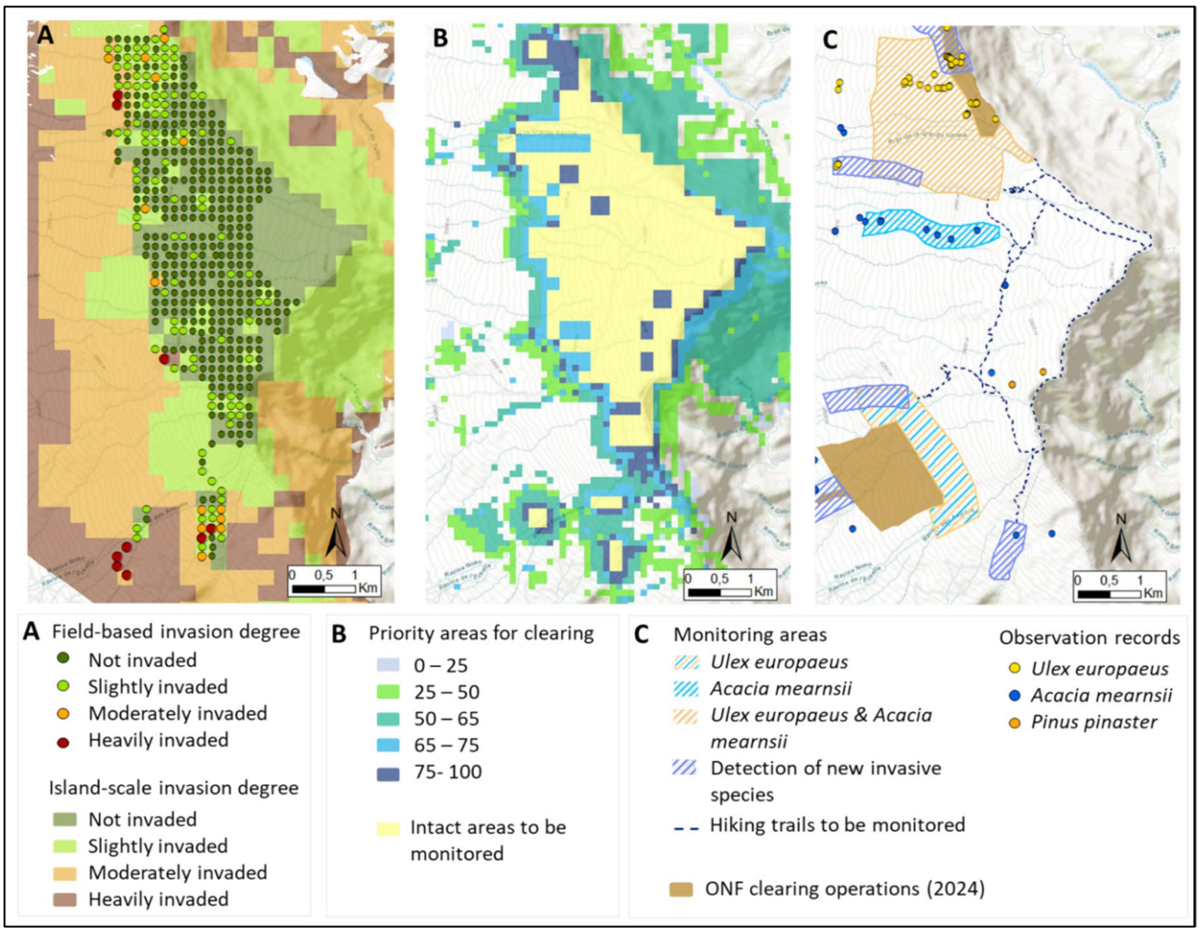


Fig. 5 Illustration of steps 3, 5 and 6 of the operational framework for the Grand Bénare site. Map of **A** invasion degree, **B** clearing priority areas and **C** proposed and ongoing interventions for invasive alien species *Ulex europaeus, Acacia mearnsii* and *Pinus pinaster*)

Early Detection and Rapid Response (EDRR) measures. Priority areas for clearing consisted of "invasion fronts" representing accessible invaded areas close to slightly or non-invaded key biodiversity areas (Fig. 5B and C).

Implementing a multi-stakeholder and multi-years clearing programme (Step 6)

This coordinated approach led to the development of a multi-stakeholder and multi-year clearing programme. Priorities identified through this study helped to spatially re-align existing clearing operations. It should be noted that over 93% of historical clearing operations (i.e. 563 ha) were already aligned with current priorities, which represent a good allocation of more than 80% of the annual department's budget (Fenouillas et al. 2023). Various types of operations have been identified as priorities based on the different sites considered and the broad array of stakeholders. Some operations were species-based and some others were habitat-based. Different types of intervention (Table 3) included: (1) the Early Detection and Rapid Response (EDRR) strategy which encompasses the interventions for both new species, emerging species, and newly invaded areas, (2) the targeted clearing for key emerging alien species (Fig. 5C), (3) the targeted clearing around species of special concern which aims to reduce the abundance of alien species located in the immediate vicinity of endangered native species populations in order to protect them, (4) the area-based clearing which represents an intervention in an slightly invaded area where controlling IAS is still feasible, (5) the restoration of burnt areas, and (6) capacity building programme aiming at developing the skills, knowledge, and resources necessary among stakeholders involved in invasive species management. Such broad range of actions, with a wide array of stakeholders is essential to contribute to GBF Target 2 and 3 regarding the restoring of 30% of degraded ecosystems and conserving 30% of land.

General discussion

This paper proposes a step-by-step operational framework integrating key stages along the knowing-doing continuum. We propose standardised methods for rapid assessment of invasion degree, spatial prioritisation and we emphasize the role of governance and partnership among stakeholders. To ensure effectiveness and increase its implementation, our framework includes five central criteria for good public policy and natural resource management (justifiable, evidence-informed, actionable, quantifiable and flexible) (García Díaz et al. 2022). It is also framed in transdisciplinary collaborative thinking to address the major barriers to evidence-informed conservation policy and actions (Rose et al. 2018). We briefly discuss below two steps not often considered in invasive plant species management research and summarise key ingredients for success based on our collective experience.

Spatial planning of clearing areas has not received much attention in the published literature (Januchowski-Hartley et al. 2011; Mačić et al. 2018) yet it stands as a pivotal step in optimising the utilisation of scarce resources, particularly in the management of invasive species (Krug et al. 2009; McGeoch

Table 3 List of interventions per site in 2022–2023

Sites	Operation type	Implementer/Stakeholders	Area/nb
Grand Bénare/Plaine des Fougères	Area-based clearing	ONF	13 clearing operations (223 ha)
Grand Bénare/Plaine des Fougères	Targeted clearing for key emerging alien species	ONF/PNR	16 clearing operations (9 ha)
Grand Bénare	Early Detection and Rapid Response in intact areas	ONF	1 operation (1523 ha)
Grand Bénare	Planting indigenous species	ONF/PNR/CBNM	1 operation (100 individuals)
Grand Bénare	Volunteer work	PNR	1 clearing operation
Grand Bénare	Capacity building programme	Dept/SPL	1 operation
Grand Bénare	Restoring burnt areas	PNR	1 operation

et al. 2016), hence achieving Target 1 of the GBF on planning for reduction in biodiversity loss. Drawing upon the extensive experience in conservation planning could provide valuable insights into prioritising the clearing of invasive alien plants (Reyers et al. 2010). This proactive approach not only safeguards native biodiversity but also optimises the efficiency and effectiveness of invasive species management efforts (Forner et al. 2022). Prioritisation is a complex process which often require a transdisciplinary approach, the use of decision support tools is highly recommended to guide managers to apportion conservation budgets and optimise their investments in an objective and measurable way (Dana et al. 2014; Forsyth et al. 2012; Masunungure et al. 2023). With the support of these tools, formal prioritisation processes outperform individual judgment because they are transparent, replicable, and consider multiple factor (Forner et al. 2022).

Another area of future research concerns monitoring and evaluating the outcomes of interventions. These activities should be included in clearing programmes to improve effectiveness as it is essential for informing decision-making (van Wilgen et al. 2012; Bennett et al. 2018). Few studies have proposed standardised methods for monitoring and evaluating outcomes of clearing interventions (Cheney et al. 2018). As monitoring can be costly and time consuming, one needs to identify the most efficient ways to conduct monitoring and evaluation (Bennett et al. 2018). Cost-effective approaches to monitoring could include the use of high spatial or temporal remote-sensing imagery to detect changes in alien plant species abundance and distribution (Royimani et al. 2019). There are however important challenges and limitations to long-term monitoring to be addressed: (a) monitoring emerging invasive alien species might be challenging as they are often below the detection threshold for remote sensing and might require more intensive monitoring (Oswalt et al. 2021); b) outcomes of clearing operations might be seen after long time periods and would require long-term monitoring (Norton 2009); (c) trade-offs between allocating resources to management or monitoring would have to be made (Bennett et al. 2018).

Key ingredients for success

A wide range of factors can influence the success of invasion management programmes. These include biological and ecological factors (related to the invasive alien species or the recipient habitat), operational factors (such as clearing efficacy, budget) or governance-related aspects (such as coordination among different stakeholders). Here we focused mainly on governance and partnership issues as these are essential in establishing successful invasive species control programmes (Lubell et al. 2017; Shackleton et al. 2019). Based on our experience and the literature, we identified some of the key ingredients to maximise the chance of success for similar invasive alien plant clearing programs (Table 4). These factors range from operational aspects around stakeholders' engagement to the use of data. Of particular importance in such long-term programme, was the central role of good governance at different levels. This was made possible by the key role of the National Park of Reunion Island to drive this process as its mandate is to protect biodiversity concerns across 80% of the island and it has put in place clear policies to interact

Table 4 Ingredients for success and level of achievement in Reunion Island

Factors	Why	Level achieved	Risk level	Examples in Reunion
Operational knowledge-action partnership	Closing the research-action gap	***	L	Fig. 2
Field data	Accurate knowledge	***	L	Online Resource 1
User friendly and user implementable outcomes	Priority area Priority programmes	**	L	Fig. 4
Multi-years and multi-stakeholders programme	Long-term restoration goals	*	M	Tables 1 and 3
Secure funding and governance	Long-term persistence	**	H	
Diverse range of actions implemented (in sufficient amounts)	Long-term persistence	*	M	Table 3
Built-in evaluation protocols	Adaptative management	*	L	Online Resource 4

Risk level indicates the risk of not achieving this factor (L—Low, M—Medium, H—High) with other stakeholders. This positioned the national park as a legitimate champion of this research-action programme. Achieving long-term sustainability of such partnership remains a challenge. While we managed to achieve some levels of strategic governance by including this operational programme in medium-term invasive alien species management strategy for Reunion Island and in operational programmes of all the partners involved, our program still lacks strong political governance with long-term political commitment. Long-term sustainability would require building flexible governance agreements that consider horizontal (within same level) and vertical (between levels) institutional connections. This will provide more effective adaptation to changing social and ecological conditions (Folke et al. 2005; Ostrom 2010). Long-term partnership needs constant attention to cope with changes in partner organisations, in a process of adaptive co-management (Armitage et al. 2009; Adams et al. 2016). This can be achieved by regular reviews and evaluation of the partnership (Cockburn et al. 2016b), including stakeholders' commitment and the extent to which the partnership meets the objectives of the different partners. A mixed funding model with external and internal funds will ensure the long-term sustainability of such a partnership (Adams et al. 2016). This echoes the need for long-term funding of restoration programs to address the GBF Targets 2 and 6.

We detailed below one key factor, not often considered, which is the establishment of an operational partnership between stakeholders.

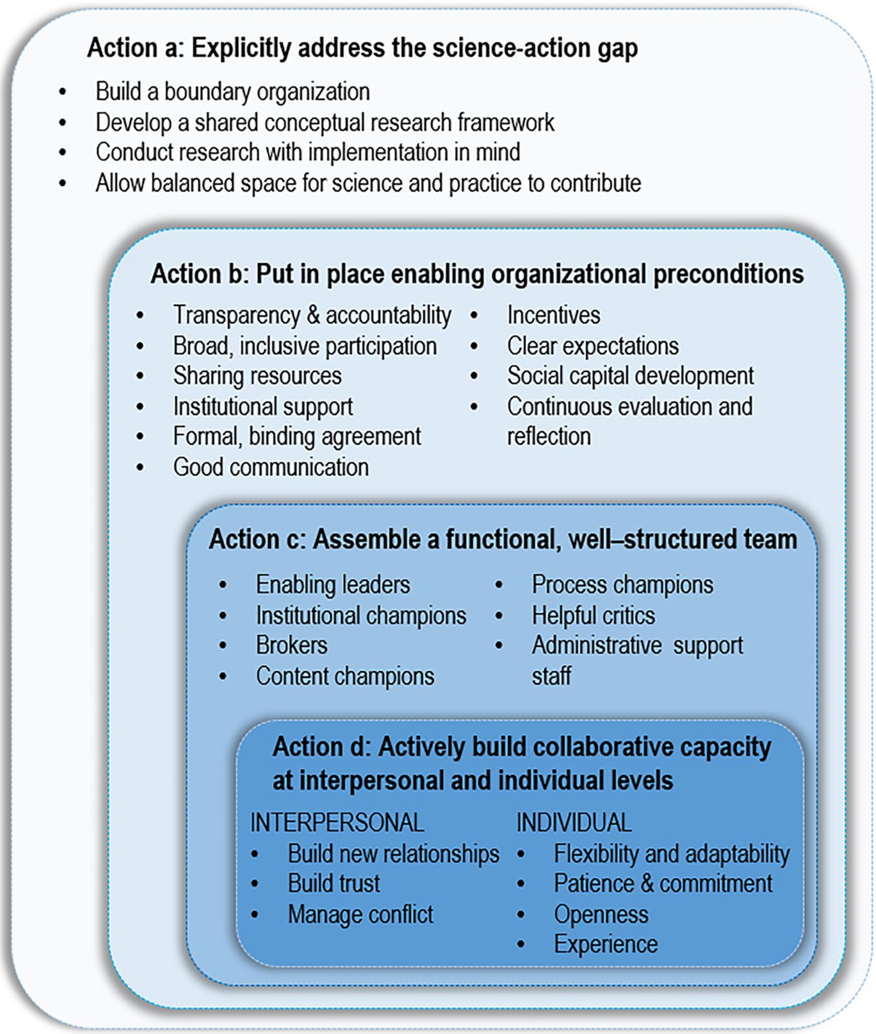
This partnership, created in 2018, established the framework for the transdisciplinary approach implemented to more effectively manage invasive alien plants in La Réunion. Similar approaches have already been initiated in other regions of the world (e.g. García-Díaz et al. 2022). For example, the work of Cockburn et al. (2016a) proposes a conceptual and operational framework to bridge the gap between science and action through a partnership approach. In this section, we show how the partnership established in our approach largely adheres to the best practices outlined by Cockburn et al. (2016a). The success of a partnership requires a certain level of investment initially; Fig. 6 presents a set of conditions that should be met to promote the success of such partnerships. These conditions are presented as actions organised at four different levels: (a) between organisations, (b) within organisations, (c) within the team, and (d) at the individual level. While implementing GBF Targets, especially Target 20 and 21 on strengthening partnership and mobilising best-available knowledge, it is crucial to bear these factors in mind.

In our case, two key factors outlined below have significantly contributed to action (a), namely bridging the science-action gap. Firstly, the establishment of the Working Group served as a boundary organisation where various stakeholders could come together and exchange ideas freely. Within this space, the three levels of governance and their regular interactions facilitated long-term interactions among different project stakeholders. These sustained interactions and the resulting knowledge-sharing between institutions often have more significant impacts on the field than the research results themselves (Shackleton et al. 2009). The establishment of cross-cutting workspaces or boundary organisations not only involves designing research programs and co-generating knowledge but actively contributes to the creation of social capital through the development of new relationships, work networks, and collaborations among participants (Cockburn et al. 2016a; Harris and Lyon 2013). Secondly, a formal binding agreement was also drafted, serving as a conceptual framework for the project. The drafting of such a document makes the joint research vision within the partnership tangible (Morse et al. 2007) and formally defines the roles of each party to ensure that researchers and implementation managers work together in a balanced manner.

Several characteristics have been implemented during the partnership, constituting a set of favourable conditions for its smooth progress (Fig. 6, action b). Participation in various workshops was inclusive as it was widely open to all voluntary participants. Resource-sharing was initiated early in the partnership, enabling access to a significant database for the creation of several maps. All documents related to the approach, the implemented methodology, or the results obtained were widely shared with all partnership members. An evaluation of the approach was also conducted.

Ultimately, these prerequisites can only be effective if project teams and participants possess certain characteristics to leverage the conducive working environment (Cheruvelil et al. 2014). Identifying champions within each institution with a predefined central role, the ability to collaborate between

Fig. 6 Enabling actions for building successful partnerships (from Cockburn et al. 2016a)



institutions and individuals were crucial factors determining the success of a partnership (Fig. 6, actions c and d). We observed important changes in the Working Group over the months as work relationships, roles, and mutual trust were established (O'Connor et al. 2021).

In conclusion, while challenges have been identified to implement the GBF Targets (Li et al. 2023), our approach provides some direction to implement some of the GBF Targets at the local level. This operational framework contributes directly to the Global Biodiversity Framework Target 1 "Plan and Manage all Areas To Reduce Biodiversity Loss", Target 2 "Restore 30% of all Degraded Ecosystems", Target 3 "Conserve 30% of Land, Waters and Seas", Target 6 "Reduce the Introduction of Invasive Alien Species by 50% and Minimize Their Impact", Target 20 "Strengthen Capacity-Building, Technology Transfer, and Scientific and Technical Cooperation for Biodiversity", Target 21 " Ensure That Knowledge Is Available and Accessible To Guide Biodiversity Action" and could potentially contribute to Target 8 "Minimize the Impacts of Climate Change on Biodiversity and Build Resilience" and Target 14 "Integrate Biodiversity in Decision-Making at Every Level". The entire operational framework, or steps of it, can be applied in many regions where invasive species management requires a multi-stakeholder approach. One can scale it from small areas (few km^2) to larger ones (tens of thousands km^2) by adjusting sampling distance (Step 3). It is particularly adapted to ecosystems invaded by large numbers of invasive alien plant species where prioritisation is needed (such as islands) and has been applied in grasslands, forest and shrublands. Invasive alien species management on Reunion Island has strongly benefited from exchange and learning networks with regions of the world facing similar challenges. We have established a regional cooperation programme with South African National Parks in particular to share experience and improve management and recommend establishing similar learning networks elsewhere. We believe that this framework holds promise for addressing plant invasions in island ecosystems or within landscapes characterised by multi-layered governance.

Acknowledgements We thank all members of the steering committee, technical committee and working groups for their contribution. We thank two anonymous reviewers and the Associate Editor who greatly helped improving the manuscript.

Authors' contribution All authors conceived the ideas, designed the approach and contributed to data collection. Mathieu Rouget and Pauline Fenouillas analysed the data and led the writing of the manuscript. All authors contributed critically to the various drafts and gave final approval for publication.

Funding This work was co-funded by the European Union: Agricultural Fund for Rural Development (EAFRD), by the Conseil Départemental de La Réunion, by the Centre de Coopération internationale en Recherche agronomique pour le Développement (CIRAD), by the national park of Reunion Island and the AFD under the grant 2022_PNR_02.

Data availability Data on field-based invasion degree for Grand Benare is available at: https://doi.org/https://doi.org/10.18167/DVN1/NCXYNX Regional data for invasion degree and priority areas for clearing is available at: https://doi.org/https://doi.org/10.18167/DVN1/4TVNWX

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

References

Adams WM, Hodge ID, Macgregor NA, Sandbrook LC (2016) Creating restoration landscapes: partnerships in large-scale conservation in the UK. Ecol Soc. https://doi.org/10.5751/ES-08498-210301

Armitage DR, Plummer R, Berkes F, Arthur RI, Charles AT, Davidson-Hunt IJ, Diduck AP, Doubleday NC, Johnson DS, Marschke M, McConney P, Pinkerton EW, Wollenberg EK (2009) Adaptive co-management for social-ecological complexity. Front Ecol Environ 7:95–102. https://doi.org/10.1890/070089

Baker CM, Bode M (2021) Recent advances of quantitative modeling to support invasive species eradication on islands. Conserv Sci Pract 3:1–19. https://doi.org/10.1111/csp2.246

Baret S, Rouget M, Richardson D, Lavergne C, Egoh B, Dupont J, Strasberg D (2006) Current distribution and potential extent of the most invasive alien plant species on La Réunion (Indian Ocean, Mascarene Islands). Austral Ecol 31:747–758. https://doi.org/10.1111/j.1442-9993.2006.01636.x

Bellard C, Cassey P, Blackburn TM (2016) Alien species as a driver of recent extinctions. Biol Lett 12:20150623. https://doi.org/10.1098/rsbl.2015.0623

Bellard C, Rysman JF, Leroy B, Claud C, Mace GM (2017) A global picture of biological invasion threat on islands. Nat Ecol Evol 1:1862–1869. https://doi.org/10.1038/s41559-017-0365-6

Bennett JR, Maxwell SL, Martin AE, Chadès I, Fahrig L, Gilbert B, Grantham H (2018) When to monitor and when to act: Value of information theory for multiple management units and limited budgets. J Appl Ecol 55:2102–2113. https://doi.org/10.1111/1365-2664.13132

Cadet T (1977) La végétation de L'île de la Réunion : étude phytoécologique et phytosociologique dissertation. Université d'Aix, Marseille, pp 10–25

Catford JA, Vesk PA, Richardson DM, Pyšek P (2012) Quantifying levels of biological invasion: towards the objective classification of invaded and invasible ecosystems. Glob Change Biol 18:44–62. https://doi.org/10.1111/j.1365-2486.2011.02549.x

Cheney C, Esler KJ, Foxcroft LC, van Wilgen NJ, McGeoch MA (2018) The impact of data precision on the effectiveness of alien plant control programmes: a case study from a protected area. Biol Invasions 20:3227–3243. https://doi.org/10.1007/s10530-018-1770-8

Cheney C, Esler KJ, Foxcroft LC, van Wilgen NJ (2020) The dominating influence of efficacy above management strategy in the long-term success of alien plant clearing programmes. J Environ Manage 271:110836. https://doi.org/10.1016/j.jenvman.2020.110836

Cheruvelil KS, Soranno PA, Weathers KC, Hanson PC, Goring SJ, Filstrup CT, Read EK (2014) Creating and maintaining high-performing collaborative research teams: the importance of diversity and interpersonal skills. Front Ecol Environ 12:31–38. https://doi.org/10.1890/130001

Cockburn J, Rouget M, Slotow R, Roberts D, Boon R, Douwes E, O'Donoghue S, Downs CT, Mukherjee S, Musakwa W, Mutanga O, Mwabvu T, Odindi J, Odindo A, Procheş Ş, Ramdhani S, Ray-Mukherjee J, Sershen S, Schoeman MC, Smit AJ, Wale E, Willows-Munro S (2016) How to build science-action partnerships for local land-use planning and management: lessons from Durban, South Africa. Ecol Soc 21:art28. https://doi.org/10.5751/ES-08109-210128

Cockburn J, O'Donoghue S, Taylor C, Rouget M, Mukherjee JR, Douwes E, Douwes E, Mukherjee S, Slotow R, Boon R, Roberts D (2016) Evaluating the outcomes and processes of a research-action partnership: the need for continuous reflective evaluation. Bothalia-Afr Biodivers Conserv 46:1–16

Conroy MJ, Peterson JT (2013) Decision making in natural resource management: a structured, adaptive approach: a structured, adaptive approach. John Wiley & Sons, UK

Convention on Biological Diversity (2022) Kunming-Montreal Global Biodiversity Framework; CBD/COP/DEC/14/5; United Nations Environment Programme: Montreal, QC, Canada. Available online: https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf Accessed from 07 May 2024

Cook CN, Mascia MB, Schwartz MW, Possingham HP, Fuller RA (2013) Achieving conservation science that bridges the knowledge-action boundary. Conserv Biol 27:669–678. https://doi.org/10.1111/cobi.12050

Cullinane TC, Sofaer HR, Cline SA, Jarnevich CS (2019) Integrating landscape simulation models with economic and decision tools for invasive species control. MBI 10:6–22. https://doi.org/10.3391/mbi.2019.10.1.02

Cybèle C, Flores O, Baret S, Chiroleu F, Reynaud B, Rivière JN, Rouget M, Sauroy-Toucouere S, Zitte Y, Strasberg D (2021) An assessment of biological control of *Rubus alceifolius* invasion on Réunion Island (Mascarene archipelago). Biol Control 163:104670. https://doi.org/10.1016/j.biocontrol.2021.104670

Dana ED, Jeschke JM, García-de-Lomas J (2014) Decision tools for managing biological invasions: existing biases and future needs. Oryx 48:56–63. https://doi.org/10.1017/S0030605312001263

Dubois NS, Gomez A, Carlson S, Russell D (2020) Bridging the research-implementation gap requires engagement from practitioners. Conserv Sci Pract 2:e134. https://doi.org/10.1111/csp2.134

Fenouillas P, Ah-Peng C, Amy E, Bracco I, Dafreville S, Gosset M, Ingrassia F, Lavergne C, Lequette B, Notter JC, Pausé JM, Payet G, Payet N, Picot F, Poungavanon N, Strasberg D, Thomas H, Triolo J, Turquet V, Rouget M (2021) Quantifying invasion degree by alien plants species in Reunion Island. Austral Ecol 46:1025–1037. https://doi.org/10.1111/aec.13048

Fenouillas P, Ah-Peng C, Amy E, Bracco I, Calichiama L, Cazal E, Gosset M, Ingrassia F, Lavergne C, Lequette B, Notter JC, Pausé JM, Payet G, Payet N, Picot F, Prolhac E, Strasberg D, Thomas H, Triolo J, Turquet V, Rouget M (2023) A research-action process to implement priority areas for alien plant clearing on Reunion Island. Biol Invasions 25:1165–1179. https://doi.org/10.1007/s10530-022-02971-8

Fenouillas P, Caubit M, Cazal E, Ajaguin Soleyen C, Strasberg D, Rouget M (2024) Standardising field-based assessment of invasion degree: a case study in two habitats of Reunion Island. Ecol Solut Evid 5:e12314. https://doi.org/10.1002/2688-8319.12314

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30:441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511

Forner WG, Zalba SM, Guadagnin DL (2022) Methods for prioritizing invasive plants in protected areas: a systematic review. Nat Areas J 42:69–78. https://doi.org/10.3375/20-47

Forsyth GG, Le Maitre DC, O'Farrell PJ, van Wilgen BW (2012) The prioritisation of invasive alien plant control projects using a multi-criteria decision model informed by stakeholder input and spatial data. J Environ Manage 103:51–57. https://doi.org/10.1016/j.jenvman.2012.01.034

Foxcroft LC, Rouget M, Richardson DM (2007) Risk assessment of riparian plant invasions into protected areas. Conserv Biol 21:412–421. https://doi.org/10.1111/j.1523-1739.2007.00673.x

Foxcroft LC, Richardson DM, Rouget M, MacFadyen S (2009) Patterns of alien plant distribution at multiple spatial scales in a large national park: implications for ecology, management and monitoring. Divers Distrib 15:367–378. https://doi.org/10.1111/j.1472-4642.2008.00544.x

Foxcroft LC, van Wilgen BW, Abrahams B, Esler KJ, Wannenburgh A (2020) Knowing-doing continuum or knowing-doing gap information flow between researchers and managers of biological invasions in South Africa. In: van Wilgen BW, Measey J, Richardson DM, Wilson JR, Zengeya TA (eds) Biological invasions in South Africa, invading nature, Springer series in invasion ecology. Springer International Publishing, Cham, pp 831–853

García-Díaz P, Montti L, Powell PA, Phimister E, Pizarro JC, Fasola L, Langdon B, Pauchard A, Raffo E, Bastías J, Damasceno G, Fidelis A, Huerta MF, Linardaki E, Moyano J, Núñez MA, Ortiz MI, Rodríguez-Jorquera I, Roesler I, Tomasevic JA, Burslem DFRP, Cava M, Lambin X (2022) Identifying priorities, targets, and actions for the long-term social and ecological management of invasive non-native species. Environ Manag 69:140–153. https://doi.org/10.1007/s00267-021-01541-3

Geary WL, Bode M, Doherty TS, Fulton EA, Nimmo DG, Tulloch AIT, Tulloch VJD, Ritchie EG (2020) A guide to ecosystem models and their environmental applications. Nat Ecol Evol 4:1459–1471. https://doi.org/10.1038/s41559-020-01298-8

Gonzalo-Turpin H, Couix N, Hazard L (2008) Rethinking partnerships with the aim of producing knowledge with practical relevance: a case study in the field of ecological restoration. Ecol Soc 13(2):53

Groves C (2013) Drafting a conservation blueprint: a practitioner's guide to planning for biodiversity. Island Press, Washington

Guo Q, Fei S, Dukes JS, Oswalt CM, Iannone BV, Potter KM (2015) A unified approach for quantifying invasibility and degree of invasion. Ecol 96:2613–2621. https://doi.org/10.1890/14-2172.1

Harris F, Lyon F (2013) Transdisciplinary environmental research: building trust across professional cultures. Environ Sci Policy 31:109–119. https://doi.org/10.1016/j.envsci.2013.02.006

Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilà M, Wilson JRU, Genovesi P, Blackburn TM (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Divers Distrib 21:1360–1363. https://doi.org/10.1111/ddi.12379

Hirsch Hadorn G, Hoffmann-Riem H, Biber-Klemm S, Grossenbacher-Mansuy W, Joye D, Pohl C, Wiesmann U, Zemp E (2008) Handbook of transdisciplinary research. Springer-Verlag New York Inc, Dordrecht, London

Honnay O, Verheyen K, Butaye J, Jacquemyn H, Bossuyt B, Hermy M (2002) Possible effects of habitat fragmentation and climate change on the range of forest plant species. Ecol Lett 5:525–530. https://doi.org/10.1046/j.1461-0248.2002.00346.x

IPBES (2023) IPBES invasive alien species assessment: full report. IPBES Secretariat, Bonn, Germany

Januchowski-Hartley SR, Visconti P, Pressey RL (2011) A systematic approach for prioritizing multiple management actions for invasive species. Biol Invasions 13:1241–1253

Knight AT, Cowling RM, Campbell BM (2006) An operational model for implementing conservation action. Conserv Biol 20:408–419. https://doi.org/10.1111/j.1523-1739.2006.00305.x

Knight AT, Cowling RM, Rouget M, Balmford A, Lombard AT, Campbell BM (2008) Knowing but not doing: selecting priority conservation areas and the research-implementation gap. Conserv Biol 22:610–617. https://doi.org/10.1111/j.1523-1739.2008.00914.x

Krug RM, Roura-Pascual N, Richardson DM (2009) Prioritising areas for the management of invasive alien plants in the CFR: different strategies, different priorities? S Afr J Bot 75:408–409. https://doi.org/10.1016/j.sajb.2009.02.072

Lavergne R (1978) Les pestes végétales de l'île de La Réunion. Info-Nature 16:9–59

Li Q, Ge Y, Sayer JA (2023) Challenges to implementing the kunming-montreal global biodiversity framework. Land 12:2166. https://doi.org/10.3390/land12122166

Lubell M, Jasny L, Hastings A (2017) Network governance for invasive species management. Conserv Lett 10:699–707. https://doi.org/10.1111/conl.12311

Macdonald IAW, Thébaud C, Strahm W, Strasberg D (1991) Effects of alien plant invasions on native vegetation remnants on La Réunion (Mascarene Islands, Indian Ocean). Environ Conserv 18:51–61. https://doi.org/10.1017/S0376892900021305

Mačić V, Albano PG, Almpanidou V, Claudet J, Corrales X, Essl F, Kark S, Marković O, Mazaris AD, Olafsdottir GA, Panayotova M, Petović S, Rabitsch W, Ramdani M, Rilov G, Tricarico E, Vega Fernandez T, Sini M, Trygonis V, Katsanevakis S (2018) Biological invasions in conservation planning: a global systematic review. Front Mar Sci 5:178. https://doi.org/10.3389/fmars.2018.00178

Mandle L, Bufford JL, Schmidt IB, Daehler CC (2011) Woody exotic plant invasions and fire: reciprocal impacts and consequences for native ecosystems. Biol Invasions 13:1815–1827. https://doi.org/10.1007/s10530-011-0001-3

Margules C, Pressey R (2000) Systematic conservation planning. Nature 405:243–253. https://doi.org/10.1038/35012251

Masunungure C, Manyani A, Dalu MTB, Ngorima A, Dalu T (2023) Decision support tools for invasive alien species management should better consider principles of robust decision making. Sci Total Environ 899:165606. https://doi.org/10.1016/j.scitotenv.2023.165606

Matzek V, Pujalet M, Cresci S (2015) What managers want from invasive species research versus what they get. Conserv Lett 8:33–40. https://doi.org/10.1111/conl.12119

McConnachie MM, Van Wilgen BW, Ferraro PJ, Forsyth AT, Richardson DM, Gaertner M, Cowling RM (2016) Using counterfactuals to evaluate the cost-effectiveness of controlling biological invasions. Ecol Appl 26:475–483. https://doi.org/10.1890/15-0351

McGeoch MA, Genovesi P, Bellingham PJ, Costello MJ, McGrannachan C, Sheppard A (2016) Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion. Biol Invasions 18:299–314. https://doi.org/10.1007/s10530-015-1013-1

McIntosh EJ, Chapman S, Kearney SG, Williams B, Althor G, Thorn JPR, Pressey RL, McKinnon MC, Grenyer R (2018) Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: a systematic map. Environ Evid 7:art22. https://doi.org/10.1186/s13750-018-0134-2

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C (2011) Global biodiversity conservation: the critical role of hotspots. In: Zachos FE, Habel JC (eds) Biodiversity hotspots. Springer, Berlin Heidelberg, Berlin, Heidelberg, pp 3–22

Morse WC, Nielsen-Pincus M, Force JE, Wulfhorst JD (2007) Bridges and barriers to developing and conducting interdisciplinary graduate-student team research. Ecol Soc 12(2):art8. https://doi.org/10.5751/ES-02082-120208

Norton DA (2009) Species invasions and the limits to restoration: learning from the New Zealand experience. Science 325:569–571. https://doi.org/10.1126/science.1172978

O'Connor RA, Nel JL, Roux DJ, Leach J, Lim-Camacho L, Medvecky F, van Kerkhoff L, Raman S (2021) The role of environmental managers in knowledge co-production: insights from two case studies. Environ Sci Policy 116:188–195. https://doi.org/10.1016/j.envsci.2020.12.001

Osipova E, Shadie P, Zwahlen C, Osti M, Shi Y, Kormos C, Bertzky B, Murai M, van Merm R, Badman T (2017) IUCN World Heritage Outlook 2: a conservation assessment of all natural World Heritage sites. Int Union Conserv Nat. https://doi.org/10.2305/IUCN.CH.2017.17.en

Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. Glob Environ 20:550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Oswalt S, Oswalt C, Crall A, Rabaglia R, Schwartz MK, Kerns BK (2021) Inventory and monitoring of invasive species. In: Poland TM et al (eds) Invasive species in forests and rangelands of the United States. Springer, Cham, pp 231–242

Pfeffer J, Sutton RI (1999) Knowing "What" to do is not enough: turning knowledge into action. Calif Manag Rev 42:83–108. https://doi.org/10.1177/000812569904200101

Pouzols FM, Burgman MA, Moilanen A (2012) Methods for allocation of habitat management, maintenance, restoration and offsetting, when conservation actions have uncertain consequences. Biol Conserv 153:41–50. https://doi.org/10.1016/j.biocon.2012.05.014

Pyšek P, Hulme PE (2005) Spatio-temporal dynamics of plant invasions: linking pattern to process. Écoscience 12:302–315. https://doi.org/10.2980/i1195-6860-12-3-302.1

Reyers B, Roux DJ, Cowling RM, Ginsburg AE, Nel JL, Farrell PO (2010) Conservation planning as a transdisciplinary process. Conserv Biol 24(4):957–965

Rose DC, Sutherland WJ, Amano T, Gonzalez-Varo JP, Robertson RJ, Simmons- BI, Wauchope HS, Kovacs E, Duran AP, Vadrot ABM, Wu W, Dias MP, Di Fonzo MMI, Ivory S, Norris L, Nunes MH, Nyumba TO, Steiner N, Vickery J, Mukherjee N (2018) The major barriers to evidence-informed conservation policy and possible solutions. Conserv Lett 11:e12564. https://doi.org/10.1111/conl.12564

Rouget M, Robertson MP, Wilson JRU, Hui C, Essl F, Renteria JL, Richardson DM (2016) Invasion debt – quantifying future biological invasions. Divers Distrib 22:445–456. https://doi.org/10.1111/ddi.12408

Roussel S, Triolo J (2016) Bilan des opérations de lutte contre les plantes exotiques envahissantes menées par l'Office National des Forêts entre 2004 et 2013. Direction régionale de l'ONF Réunion, Saint-Denis, La Réunion

Royimani L, Mutanga O, Odindi J, Dube T, Matongera TN (2019) Advancements in satellite remote sensing for mapping and monitoring of alien invasive plant species (AIPs). Phys Chem Earth Parts a/b/c 112:237–245. https://doi.org/10.1016/j.pce.2018.12.004

Shackleton CM, Cundill G, Knight AT (2009) Beyond just research: experiences from southern africa in developing social learning partnerships for resource conservation initiatives: developing social learning partnerships. Biotropica 41:563–570. https://doi.org/10.1111/j.1744-7429.2009.00559.x

Shackleton RT, Adriaens T, Brundu G, Dehnen-Schmutz K, Estévez RA, Fried J, Larson BMH, Liu S, Marchante E, Marchante H, Moshobane MC, Novoa A, Reed M, Richardson DM (2019) Stakeholder engagement in the study and management of invasive alien species. J Environ Manag 229:88–101. https://doi.org/10.1016/j.jenvman.2018.04.044

Strasberg D, Rouget M, Richardson DM, Baret S, Dupont J, Cowling RM (2005) An assessment of habitat diversity and transformation on La Réunion Island (Mascarene Islands, Indian Ocean) as a basis for identifying broad-scale conservation priorities. Biodivers Conserv 14:3015–3032. https://doi.org/10.1007/s10531-004-0258-2

Van Rees CB, Hand BK, Carter SC, Bargeron C, Cline TJ, Daniel W, Ferrante JA, Gaddis K, Hunter ME, Jarnevich CS, McGeoch MA, Morisette JT, Neilson ME, Roy HE, Rozance MA, Sepulveda A, Wallace RD, Whited D, Wilcox T, Kimball JS, Luikart G (2022) A framework to integrate innovations in invasion science for proactive management. Biol Rev 97:1712–1735. https://doi.org/10.1111/brv.12859

van Wilgen BW, Forsyth GG, Le Maitre DC, Wannenburgh A, Kotzé JDF, van den Berg E, Henderson L (2012) An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. Biol Conserv 148:28–38. https://doi.org/10.1016/j.biocon.2011.12.035

van Wilgen BW, Wannenburgh A, Wilson JRU (2022) A review of two decades of government support for managing alien plant invasions in South Africa. Biol Conserv 274:109741. https://doi.org/10.1016/j.biocon.2022.109741

Vavra M, Parks CG, Wisdom MJ (2007) Biodiversity, exotic plant species, and herbivory: the good, the bad, and the ungulate. For Ecol Manag 246:66–72. https://doi.org/10.1016/j.foreco.2007.03.051