The Applicability of IPBES Management Actions for Invasive Alien Species

The Case of Hedychium coronarium in Otún Quimbaya

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Abstract

Biological invasions increasingly disrupt ecosystems, having long-term ecological, social and economic impacts. To mitigate these effects, global approaches such as the strategic actions for integrated governance of invasive species by the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) have been proposed. However, their success depends on the applicability to local contexts. This study analysed the feasibility of global strategies to the case of *Hedychium coronarium* in the Otún Quimbaya Fauna and Flora Sanctuary (SFFOQ), in Colombia. Combining an exploratory review and stakeholder interviews, the research focused on the six IPBES objectives –prevention & preparedness, early detection, eradication, containment & control, ecosystem restoration and public awareness– alongside the seven strategic actions for integrated governance of the 2023 IPBES assessment. The results indicated that the IPBES strategic actions do not align completely for the local context. Broad and top-down strategies, limited institutional coordination and a lack of context-sensitive implementation tools were the major barriers. Additionally, national regulations constrain effective management through institutional inconsistency, short-term funding and contracts, top-down decision making and low prioritisation of invasive species. This research revealed that although the IPBES strategic actions provide useful guidance and are an important step, national support and adaptation to local realities are necessary for its applicability. To manage invasive species more effectively, it will be essential to strengthen long-term funding, data sharing and local authority with the help of focused national measures and IPBES-facilitated collaboration.

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1. Introduction

Invasive species are one of the five most important direct drivers of biological loss globally (IPBES, 2023). The overall definition of biological invasion by the Intergovernmental Science-Policy Platform of Biology and Ecosystem services (IPBES) is "a process that transports (moves) and introduces a species outside of its natural range, intentionally or unintentionally by human activities to new regions where it may become established and spread" (IPBES, 2023). An alien species is one that has been introduced by human activity to a new region that defeats barriers that would otherwise be restricted by its natural range (IPBES, 2023). This establishment in a foreign ecosystem can happen through global trade, tourism, climate change, and land-use change (IPBES, 2023).

Biological invasion is divided into four stages of the process (Li & Yu, 2023):

Transport: when humans intentionally or unintentionally move a species outside its native range.

Introduction: when the species gets into the wild from transportation of captivity.

Establishment: when a stable, self-sustaining population establishes in the new environment.

Spread: when the species disperses within the new region.

The most concerning stage of biological invasion is the settling of Invasive Alien Species (IAS), which are species that have established themselves and have negative impacts on the ecosystem (Pagad et al., 2018). More than 37,000 established alien species have been identified across the world due to human activity, with an increasing rate of around 200 species each year (IPBES, 2023).

The effects of invasive species can disturb and even harm ecosystems, pose serious health risks to people, and cause economic losses. The ecological impact of IAS is defined as "a measurable change in the properties of an ecosystem" (Ricciardi et al., 2013) suggesting that all introduced species have the potential to affect the environment just by integrating into it, even if they are not yet established or widespread (Bacher et al., 2023). Invasive species have contributed, either alone or alongside other factors, to 60% of recorded global extinctions (IPBES, 2023). Direct threats posed by IAS include outcompeting native species for food, preying on native species, and spreading diseases (IPBES, 2023.). Since ecosystems are not adapted to IAS, these species often lack natural predators, allowing them to reproduce and spread rapidly (Invasive Species, n.d.).

Moreover, IAS also impact humans; 16% of IAS have harmful effects on nature's contributions to people and 7% affect good quality of life (IPBES, 2023). These impacts include disrupting ecosystem services and human well-being, such as reducing food resources, altering the water cycle, spreading diseases and impacting cultural and traditional practices (Bartz & Kowarik, 2019; Charles & Dukes, 2007).

Likewise, economic issues arise from IAS. Researchers estimate that IAS have cost approximately US $644 billion globally between 1970 and 2020 (Agriculture, forestry and fishery industries have lost hundreds of billions due to invasive alien species during the last 50 years worldwide, 2025). This shows that it is a costly mistake to regard biological invasions as a non-human problem.

This paper will take the case of *Hedychium coronarium* (*H. coronarium*) in Santuario de Fauna y Flora Otún Quimbaya (SFFOQ) [Otún Quimbaya Fauna and Flora Sanctuary]. *H. coronarium*, native to the Himalayas and southern China, is a rhizomatous, perennial, herbaceous macrophyte

(Wagner et al., 2020). It grows in humid areas, especially along forest and riverbanks, and damp pastures, reaching an average height of one to two meters (Figure 1) (ROJAS, 2010; Mora-Goyes et al., 2015). This species is a fast-growing plant that reproduces both through rhizomes and sexually via seeds (Rojas-Sandoval & Acevedo-Rodríguez, 2013). While *H. coronarium* is visually pleasing, it is environmentally harmful invading shallow water areas, lake banks, drainage channels and streams (Wagner et al., 2020). Due to its persistent nature of being highly adaptable to different environments, tolerant to shade and fast growing, the plant can overtake and outcompete other species (Rojas-Sandoval & Acevedo-Rodríguez, 2013).

Figure 1. *Hedychium coronarium* (Hedychium coronarium J.Koenig, n.d.)

Due to increasing concerns that IAS have on the environment, society and economy, effective management is crucial (Li and Yu, 2023). However, dealing with IAS is costly and restricted by available resources; therefore, it is essential to allocate time, funding and personnel carefully to ensure successful and long lasting results. In fact, most of the expenses are associated with damage costs (Heringer, 2021). Therefore, increasing the focus on integrated governance can help address current knowledge gaps (IPBES, 2023). In this context, integrated governance seeks to incorporate the roles of the institutions, actors and equipment involved in

human-nature interactions to coordinate strategic actions for improved prevention and control for biological invasions (IPBES, 2023). The IPBES provides globally applicable guidelines to support integrated governance, proposing an approach to help the planning and execution of measures aimed at reducing the spread and mitigating the impact of biological invasions (McGeoch et al., 2023). In order for success, this should include multiple levels of governance, diverse actors and decision-makers, and a recognition that biological invasions are multi-staged processes and driven by multiple interacting factors (McGeoch et al., 2023). Accordingly, the recent IPBES assessment includes seven strategic actions, visible in Figure 2.

According to IPBES assessment (2023), available data stated that the highest percentage (34%) of IAS-related impacts have been reported in the Americas. However, the majority of the studies regarding IAS concentrate in countries of the global north (Sandoval et al., 2022). This makes Latin America under-represented in research available, especially for countries that are highly diverse and vital ecosystems (Jenkins et al., 2024).

Focusing on Colombia, it is the second most biodiverse country in the world, making it a biodiversity hotspot for many endemic species (Conpes, 2021). A total of 506 introduced, invasive, or transplanted species have been recorded in the country (SiB Colombia, 2020), of which 22 have been officially recognised (Baptiste et al., 2010). This illustrates the existing gaps in research and management of IAS (Sandoval et al., 2022; Baptiste et al., 2010). This is particularly concerning in ecosystems that are ecologically, socially and economically important and under threat, such as the national park SFFOQ that this paper will focus on. Species like *H. coronarium* have established themselves with a lack of studies detailing their ecological and social effects (Guerrero Cupacán, 2020). This lack of knowledge hinders conservation and restoration strategies (Hardy et al., 2024). Studies are needed to document the scientific and

practical knowledge of IAS management in local contexts. This is particularly important given the lack of studies available in English on IAS (Angulo et al., 2021), as visible for *H. coronarium* in Colombia. This limits international recognition of the problems that *H. coronarium* is causing in Colombia. Therefore, the aim of this research is to examine IAS in a regional context of the

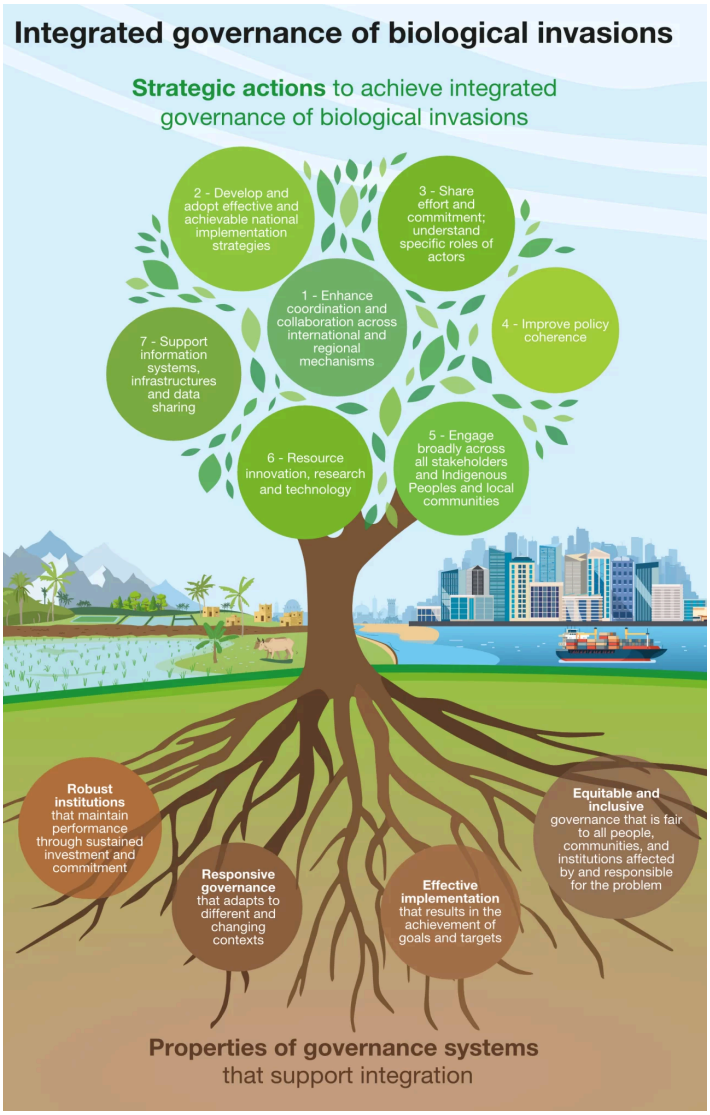

Figure 2. Integrated governance of biological invasions (IPBES, 2023)

SFFOQ, focusing on the specific case of *H. coronarium*. The paper seeks to find out the applicability of the IPBES guidelines to specific local contexts as effectiveness is essential for

successful biodiversity conservation, ensuring that global initiatives are practical and location-specific.

This is done by answering the following research question:

To what extent do the strategic management actions for biological invasions proposed by the IPBES apply to the local context of Hedychium coronarium in Otún Quimbaya*?*

The paper will begin by outlining the methods utilized in this thesis, followed by the results which include an exploratory review and semi-structured interviews. Each will be structured according to the six management objectives and actions for biological invasions from the IPBES assessment –prevention & preparedness, early detection, eradication, containment and control, ecosystem restoration and public understanding– to answer the research question (Figure 6). Following the discussion will draw on these six management objectives and actions to analyse how applicable they are to the seven strategic actions for integrated governance.

2. Methods

2.1. Study site

H. coronarium was introduced to the Americas in 1888 by Chinese immigrants as an ornamental plant (Orozco-Cardona et al., 2017). According to Tunison (1991) Smith recognised it as a pest in 1985 in Maui, Hawaii. Due to its ornamental use, *H. coronarium* has spread globally, especially in isolated regions (Figure 3) (Hedychium Coronarium, n.d.). Currently, it is recognised as invasive in 53 countries (Hedychium coronarium J.Koenig, 2023). According to the Global Biodiversity Information Facility (GBIF), the plant can be found in each country of the Americas (*Hedychium coronarium* J.Koenig in GBIF Secretariat, 2025).

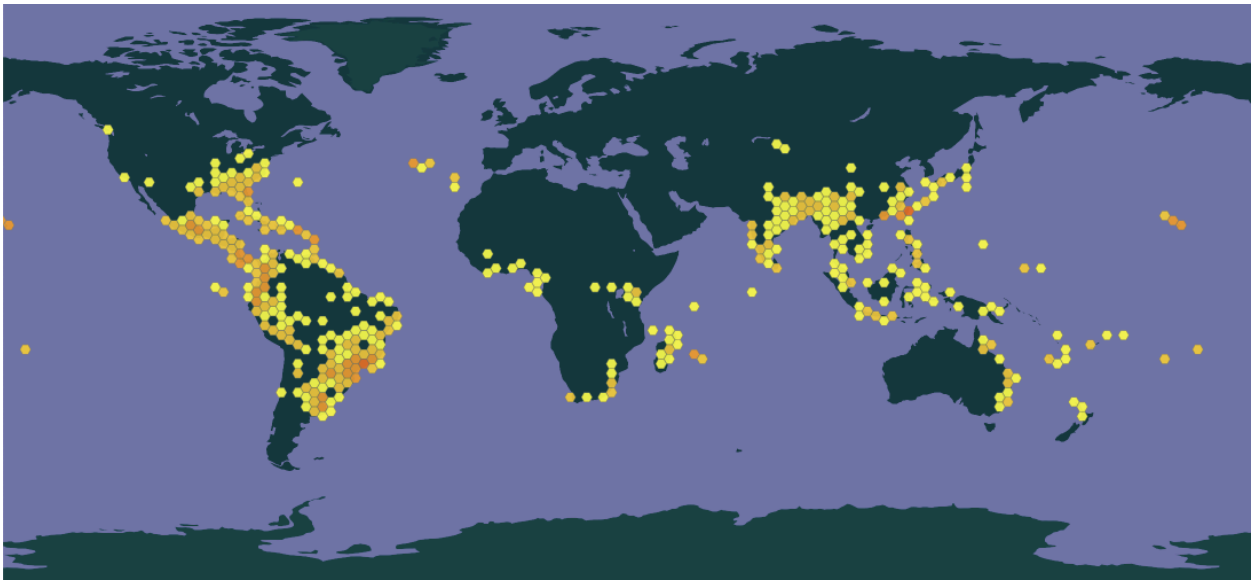

Figure 3. Occurrence of *H. coronarium* world wide (*Hedychium coronarium* J.Koenig in GBIF Secretariat, 2025)

According to GBIF, in 2022, the occurrences of the IAS spiked with a total of 1,612 occurrences recorded, with Colombia being the 5th place of observed occurrences (Figure 4).

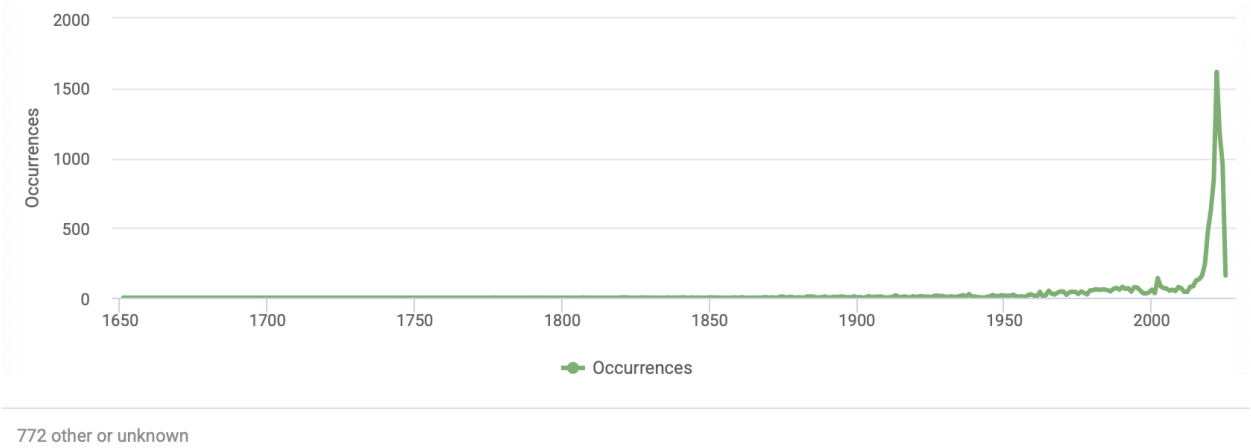

Figure 4. Occurrence of *H. coronarium* from 1650 to 2025. Occurrences were primarily human observations (61.5%), via platforms such as iNaturalist, Research-grade Observations (Hedychium coronarium J.Koenig in GBIF Secretariat, 2025).

While the exact introduction date of *H. coronarium* to Colombia is unknown, the first recorded observation was in 1940 by José Cuatrecasas (*Record Hedychium coronarium J. Koenig,* n.d.). By 2017, the species was found in 15 Colombian departments including the study site, SFFOQ (Figure 5) (Cárdenas-López et al. 2017). Since, *H. coronarium* has been used for throat ache, flu, muscle pain, stomach pain, infusions and decoration purposes (Orozco-Cardona et al., 2017).

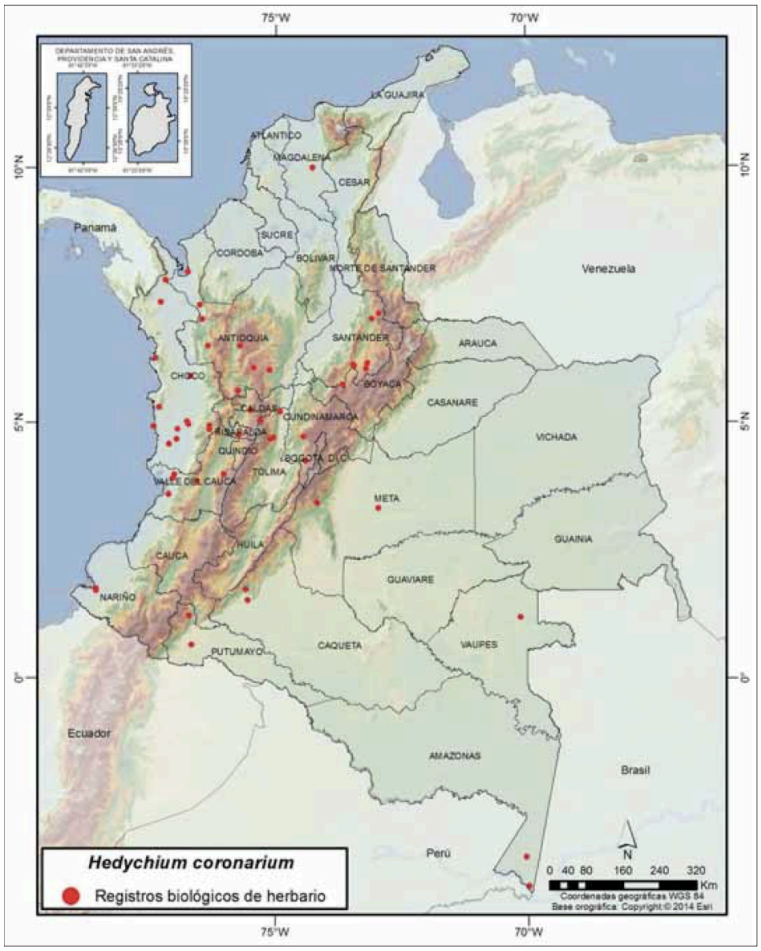

Figure 5. Distribution of Hedychium coronarium in Colombia. (Cárdenas-López et al., 2017, p. 69)

The SFFOQ belongs to the national parks of Colombia and is operated under the Ministerio de Ambiente y Desarrollo [Ministry of Environment and Sustainable Development] of Colombia (Parques Nacionales Naturales, n.d.; Santuario de Fauna y Flora Otún Quimbaya, n.d). The park lies in the municipality Pereira and the department of Risaralda. It is an important ecotourism destination and conservation area, especially because it lies in the heart of the Eje Cafetero which is a key coffee production site in the sub-andean rainforest (Colombia, P. N. N. de, n.d.). Declared a protected area since 1996, SFFOQ covers 489 hectares at altitudes between 1750m to 2250m.

The SFFOQ has perfect climatic and biological conditions for *H. coronarium* to spread due to its water bodies, pastures and fragmented forests (Orozco-Cardona et al., 2017). Since 2005, *H. coronarium* has been detected as excessively colonizing different habitats in the park (Serna et al., 2018). In 2011, the invasion of *H. coronarium* was 4.5 ha, which led the park to establish restoration strategies (Serna et al., 2018).

2.2. Analysis

For the assessment, the exploratory review and the semi-structured interviews applied the six management objectives and actions for biological invasions outlined by the IPBES assessment (Figure 6) (IPBES, 2023). From this analytical framework only the *Objectives* column was used to apply it to *H. coronarium*. This allowed for a structured comparison between the review and interviews.

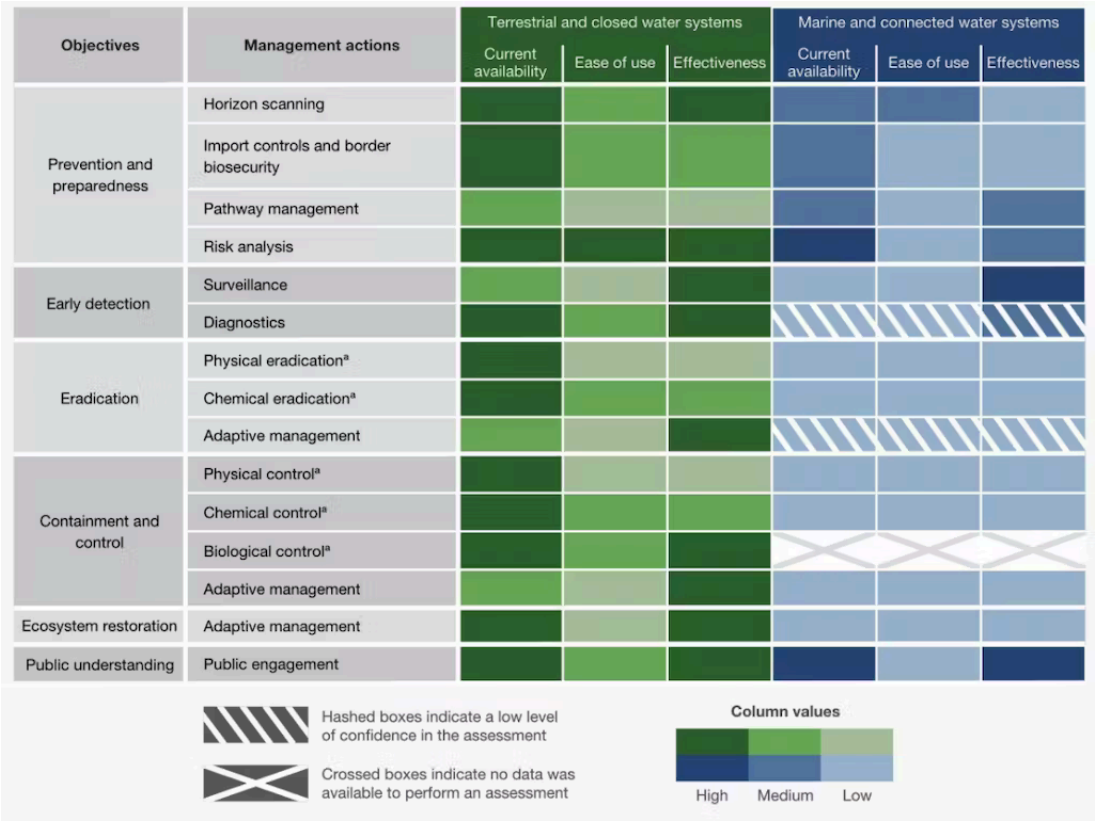

Figure 6. Objectives and actions for managing biological invasions from the IPBES (Eco-Business, 2023).

2.2.1. Exploratory review

For the secondary data collection, a comprehensive literature review was conducted to examine management strategies for *H. coronarium*. Sources in English and Spanish were included, to capture diverse perspectives and regional insights. For the exploratory review 23 sources were used (Figure 7). These sources include reports, research papers, NGO and government publications, citizen science platforms and global research institutes. In terms of geographic focus, there are local to global sources included.

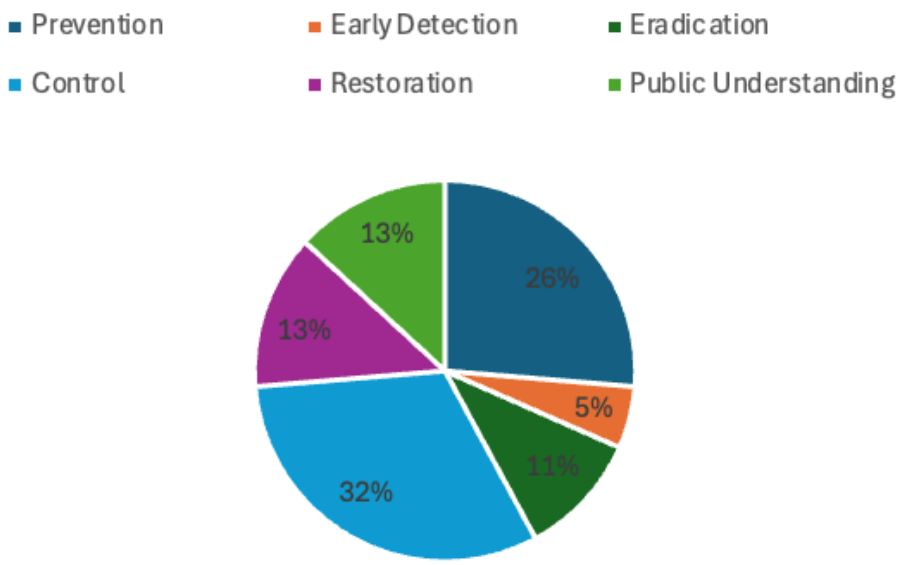

Figure 7. Pie chart of literature source categorisation by management strategies of biological invasions (prevention & preparedness, early detection, eradication, containment & control, ecosystem restoration and public understanding) in the exploratory review. Percentages represent the amount of sources that refer to the respective category (among others).

2.2.2. Semi-structured interviews

For the primary data collection, semi-structured in-depth interviews were carried out, to have a flexible interview protocol that enables follow-up questions based on interviewees' responses. The interviews aimed to supplement existing literature and capture different perspectives that the exploratory research was not able to highlight. Interview participants were identified through a combination of online research, personal contacts and snowball sampling (Naderifar et al., 2017). Five interviews were done online with a duration of around 30 to 60 minutes. Although the interview guide included 15 questions (see appendix 2), the interviews were conducted in a conversational way to lessen rigidity and create a more comfortable and open environment.

The five interviewees each have a different stakeholder role in relation to the IAS. The first stakeholder is María Piedad Baptiste Espinosa who is a researcher at the Alexander von Humboldt Biological Resources Research Institute (IAVH). The IAVH is a civil non-profit organization that was founded in 1993 (*Alexander von Humboldt Biological Resources Research Institute (IAHV)*, n.d.). The second stakeholder is Mauricio Aguilar-Garavito who is an expert in ecological restoration and researcher in ecological disturbance and succession who has worked closely with *H. coronarium*. Maria Girleza Ramirez Gonzalez is a biologist and is working at the SFFOQ. Likewise, Robinson Armando Cruz Apache and Álvaro Ríos work as well at the SFFOQ. Robinson is the park manager and Ríos is an ecotourism professional who has been working for the park since 16 years. Table 1 illustrates the participant names and how they will be addressed throughout the paper.

Participant Name	**Stakeholder Role**
María Piedad Baptiste Espinosa	NGO member
Mauricio Aguilar-Garavito	Academic
Maria Girleza Ramirez Gonzalez	Biologist
Robinson Armando Cruz Apache	Park manager
Álvaro Ríos	Park ranger

Table 1. Participants name and their stakeholder role.

2.3. Procedure and ethics

Potential participants were contacted via email. Ethical procedure guidelines from the Ethics Committee of Campus Fryslan were followed throughout the data collection. There were no direct risks in participating in this study. However, emotional responses could have occurred depending on the participant's connection to the topic. Personal information was not requested at any point. Participants were asked about their preferences to remain anonymous, which none of

them indicated. However, confidentiality was ensured throughout the entire process. An informed consent sheet was sent out before the interview to inform the individuals about the research and their rights. All interviews were conducted in Spanish. With the participants' consent, the interviews were voice recorded. The interviews were held online via Google Meet. Audio recordings and interview transcripts were securely stored, with access restricted only to the researcher. The Informed consent sheet and ethical consideration checklist can be found in the Appendix 3, 4 & 5. My positionality can be found in Appendix 6. Afterwards, interviews were transcribed with the online transcription tool Turboscripe and were consequently themed to find recurring responses. Themes were identified and analyzed based on the IPBES objectives and actions for managing biological invasions.

3. Results

The IPBES objectives and actions for managing biological invasions include prevention & preparedness, early detection, eradication, containment and control ecosystem restoration and public understanding (Figure 8) (IPBES, 2023).

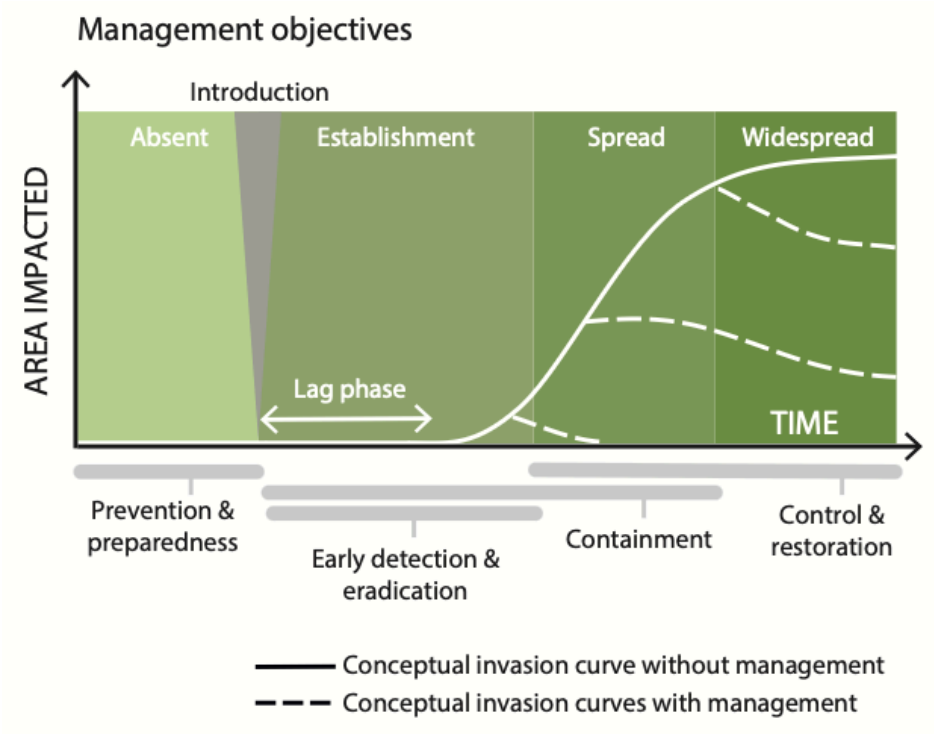

Figure 8. Application of various tools and methods along the conceptual diagram of management along the invasion curve which provides a continuum for management interventions (IPBES, 2023, p.570).

Prevention and Preparedness include pre-border planning, safe and controlled trade practices, international regulations to support prevention and border biosecurity (IPBES, 2023). This can include risk assessment and regulated species lists. If prevention and preparedness fails, early detection can help the reduction of IAS. This can involve tools risk analysis which can help identify early establishments and habilitate rapid interventions. If the species has already spread, eradication can be a successful and cost-effective method. This can happen in the form of physical or chemical eradication. When eradication is not feasible, IAS are contained and

controlled through physical, chemical and biological strategies. Ecosystem restoration, which involves adaptive management, is meant to assist the recovery of the ecosystem, including long-term monitoring. Lastly, public understanding encompasses the engagement with the public to raise awareness.

3.1. Exploratory review

3.1.1. Prevention and preparedness

Globally, 83% of countries have no existing national regulations or legislations targeted to prevention measures of IAS (IPBES, 2023). In terms of Colombia, the *Plan Nacional para la Prevención, el Control y Manejo de Especies Introducidas, Trasplantadas e Invasoras* [National plan for prevention, control and management of introduced, transplanted and invasive species] outlines the environmental, economic and health risks posed by IAS in Colombia and national regulations and legislations on IAS including prevention measures.

H. coronarium has been classified with a high invasion risk score of 5.82, due to its strong establishment ability, potential impact and difficulty of control and eradication (Baptiste et al., 2010). Its dense rhizomes, which can reach up to 50 cm above the ground, form thick masses, complicating control efforts and preventing native regeneration.

Nevertheless, Table 2, illustrates all the important regulations and enforcements important for the *H. coronarium* management in Colombia. Moreover, Colombia's national strategy has recommended biosecurity measures at ports and borders, alongside developing accurate research to understand the species' impact, distribution and potential uses (Ministerio de Ambiente y Desarrollo Sostenible, 2011). This can serve for informed decision making and support management actions.

Year	Regulation/Law/Decree	Description
1974	Decree 2811 - *Código Nacional de Recursos Naturales Renovables y de Protección al Medio Ambiente* (CNRN) [National Code of Renewable Natural Resources and Environmental Protection]	Foundational framework for environmental management and protection in Colombia, including the prohibition of harmful species introductions and requirements for permits for exotic species (Decreto 2811 de 1974, 1974).
1978	Decree 1608	Regulation on wildlife and hunting licensing (Decreto 1608 de 1978, 1978).
1993	Law 99	Created the National Environmental System (SINA) and the Ministerio del Medio Ambiente (Ministry of Environment), assigning responsibility for IAS regulations and enforcements (Guerrero Cupacán, 2020).
1994	Law 165 - adoption of the Convention on Biological Diversity (CBD)	Ratified CBD and developed national action plans to manage IAS, committing Colombia to prevent, control or eradicate IAS (Ley 165 de 1994, 1994).
2008	Resolution 0848	Published the first officially recognised list of IAS published in Colombia, indicating a significant advancement in the formal recognition and management of IAS (Baptiste et al., 2010).
2010	Resolution 0207 and IAS Risk Analysis Report	Enhanced the official IAS list and improved regulatory measures for their management. Similarly, a risk analysis and categorization for introduced species in Colombia was proposed, helping prioritizing management efforts (Baptiste et al., 2010; Colombia Potencia de la Vida, n.d.).
2011	Resolution 654	Further updates the official IAS list, based on ongoing assessments and identifications (Colombia Potencia de la Vida, n.d.).
2014	Resolution 1204	Formation of the National Technical Committee on IAS, providing advisory support on policies and

		coordination among stakeholders for IAS management concerning the prevention, control and management of IAS as well evaluating risks associated with the introduction and spread of IAS (Ministerio de Ambiente y Desarrollo Sostenible, 2014).
2015	Decree 1076	Mandated environmental licensees for the introduction of foreign plant species (Orozco-Cardona et al.,, 2017).
2022	Resolution 0346	Released an updated and expanded official list of IAS, incorporation of new species and reinforcing management strategies (Resolución 0346, 2022).
2024	Plan of Action for Biodiversity 2030	Implemented a national biodiversity action plan that aligns with global objectives, highlighting the significance of IAS management in biodiversity conservation efforts (Ministerio de Ambiente y Desarrollo Sostenible, 2024).

Table 2. Relevant regulations, laws and decrees of Colombia

In terms of research, several studies have explored whether the treated *H. coronarium* has medicinal and cosmetic applications, which could contribute to the plant residue management (Flórez López, 2022; Panigrahy et al, 2020; Shrotriya et al., 2007; Tammasorn et al., 2023). However, there is a lack of accurate research on H. coronarium, particularly on the ecological impact on the native ecosystem (Aguilar-Garavito, 2015). This is a significant barrier because it hinders informed decision-making and effective preparedness.

At the local level, awareness-raising efforts for personnel, tourists and other stakeholders and guidelines to deal with H. coronarium in SFFOQ have been implemented to prevent the spread of the IAS (Aguilar-Garavito, 2015). However, tourism remains a constant risk factor for the spread of H. coronarium, especially if preventative actions are not sustained.

Applying general management strategies on biological invasions such as early risk analysis and pathway management, is essential to strengthen prevention and preparedness. Additionally, expanding scientific research on *H. coronarium*, including its ecological impact, spread mechanisms and control capacity is essential for informed decision making (Maya et al., 2020).

3.1.2. Early detection

At the national level, there is limited information on early detection programs, the focus is more on control methods once the species is established (Cardenas et al., 2015). For the local context, early detection has been informally done since 2005 when the park encountered a rapid establishment of *H. coronarium* in different habitats (Aguilar-Garavito, 2015). These observations early on helped establish a restoration plan. However, Cardenas et al. (2015) state that there is a need to establish national detection systems and set up alert networks.

3.1.3. Eradication

Globally, over the last 100 years, 88% attempts of eradication programs have been successful (IPBES, 2023). However, the IPBES assessment (2023) explains that eradication processes are usually difficult to carry out in terms of sustained funding, technical challenges, capacity-building, monitoring and effective biosecurity legislation.

Colombia's national plan is the main strategic guideline for IAS (Ministerio de Ambiente y Desarrollo Sostenible, 2011). The report includes as one of the primary objectives to eradicate IAS. For the eradication process efforts are context dependent. If the invasion is in its initial stages, manual elimination of the IAS can be enough to allow for spontaneous ecosystem recovery (Aguilar-Garavito, 2015). However, once the species becomes established, the eradication process becomes more difficult because of the dense rhizomes. If any rhizomes

remain, it can lead to the re-establishment of the IAS. Hence, elimination of both aboveground and underground biomass is crucial(Aguilar-Garavito, 2015).

Locally, actions for *H. coronarium* started in 2012 due to the aggressive spreading that began in 2005. Priority sites were addressed until 2013. The operational process involved two staff members of SFFOQ.

For eradication improvements, guidelines suggest concentrating removal, transportation, and waste management tasks during the dry months, while follow-ups and revegetation activities should be done during the rainy months (Aguilar-Garavito, 2015). Likewise, processing the biomass, especially the rhizomes, is a critical part which requires several management systems and logistical coordination (Cárdenas et al., 2015).

Finally, it is important to mention that eradication and control methods often overlap in this case as local elimination efforts always need to be carried out for *H. coronarium*, but complete eradication across the entire national park has not been achieved. This means that eradication functions as a form of control rather than complete removal. Thus, specific measures can be found in the Containment and Control section.

3.1.4. Containment and control

Globally, containment and control of IAS has been successful in terrestrial systems, but they tend to be effective short-term rather than long-term. Classical biological controls (CBC) have been effective for more than 100 years on landscape levels (IPBES, 2023). In over 60% of the documented cases CBC has succeeded. Physical and chemical controls are rather short-term suppressive and labour intensive (IPBES, 2023).

Focusing on the regional scale, containment and control activities started in 2013. During the removal process, an average yield of 70.8 m2/man-day was obtained, which included

biomass extraction, packaging, and transportation (Aguilar-Garavito, 2015). Initial manual removal and quarterly follow-up controls of regrowth were done during the first year and semiannual controls starting from the second year. Tools such as machetes were used for manual removal of above-ground biomass, and bars, pickaxes, and shovels were used for underground biomass. The removed plant was dried, rhizomes were chopped and then processed through vermicomposting[1] and controlled incineration. A total of 34 tons of biomass was processed. From these, 30 tons were incinerated and four tons were converted into organic fertilizer (Aguilar-Garavito, 2015). The incinerated waste took eight months to process due to the volume of the material, the high moisture concentration in the rhizomes, and the atmospheric humidity of the area. The composting process took five months, where two months were for drying the material and three months for vermicomposting (Aguilar-Garavito, 2015). The left material (compost and ash) was used as a substrate for the plant material in the SFFOQ nursery. Temporary and final storage was done by propagule traps around the perimeter of storage and covered with plastic, tarps or zinc sheets on a concrete floor. At the eradication site, ditches and walls were created for erosion prevention. After the first quarterly control they revegetated the area (Cárdenas et al., 2015). During follow-up controls, manual uprooting was mainly used, and in some cases hoes were employed to remove rhizomes that were not extracted during the initial removal. Six months after these procedures there was no regrowth visible of *H. coronarium*. This process was classified successful as visible in Figure 9 (Aguilar-Garavito et al. 2012).

[1] Vermicomposting is the process of using earthworms to break down organic waste (Sharma & Garg, 2019).

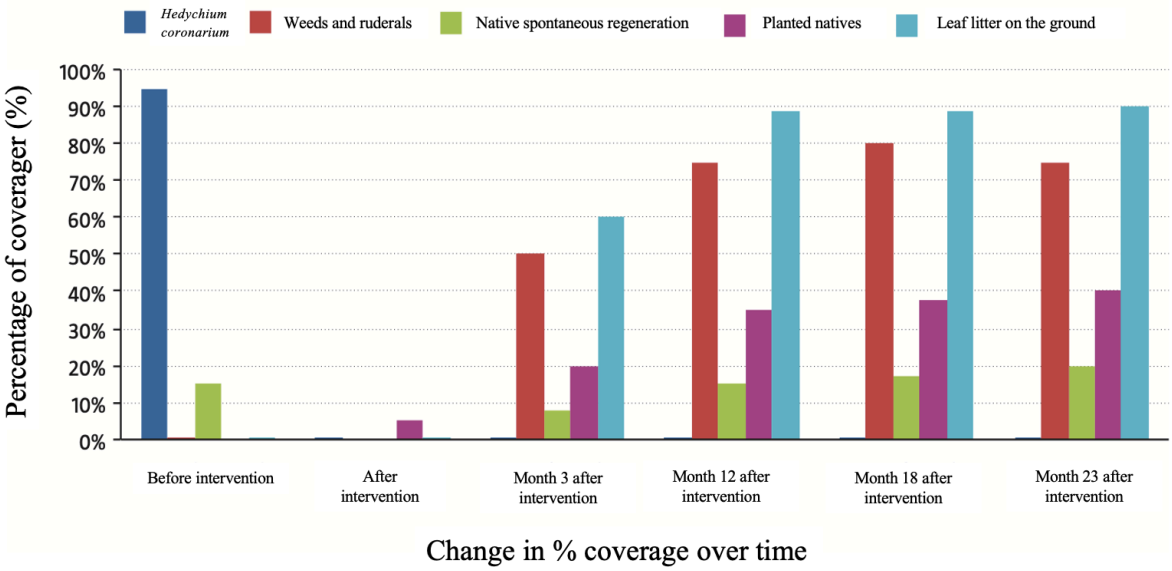

Figure 9. Change over time in the percentage of cover of weeds, ruderals, native species and leaf litter in areas degraded by weed invasion, before and after interventions with the ecological restoration strategy. Recolonization rate was less than 0.1% of the total inverted area and an increase in species richness from 7 species to 46 species after two years. Adapted and translated from Aguilar-Garavito (2015, p. 126).

The above explained process is a very labour intensive job (Wagner et al., 2020), which is why researchers suggest a work team of at least five workers and one coordinator that exclusively work for the restoration process instead of two people (Cárdenas et al., 2015).

Other investigations from various countries have studied control methods for *H. coronarium* that can serve as an example for SFFOQ. Machado et al. (2020) conducted a study in a riparian forest in Brazil that included four different treatments for the control of *H. coronarium*: chemical control (herbicide); topsoil transposition (soil); chemical and topsoil (herbicide and soil); and no intervention. The findings showed that chemical control was very effective at reducing cover, ramet number and height. Topsoil transposition alone did not have an impact in the IAS. However, chemical and topsoil transposition together showed better heterogeneity and more richness, abundance and cover in native species. Therefore, the management strategies

resulted most effectively with integrated management (chemical and topsoil). Alongside, active monitoring was important as after 11 months ramets of *H. coronarium* survived (Machado et al., 2020). This approach not only controls IAS but also promotes the recolonization of endemic species. Therefore, chemical control can be highly effective but it needs the correct herbicide for the environment in relation to the right dosage and consistent application and monitoring (Machado et al., 2020).

Other studies such as in Brazil and Argentina (Soares & Barreto, 2008; Mc Kay et al., 2021) investigated biological control agents which are natural enemies from the plant's native range to control its spread in non-native areas (Biocontrol., n.d.). Although the outcome was that the used fungi to control the plant was not particularly suitable for biological control, it could be an effective strategy to weaken the species and slow the spread (Soares & Barreto, 2008). Mc Kay et al. (2021) suggest that a preliminary list of test plants should be created and proposed helping national control methods for Argentia.

Moreover, the Kamakou preserve on Molokai did a combination of manual and mechanical removal (Tunison, 1991). This process was labour intensive and needed consistent monitoring (Tunison, 1991). In general, due to *H. coronarium*'s rhizomes, mechanical removal has been unsuccessful due to its regenerative nature (Rojas-Sandoval & Acevedo-Rodríguez, 2022). However, Motooka et al. (2002) found that on Hawaii *H. coronarium* is very sensitive to the herbicide Metsulfuron. This chemical is "selective" and does not kill every plant. It is intended to be used in pastures and areas not used for crops (Motooka et al., 2002). Nevertheless, other studies in different contexts have not supported this.

3.1.5. Ecosystem restoration

The IPBES assessment (2023) states that most research for restoration was unable to quantify the effectiveness of ecosystem restoration because the initial state of the ecosystem was not examined. This has led to inconsistencies in ways to combat IAS.

Aguilar-Garavito & Ramirez (2015) assert that preserving ecosystems is generally cheaper and more viable than restoring them. Thus, before destroying an ecosystem it is crucial to consider the long-term cost and difficulties of restoring an area before permitting ecosystem degradation. However, for the case of *H. coronarium*, invasion has happened and restoration is necessary.

Ecosystem restoration actions that have been done in SFFOQ were the creation of restoration strategies in 2012, including diagnostic characterisation, design of restoration techniques, implementation, community involvement and monitoring & evaluation (Aguilar-Garavito, 2015). Afterwards, annual data collection monitored the percentage of regworth of *H. coronarium* versus natives species (Cárdenas et al., 2015).

However, Colombia's restoration has faced challenges due to a lack of acknowledgement and clarity (Aguilar-Garavito & Ramírez, 2015). This has created confusion and limited awareness, with restoration frequently being understood as synonymous with reforestation or revegetation (Aguilar-Garavito & Ramírez, 2015). For instance, in non-forest ecosystems such as páramos and savannas, the misconception has resulted in inappropriate afforestation with exotic species, worsening biological invasions and environmental conflicts. Additionally, restoration practitioners are unable to precisely define clear target outcomes because of the lack of knowledge regarding long-term consequences brought on by stochasticity and environmental variability (Aguilar-Garavito & Ramírez, 2015). According to Aguilar-Garavito et al. (2025),

only 24% of restoration projects in Colombia report any monitoring and 2% monitored effectiveness. If monitoring occurs, it usually is short-term and focused more on tree survival or area coverage, rather than on IAS-related outcomes.There are also difficulties in establishing clear motivations for restoration, who is responsible and poorly assessed cost-benefit ratio. Similarly, the evaluation poses challenges due to the interdisciplinary nature which includes a variety of actors, interests and perspectives within the process. Ecosystem restoration needs to consider sociopolitical, economic, and educational decisions to be successful (Tedesco et al., 2023). A step that has been taken to combat this confusion and ignorance is in Aguilar-Garavito & Ramírez (2015) research, who have clarified the definition, purpose and objectives of ecological restoration, to address misunderstandings of the concept.

3.1.6. Public understanding

The IPBES (2023) states that globally there is a lack of public awareness which poses a major barrier to successful IAS management. There are also platforms such as the GBIF who provide open access on IAS to raise awareness and support monitoring (GBIF, n.d.). Also there are citizen science initiatives that encourage the general public to know more about (invasive) species like iNaturalist (INaturalist, n.d.).

For SFFOQ, the community has been engaged through informative and preventative talks, communal gathering to help eradicate the plant, an information campaign and 13 volunteer park rangers helped with the characterisation, restoration and monitoring activities (Aguilar-Garavito, 2015). In 2015 all visitors received an introductory talk about the problems related to IAS. It was estimated that during the eradication processes in 2013, more than 360 people attended (Aguilar-Garavito, 2015). Similarly, SFFOQ received support from the public services company Aguas y Aguas de Pereria (Aguilar-Garavito, 2015). They supported the

restoration efforts by helping process the removal waste of *H. coronarium* with one of their facilities from their farm. Moreover, as a Community Communication strategy they were in the Radio of National Natural Parks, educating on *H. coronarium* (Cárdenas et al., 2015).

3.2. Interviews

3.2.1. Context

The academic explained how *H. coronarium* has biological and social impacts in and around the national park. Biologically, the species causes a loss of native flora and fauna and interferes with the water circulation in soils and streambeds. Socially, the academic mentioned that the agricultural sector and water system is particularly affected, as the plant spreads into farmland and takes up the water for the crops. This requires farmers to invest time, money and labour in its control, however, they can lack the technical knowledge necessary to manage *H. coronarium* effectively.

The biologist noted that these social concerns are not considered urgent. Although *H. coronarium* is invasive, other species, like the *Ulex europaeus*, present more serious risks and need immediate care. The academic mentioned that *H. coronarium* remains at a controllable stage, offering a valuable opportunity for effective treatment and intervention. The invasion status, as the park manager said, of *H. coronarium* in SFFOQ is 1% which is almost 5 hectares from 489 hectares.

3.2.2. Prevention and preparedness

At the organisational level, the NGO member mentioned that the Humboldt Institute started working on a list of species based on invasion risk analysis in 2009. This was done with an interdisciplinary group of people from multiple countries including researchers from the Ministry of Environment, research institutes and environmental authorities. The result was a

protocol for different groups of species, published in 2010. This included the first list of exotic species, which was approved by the Ministry of Environment. The document served as a tool to support decision-making regarding IAS. The NGO member mentioned that the most recent document, in agreement with the Ministry of Environment, created a management plan for the hippopotamus invasion in Colombia.

In terms of on-ground-prevention methods, the biologist stated that once *H. coronarium* is removed, physical barriers are installed around the cleared area to prevent recolonisation.

3.2.3. Early detection

Regarding early detection, no specific actions were mentioned in the interviews, as this stage has already passed in the SFFOQ. However, the site is currently at a strategic point for early research, which supports early detection by generating the knowledge necessary for effective species identification and monitoring.

3.2.4. Eradication

According to most interviewees, eradication is considered the most effective method for managing *H. coronarium*. Due to its rapid reproduction, especially since the seeds disperse easily, complete removal is crucial.

Interviewees explained that eradication methods for *H. coronarium* were carried out through manual removal. The biologist stated that the existing protocol is successful, as it focuses on removing the entire plant, including the meter long roots. When the extraction is done periodically, the germinating individuals need continuous extraction. The academic explained that elimination requires biannual removal of leaves, rhizomes, seeds and saplings, in addition to measures such as rhizome traps and trenches.

The biologist noted that a major barrier of the current eradication method is its high operational costs, specifically regarding personnel, machinery and equipment required to extract the entire plant. The IAS often grows in difficult terrain and manual eradication requires continuous monitoring and repeated interventions.

3.2.5. Containment and control

The academic stated that there are always trade-offs with each control method, especially in Colombia's national natural protected areas, because of numerous legal, ecological and socio-political constraints. The park ranger stated that in 2007, control included covering *H. coronarium* with black plastic to kill the foliage and weaken the rhizomes for easier removal. Nevertheless, this method is very time-consuming and difficult in dense vegetation. Current methods include manual tools, machetes, grills to remove the rhizomes. The biologist added that no herbivory activity has been observed that would control *H. coronarium*.

The biologist stated that the dry season is the best time for control as leaves are dehydrated, facilitating the removal process. Topsoil removal is a supplementary method that involves removing the compact rhizome layers in exchange with other soil types. The academic shared that this strategy has only been used occasionally, as it is difficult to implement due to topography and costs. Four interviewees described control methods as labour-intensive, but effective in SFFOQ. The academic explained that cover reduced to less than 5% a hectare in one year, to less than 0.1% after four years and signs of ecological succession appear after five years in 25 plots. The academic observed that even though results differentiated between plots, similar survival rates of *H. coronarium* across wetter and drier sites were visible.

The park ranger and the biologist pointed out that control of H. coronarium close to roads may assist seed dispersal, especially along high-traffic roads that connect to other protected areas.

The academic and the biologist state that agrochemicals for the control and eradication can be utilised by farmers, but they are prohibited in national parks in Colombia due to legal and policy limitations. The academic suggested regulated use in some cases, but acknowledged the environmental sector's opposition to chemical methods. Finally, the biologist noted potential uses of *H. coronarium* biomass after removal, including in medical products, aesthetics and compost, although such research and initiatives remains limited.

3.2.6. Ecosystem restoration

The academic stated that control and monitoring are key to ecosystem recovery. In SFFOQ, three successive controls were conducted in the first year. If maintained, ecological succession begins after two to three years, with native herbaceous plants followed by shrubs and trees by the fourth year. He highlighted that regular check-ups and removal of remaining scrub are crucial for success.

The biologist mentioned a protocol that supports the step-by-step restoration process for monitoring *H. coronarium*. She gave the example of *Ulex europaeus,* which is managed through multi-stakeholder collaboration (Pontificia Javeriana University, corporations and Bogotá city). The biologist noted that although resource allocation for this IAS is difficult, its impact –especially on water availability in Bogotá– has promoted significant research and management efforts. Overall, all interviewees agreed that regular monitoring is essential for control and eradication.

3.2.7. Public understanding

All five interviewees mentioned that public involvement and awareness are crucial for effective ecosystem restoration. The academic stated that general understanding of IAS exists among the public and NGOs are typically well-informed about how to manage related challenges.

At a national level, the NGO member explained that the Humboldt Institute collaborates with regional ministries to socialize IAS management plans and raise awareness about the importance of controlling certain species.

The biologist explained that in Colombian society, there is a strong link between ecosystem services and human well-being. A species like *H. coronarium* only drew attention after it impacted the agricultural sector via the water system. The biologist noted that other species that pose greater threats to ecosystem services tend to be prioritized.

Overall, *H. coronarium* does not generate alarm. According to the park ranger, some people believe *H. coronarium* is native and are unaware of its expansion in the park. For this reason, infographics have been developed for schools and public places to raise awareness on environmental issues including IAS.

The biologist and the park manager confirmed that educational efforts help Colombian citizens and visitors identify the introduced species, including those that are potentially invasive and significantly impact biodiversity. The park ranger added that because the plant is often used as an ornamental plant, people do not perceive it as a threat to the ecosystem.

3.2.8. Additional information

3.2.8.1. Research and innovation.

All interviewees emphasized the need for further research to support informed decision-making for managing *H. coronarium*, due to its limited understanding about the effectiveness of the control methods and the species' biological behaviour.

The biologist explained a lack of understanding regarding herbivory and the presence of natural enemies. The park manager highlighted the inconsistencies in field methods, such as whether partial or complete removal of the rhizomes is more efficient.

The NGO member suggested the need for further research on alternative and potentially more effective management strategies. The biologist stressed on the importance of genetic research and explained that in 2018, the SFFOQ team carried out a genetic study to inform future biotechnical control methods, which could enhance management while reducing environmental impacts. The study discovered that the genetic diversity is not alarming, which is confirmed by a separate study in Valle de Aburrá suggesting a lower-than-expected ecological impact. Despite this, the Humboldt Institute categorizes *H. coronarium* as a potentially invasive species.

All interviewees agreed on the importance of early research, as it allows for preventive and restorative measures and helps avoid higher costs in the future. As the NGO member noted, early research not only improves understanding but also gives managers the resources they need for long-term management.

3.2.8.2. Funding and resource limitations.

All interviewees stressed the significant operational costs related with managing *H. coronarium*, visible in research and fieldwork for the genetic projects which rely on university

partnerships for funding. The biologist highlighted that the park's budget cannot cover the research and management costs, making external funding essential. Furthermore, the park ranger shared that national funding priorities tend to favour the Amazon rainforest over sub-Andean forest like SFFOQ, resulting in minimal resource availability. The park manager confirmed that no resources are allocated to reduce the pressure on natural habitats, especially because manual eradication is labour-intensive and costly. The park ranger explained that a lack of personnel limits the scale of operation. He and the academic stressed the need for permanent staff to achieve long-term success. The academic added that technical capacity exists, but the limited resource availability hires further actions.

3.2.8.3. Institutional & policy limitations.

The academic explained the institutional and policy limitations affecting ecosystem restoration and IAS management. He pointed out that decision-making at the regional level is constrained by bureaucratic structures, as decisions are made by the national or territorial authorities. This was affirmed by the park ranger who highlighted that the centralisation limits the ability of local managers to implement necessary changes.

The academic highlighted that short-term contracts severely hinder continuity in advancing restoration and monitoring projects. Contracts usually last between three months and one year, after which employees, despite their performance, are changed to other positions. The academic argued that to retain institutional knowledge and ensure continuity, staff need to be hired as long-term employees. The current model creates discontinuity in the system and impedes progress in monitoring efforts. The park manager and ranger support this view. Furthermore, the academic noted that existing financial and regulatory frameworks are poorly aligned with the needs of IAS management. He specified that although funding periods are

yearly, limiting the invasion needs consistent work for around four to six years. He noted that despite substantial progress over three years, the invasion could have been fully managed if institutional support had been sustained. All in all, he highlighted that although the criticism is misdirected towards the technique of monitoring, the major barrier lies in the inconsistent resource allocation, ineffective governance and limited political will.

3.2.8.4. Collaboration & capacity building.

The NGO member recognised that Colombia has an interdisciplinary approach, with diverse professionals involved in management projects. The park ranger stated that since 2007, SFFOQ included forest engineers, ecologists, geographers and anthropologists in the management strategies. However, the NGO member noted the need for greater collaboration between the agricultural and environmental sectors. The academic affirmed this and emphasized the need for skilled technicians with the ability to create and modify technologies or new tools. According to all interviewees, there is a lack of international collaboration. The park ranger stated that no international resources have reached SFFOQ. The academic added that capacity-building such as improving equipment and training local teams to operate and manage these tools, would be more effective than direct financial aid. He also recommended long-term guidance and partnerships.

At a regional level, collaboration exists among natural parks. For instance, the park ranger mentioned the genetics studies involved coordination with parks from similar ecosystems in the Eje Cafetero region. However, most interviewees agreed that such regional collaboration needs to be fostered.

Finally, collaborations with universities both national and international were highlighted as valuable for research and support. The park manager noted that the Pontifica Javeriana University is currently researching IAS, including *H. coronarium*. All interviewees agreed that cross-institutional collaboration is essential to ensure effective execution of management projects.

4. Discussion

The purpose of this paper was to analyse the feasibility and applicability of the IPBES strategic actions for managing biological invasions in the local context of *H. coronarium* in SFFOQ. Overall, the literature and interviews present complementary information into the progress and persistent gaps. Although national prevention strategies exist, they have weak implementation, are outdated and reintroduction risks are still substantial. Currently, no official monitoring systems support early detection efforts. Manual eradication, although labour-intensive and underfunded, has shown success in managed areas. Containment and control methods have used physical barriers and manual removal techniques for *H. coronarium*. Interviewees highlighted that management techniques have resulted effectively, however national regulations and sustained funding hinder long-term contracts and monitoring. Local decision-making authority is also limited. Interviewees emphasize the need for further research, especially on biotechnical controls. Although cooperation with national universities has been essential, broader capacity-building and international support is needed. Lastly, the six objectives for managing biological invasions tend to overlap and are general, making them subject to misinterpretation depending on upbringings, priorities and circumstances of each local setting. The following section discusses the seven strategic actions in relation to SFFOQ.

4.1. Enhance coordination and collaboration across international and regional mechanisms

The first strategic point from the IPBES emphasizes the need to strengthen multilateral approaches and facilitate knowledge sharing between nations and regions, as biological invasions are inherently transboundary and require coordinated global and regional action (IPBES, 2023).

Based on the findings, it can be derived that Colombia and the SFFOQ receive limited international collaboration. Interview responses highlighted a lack of external support, especially for funding, technical equipment and specialized training.

Although Colombia has a national plan for IAS (Ministerio de Ambiente y Desarrollo Sostenible, 2011), it is outdated, indicating that attention towards IAS is currently limited. When governmental attention in Colombia is directed at IAS, it is often driven by an alarming state of invasion, impacting people's lives and ecosystem services, such as the invasion of *Ulex europaeus* (Aguilar-Garavito, 2015). The IPBES report can be helpful for understanding the importance of collaboration, but it remains each country's responsibility to create, implement and follow-up a national plan that focuses on local solutions and engages with local actors.

At the national level, based on the results some collaboration in Colombia is present but this cooperation needs further strengthening. These findings align with the identified weak cross-regional and international collaboration that the IPBES assessment mentions (IPBES, 2023). The IPBES report successfully identifies the need for more collaboration, however, the report lacks guidance on how collaborations such as those in Colombia could be operationalized, particularly in local contexts like SFFOQ where regional collaborations already pose a challenge (Stevance et al., 2019; Krug et al., 2020). Despite the IPBES assessment (2023) highlighting that biological invasions are inherently transboundary –such as *H. coriandrum*– every ecosystem and local context has different circumstances that need to be considered. Hence, local mechanisms

play a crucial role in building cross-regional collaborations. In terms of local to regional partnerships, it is Colombia's responsibility to strengthen these networks, while the IPBES should provide the necessary support for this process. This seems to be feasible as individual institutions are willing to collaborate seen through the existing partnerships and the willingness of stakeholder interviews.

4.2. Develop and adopt effective and achievable national implementation strategies

The second strategic action by the IPBES aims to guarantee actionable implementation of national-level policies by having strong legal frameworks, consistent enforcement, prioritization of monitoring and the ability to adapt (IPBES, 2023).

In Colombia, several regulations support conservation efforts. The SFFOQ is part of Colombia's National Natural Parks System and is protected under Decree 2811 of 1974, Decree 622 of 1977, Law 99 of 1993 and Decree 1076 of 2015 (see table 2). Accordingly, only activities aligned with conservation measures are permitted such as low impact recreation (ecotourism), environmental education, scientific research and conservation and recovery activities. The use of natural resources requires environmental authorization in accordance with conservation goals. The management plan under the national laws need to be complied by all users like government, communities and private actors.

Although interviews showed that national funding is primarily directed toward the Amazon rainforest, the Andean forest –where SFFOQ is located– is amongst the most targeted for restoration in Colombia (Murcia et al., 2017). In theory, this suggests that SFFOQ receives support and funding for restoration. In practice, however, effective long-term monitoring and funding is lacking. Many IAS-related projects are poorly standardized and often superficial. Short-term contracts and limited personnel further weaken local implementations. Outdated

plans and limited research show that even in Colombia's high-priority zones, IAS such as *H. coronarium* are inadequately addressed.

On top of this, bureaucratic barriers and limited decision-making power on a local level hinder consistent enforcement of national policies and limited potential for adaptive management. For instance, this is evident in the limited awareness and use of tools such as the IPBES Risk Analysis for Alien Taxa (RAAT) framework in local context like SFFOQ. It is an effective tool for prioritizing and managing IAS. In practice, prioritisation in SFFOQ, is based on perceived threat, institutional inertia or available funding, instead of formal risk evaluations. Therefore, the RAAT framework results to not be applicable in practice in this local context due to Colombia's institutional system.

Overall, the implementation of national objectives into feasible local actions is hindered by a lack of local authority, funding and adaptive mechanisms. This suggests that while national-level frameworks and strategies proposed by the IPBES assessments may exist, in practice this objective is not effectively operationalized in SFFOQ. It can only be overcome by strong legal frameworks and consistency enforced and moved by the government, as it has been shown in cases like Reaser et al. (2020a) and Woodford et al., (2016).

4.3. Share efforts, commitments and understanding of the specific roles of all actors

The third strategic action proposed by the IPBES refers to promoting clearly defined and differentiated responsibilities among stakeholders involved in managing IAS (IPBES, 2023).

The findings suggest some current and past interdisciplinarity. However, there is ambiguity with role distributions across multiple actors like responsibilities and actions for restoration processes. The government contributes to this ambiguity by limiting local actors from being involved in decision-making and funding. While local people in the SFFOQ have the

capacity and knowledge to contribute meaningfully to local management efforts, their roles are unsupported and undervalued. This finding is supported by the IPBES objective which stresses on implementing clear roles defined between entities. Therefore, the IPBES secretariat has established an open registry of IPBES stakeholders for any individuals or organizations that can either benefit from or contribute to the implementation of the IPBES action plan or who can inspire others to do so (Secretariat, n.d.). This has the aim to enforce science-policy through the four functions: assessments, knowledge generation, policy support and capacity-building.

In terms of integrating ILK, data is frequently non-quantitative, transmitted orally and based on interconnectedness, making it difficult to combine with scientific indicators most commonly applied (Berkes & Berkes, 2009; Turner & Clifton, 2009). For this reason, IPBES emphasizes the need for a range of complementary techniques, from generic to context-specific, using multiple evidence bases across spatial and temporal scales (Diaz et al., 2018). The IPBES facilitates groups of practice communities which bring together experts, policymakers, practitioners and local stakeholder to access and share information (Opportunities for communities of practice to engage with and contribute to the work of the Intergovernmental Platform on Biodiversity and Ecosystem Services, n.d.). This enables increasing collaboration, diverse perspectives for the previously mentioned four functions. Establishing a platform of exchange and collaboration for Colombia could help assign specific roles for the management of IAS such as *H. coronarium* in SFFOQ (Figure 10).

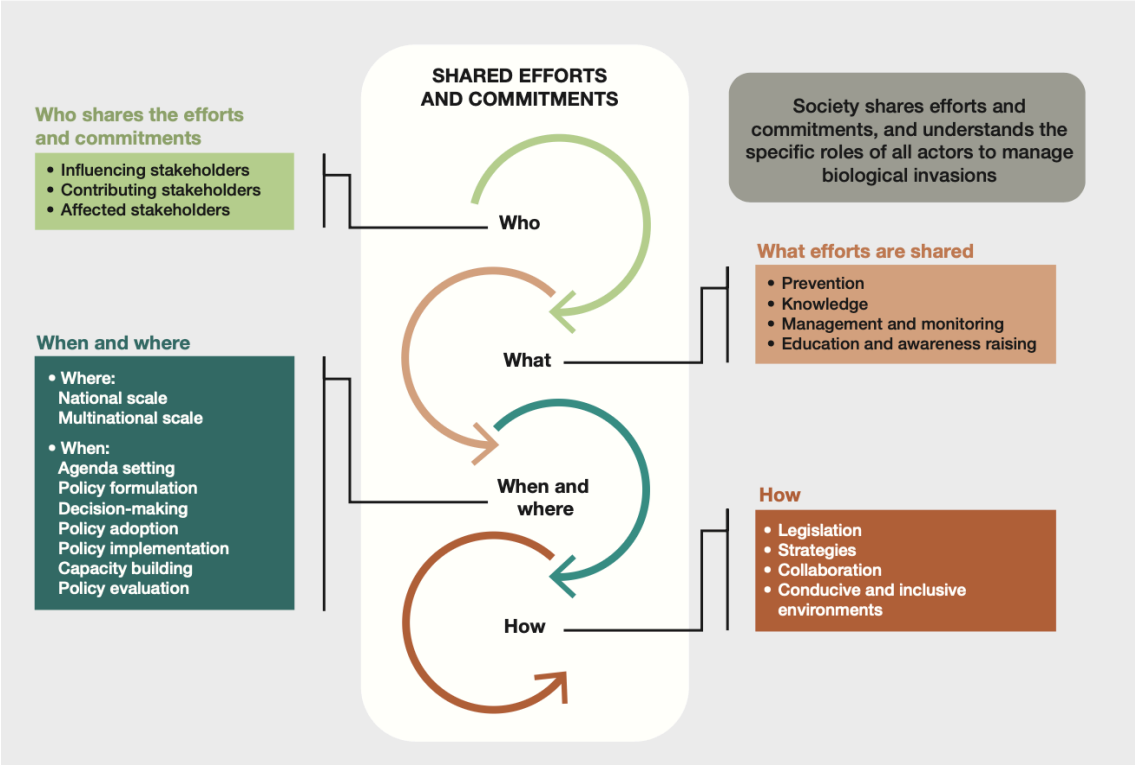

Figure 10. Approach showing the need to connect people, knowledge, governance, policy tools by sharing efforts and commitments and understanding the specific role of all actors for the prevention and control of invasive alien species. It encourages efficient communication and coordination, with each stakeholder or institution having a distinct function in an integrated governance plan (IPBES, 2023, p.817).

4.4. Improve policy coherence

The fourth strategic measure identified by the IPBES involves reducing fragmentation across policies which includes exploring governance arrangements across numerous drivers and goals, helping establish and sustain reflexive governance capacity and could overcome current gaps in regulations targeting IAS (IPBES, 2023).

As mentioned, for Colombia, there is a lack of coordination between national and local authorities. Local stakeholders express frustration about the system of the national parks, as the top-down system hinders necessary decision-making at the local scale. From the results, this resulted as one of the main aspects of unsuccessful management of *H. coronarium*. Such an

example is visible with suggested control methods from other countries not being applicable in SFFOQ due to national restrictions. Likewise, restoration and eradication efforts are constrained by unmanagable timeframes like one-year funding cycles for a project that requires at least three years.

The IPBES report outlines a step-by-step process for assessing policy instruments by helping to identify the context (historical, social, economic, political, ecological, institutional and legal), policy goals, important policy instruments and assessing implementation, governance systems, stakeholders, impacts, outcomes and operational scales (Galega et a., n.d). While this step-by-step process can be useful, it assumes that local actors have the means to access the IPBES report and crucial resources, can overcome language barriers posed by technical reports or key tools that are not translated and receive guidance on the relevant policy instruments (Guibrunet et al., 2024; Wiegleb & Bruns, 2025). Likewise, this approach is again a top-down approach with limited flexibility for local actors. Top-down is not always useful for cases in which local structures might not adapt to these mechanisms (Eakin et al., 2011; Van Assche et al., 2022), like in SFFOQ where informal practices and adaptive management can be more effective. Furthermore, the IPBES assessment lacks detailed case studies of local implementations of how to align policies in favour with IAS management (Foxcroft & McGeoch, 2011; McElwee et al., 2022).

Nevertheless, the suggested reduction of fragmentation across policies from the IPBES could be more effective in the future in SFFOQ if the government long-term funding sources are found, giving local institutions the ability for decision-making and if national regulations integrate IPBES platforms, meanwhile the IPBES experts support and guide nationally these steps.

4.5. Engage broadly across governmental sectors, industry, the scientific community, Indigenous Peoples and local communities and the wider public

The fifth objective emphasises inclusive co-design and co-implementation of IAS management with various stakeholders, including governmental sectors, industries, scientist and Indigenous Peoples and Local Communities (IPLC). The IPBES assessment recommends that stakeholder engagement be built into management plans and budgets and tracked over time to allow adaptive learning (IPBES, 2023). This includes citizen science, education campaigns and community-based monitoring.

The findings showed that *H. coronarium* in SFFOQ is still widely seen as an ornamental plant without the knowledge of its invasiveness. To address this, the park has implemented education campaigns to combat this unawareness through infographics and visits to schools. Likewise, scientists and regional stakeholders express willingness to combat *H. coronarium*, but the institutional channels hinder this process.

The IPBES places high emphasis on inclusivity of co-production of knowledge between scientists and IPLC. It also empowers and recognises ILK within decision-making (Indigenous and local knowledge: Our work, 2023; Krug et al., 2020), which can be useful for cases like SFFOQ to receive support on acknowledging local knowledge. The IPBES has a diverse team of experts and specifically implements several procedures to seek out diverse knowledge systems. However, studies find that there are still some geographic and epistemic biases in the literature that was included in the assessments of the IPBES, showing a discrepancy between IPBES's "knowledge-making practices" (Wiegleb & Bruns, 2025, p.73) and its western dominance in environmental evaluations (Guibrunet et al., 2024). Whilst the IPBES recognises the co-production of knowledge, adaptive learning and context-specific engagement, its practical

applications are more challenging at the local level. In SFFOQ, short-term contracts, lack of sustained funding and centralization of decision-making, make long-term engagement difficult to sustain. The IPBES suggests that funding for engagement should be built into project budgets (IPBES, 2023), nevertheless, there is limited guidance on how to carry out these actions in bureaucratically constrained settings (Krug et al., 2020). There is a need for more concrete actions on more context-specific models for local engagement to redistribute power and resources effectively. This would need guidance on how to align policies across agencies and scales in real-context specific bureaucratic examples from the IPBES.

Developing and strengthening engagement strategies suggested by the IPBES, like citizen science or co-design workshops, alongside with continuous expansion of environmental education, engagement of local and national stakeholder and collaborations with universities could help to involve citizens more (Krug et al., 2020; Strasser & Haklay, 2018). This could simultaneously target misinterpretations of restoration work, create awareness of IAS, assign clear roles and targets and have an updated national plan.

4.6. Support, fund and mobilize resources for innovation, research and environmentally sound technology

The sixth action plan from the IPBES focuses on improving research, including improving risk assessments, developing forecasts, scenarios and models and increasing innovative science and environmentally sound technologies to support the prevention and control of IAS (IPBES, 2023).

In Colombia, some progress has been made on fostering research like the genetic studies conducted in collaboration with universities. Nevertheless, a hindrance is the lack of funding for more research and innovation. In Colombia other IAS are more prominent threats which puts less

emphasis on *H. coronarium* and reduce motivation for further research on the IAS. Participants also stressed that capacity building would be more effective than short-term funding grants. For instance, investing in technical training and local staff development would help have long-term monitoring and effective management and strategies.

The IPBES report recognises global inequalities and disparity in national capacities, advocating for international assistance and capacity-building for under-sourced areas (IPBES, 2023). The report highlights the need for long-term planning and funding instead of one-off projects. Furthermore, the IPBES stresses on innovation and adaptability through instruments adapted to ecosystems and feasibility and innovation initiated locally, instead of new, high-cost technology development. However, this is also a weak point because while the IPBES includes the need for cross-border knowledge sharing and capacity-building as in risk assessment training and tools, there is an over reliance on technical solutions which may be less applicable in under-resourced contexts like SFFOQ (Dunkley et al., 2018; Wiegleb & Bruns, 2023). In the park, it is unrealistic to apply some technology recommended by the IPBES (such as remote sensing or genetic detection systems) as the budget and infrastructure constraints. Although the willingness for scientific research and biotechnology is present in the local context, there is no clear guidance on how under-resourced countries and local institutions can access these technologies or establish international partnerships to support them. A potential improvement could be the establishment of a national platform for IAS aimed at synthesising data and research to increase information sharing, monitor developments and inform about updates (Reaser et al., 2020b). Furthermore, IPBES encourages regional and international collaboration which can be useful for SFFOQ for increased attention and funding to access external support, which could result in more efficient eradication tools and early-warning systems.

4.7. Support information systems, infrastructures and data sharing

Lastly, the seventh objective of the IPBES highlights the development and use of robust information systems and infrastructure to support integrated governance of biological invasions (IPBES, 2023). The emphasis lies on the importance of data sharing and information systems across institutions and regions for integrated governance for biological invasions and social sciences.

For SFFOQ, data collection is based on visual observations by staff and citizen science through iNaturalist. However, citizen science is barely integrated into official decision-making processes. Likewise, there is limited research available on *H. coronarium* in Colombia, especially in English. For instance, there are no relevant entries in academic databases such as Scopus regarding Colombia. In CABI, *H. coronarium* is not even classified as an IAS for Colombia (Rojas-Sandoval & Acevedo-Rodríguez, 2013). A likely reason for this is that the majority of the existing studies is grey-literature or published in Spanish, which is often underrepresented in global databases (Amano et al., 2016). Notably, some sources cited in the exploratory review overlap with the interviewees, which may suggest a limited number of researchers and experts in this field who are specifically dedicated to this issues. Furthermore, most available studies are outdated, with the majority published between 2010 and 2015.

In terms of the IPBES report, there is an emphasis on open science to ensure the accessibility of sharing data and information (Benaboki, n.d.). They also collaborate with data-sharing institutions such as the GBIF to enable wider data sharing and conform its data management procedures to international standards. However, the above local limitations make it difficult to execute the IPBES objective. If foundational research is lacking or inaccessible, information and data cannot be shared or used by stakeholders. Furthermore, the IPBES

highlights the importance of information systems but does not address specifically the disparity in digital access particularly in underfunded regions such as SFFOQ, where there is limited ability for data storing or sharing on digital platforms (Wiegleb, & Bruns, 2025). This is demonstrated in McElwee et al. (2020) who highlight major documentation gaps and regional disparity in available literature on ILK. Although assessments and sharing of data and information is helpful and important, it is impossible to obtain a fair balance of evidence throughout the world because they only analyse existing publications and do not generate new data, exacerbating the imbalance.

Nevertheless, SFFOQ can strengthen its citizen science by encouraging a wider spread of data sharing and enforce collaboration with universities to co-investigate on IAS such as *H. coronarium* (Baker et al., 2024). Furthermore, periodic regional reporting is crucial and should be implemented to keep track of the current situation which can mitigate further spreads of IAS or the establishment of new ones. Data sharing with national and governmental institutes can help policy shaping.

4.8. Limitations and future research

There are some limitations for this study that should be acknowledged. This is the first study to apply the IPBES strategic actions integrated governance of biological invasions to a local context in Colombia. As the framework is fairly recent, a limited amount of studies apply this framework to specific contexts. On elimination is that the assessment was applied to a specific context which limits the generalizability of the findings to other regions in Colombia or other IAS. Likewise, due to time constraints and accessibility, some actors may be underrepresented. Including a broader range of stakeholders such as local citizens, general public, diverse NGO actors, researchers and government agencies would have provided a more

comprehensive analysis of the framework's applicability. Furthermore, interviews were only conducted online, limiting the range and depth of stakeholders' responses. In-person fieldwork could have provided more insights and captured local ILK. Similarly, as the framework is relatively recent, much of the discussion anticipates sources that take inconsideration earlier IPBES assessments. While the objectives are similar, the arguments can lack support from research based on this framework. Additionally, due to the scope of this thesis, not all IPBES objectives were possible to analyse in depth, which led to a focus on the most relevant ones.

For future research, there is a need to conduct broader stakeholder analysis in SFFOQ, incorporating in-person field work to receive a deeper insight of stakeholders views. Similarly, more studies should investigate the applicability of the framework in different countries, contexts and IAS to test the applicability and flexibility of the IPBES framework. This could assist the improvement of global objectives and guidelines and further clarify requirements for successful local implementations

5. Conclusion

This study analysed the applicability of the IPBES strategic actions for integrated governance of biological invasions, using the case of *H. coronarium* in SFFOQ. Through an exploratory review and semi-structured interviews structured around the IPBES objectives –prevention & preparedness, early detection, eradication, containment and control, ecosystem restoration and public understanding– the research found that although the IPBES assessment offers valuable conceptual guidance, its practical implementation at the local level at times is limited.

The discussion illustrated two overarching barriers to the effective application of the IPBES framework for SFFOQ. Firstly, some IPBES objectives lack contextual feasibility at the local context. The IPBES assessment is an important step toward integrated governance, but it lacks detailed guidance on how to operationalize its strategies in local contexts. Although it acknowledges the importance of knowledge co-production and cross-border collaboration, it can be broad and lack specific guidance for implementation at the local scale. It often fails to address structural challenges such as data access, technological limitations, language barriers and weak institutional coordination.

Secondly, the IPBES framework can be applicable but national regulations in Colombia impose successful execution. Findings show that in SFFOQ, eradication and control methods are effective, but are often restrained by institutional, financial and political regulations. This includes labour-intensive eradication and control methods, limited local authority and personnel, short-term funding, institutional inconsistency, outdated national plans and top-down decision-making which collectively undermine consistent monitoring and adaptive management.

Although *H. coronarium* is not currently considered the most alarming IAS, its management is crucial to prevent further environmental, social and financial harm.

For Colombia, key priorities should include strengthening local authority, investing in local research, improving long-term funding, implementing consistent monitoring, creating national IAS data-sharing platforms and clarifying and aligning restoration objectives. Educational outreach and public awareness is also crucial. Throughout this process, the IPBES framework should serve as a guide to support local and national actors, strengthening collaborations, increasing awareness, developing national data sharing platforms and fostering funding.

While this study would benefit from a broader stakeholder inclusion, the case of *H. coronarium* shows that although the IPBEs framework has the potential to serve as a basis for integrated governance, its effectiveness depends on a more context-sensitive, inclusive and grounded approach to implementation.

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7. Appendices

Appendix 1: Positionality

Coming from the global north as a white, middle-class female student, I was conscious that my upbringings could affect how I perceived the data and findings. I was aware that my identity as a non-Colombain and outsider might have shaped the responses of the interviewees. However, having spent time in Colombia as part of my exchange, I gained a deeper understanding of the local context which helped this research project. While my perspective is shaped by external experiences, I aimed to stay conscious of my position throughout my research, acknowledging the limitations and potential biases I have. I tried to keep my own ideas and understandings of the local context separate to not influence the findings.

Appendix 2: Interview guide

In Spanish:

1. ¿Está familiarizado con la especie invasora *Hedychium coronarium* o "matandrea"? ¿y ha trabajado directamente con ella?
2. ¿Conoce los impactos ecológicos y económicos de la matandrea en Colombia? ¿Cuáles son?
3. ¿Qué características la hacen problemática en Colombia?
4. ¿Está de acuerdo con las estrategias de manejo que se han utilizado en el Parque Otún Quimbaya para controlar *H. coronarium*?
5. ¿Cuáles estrategias de manejo conoce que se han propuesto a nivel nacional y mundial para controlar esta especie invasora?
6. Sabe si se han implementado en Colombia?
    a. Si la respuesta es afirmativa: ¿Desde cuándo se implementan estas estrategias en Colombia/Otún Quimbaya y cómo han evolucionado con el tiempo?
7. ¿Considera que han sido exitosas? ¿Por qué sí o por qué no?
8. ¿Cuáles han sido los principales obstáculos o desafíos en la implementación de estas estrategias?
9. ¿Cómo percibe el nivel de apoyo y recursos asignados al control de especies invasoras en Colombia?
10. ¿Existen colaboraciones nacionales o internacionales en este ámbito?
11. ¿Considera que se necesita más apoyo financiero, técnico o político?
12. ¿Cómo es el nivel de conciencia y conocimiento de la población local sobre *H. coronarium* y otras especies invasoras?
13. ¿Qué cree que se podría mejorar en la gestión de esta especie en el país?
14. ¿Existe una especie invasora más prominente que se tiene que manejar? ¿Por qué?
15. Desde su experiencia, ¿qué recomendaciones daría para fortalecer las estrategias de manejo en Colombia?

In English:

16. Are you familiar with the invasive species Hedychium coronarium or ‘matandrea’? Have you worked directly with it?

17. Are you aware of the ecological and economic impacts of matandrea in Colombia? What are they?
18. What characteristics make it problematic in Colombia?
19. Do you agree with the management strategies that have been used in Otún Quimbaya Park to control H. coronarium?
20. What management strategies do you know of that have been proposed at the national and global levels to control this invasive species?
21. Do you know if they have been implemented in Colombia?
22. If so, since when have these strategies been implemented in Colombia/Otún Quimbaya and how have they evolved over time?
23. Do you consider them to have been successful? Why or why not?
24. What have been the main obstacles or challenges in implementing these strategies?
25. How do you perceive the level of support and resources allocated to the control of invasive species in Colombia?
26. Are there any national or international collaborations in this area?
27. Do you think more financial, technical or political support is needed?
28. What is the level of awareness and knowledge of the local population about H. coronarium and other invasive species?
29. What do you think could be improved in the management of this species in the country?
30. Is there a more prominent invasive species that needs to be managed? Why?
31. Based on your experience, what recommendations would you make to strengthen management strategies in Colombia?

Appendix 3: Information Sheet

Invasive alien species

Dear participant,

Thank you for your interest in taking part in this research. This letter explains what the research entails and how the research will be conducted. Please take time to read the following information carefully. If any information is not clear, kindly ask questions using the contact details of the researchers provided at the end of this letter.

WHAT THIS STUDY IS ABOUT?

This research is part of the thesis research conducted by Kira Gloxin, a bachelor student of Global responsibility & leadership from the Rijksuniversiteit Groningen, faculty Campus Fryslan. This study will explore the management strategies for invasive alien species in Colombia's Santuario de Fauna and Flora Otún Quimbaya National Park. The focus will be on the white ginger lily (*Hedichium coronarium*) and its persistence within the park. The aim of this study is to understand the management strategies that have been implemented in Colombia for controlling Hedichium coronarium and explore how these strategies could be improved by learning from successful examples in other countries.
First, a literature review will be done to gather prior knowledge of actions taken in other countries. Following this, interviews will be conducted to understand the challenges of preventing the national park from implementing effective strategies for controlling this invasive alien species. The objective is to interview 3 to 6 people with expertise who have knowledge and experience in this field or are exposed to this problem. I consider you a valuable contributor to this research, as your unique insights on the invasive *Hedychium coronarium* would greatly enhance the study.

WHAT DOES PARTICIPATION INVOLVE?

If you agree to take part, you will be asked to dedicate 45–60 minutes for an online interview. You may choose in which language (English or Spanish) you would like the interview to be held. It is expected that you provide honest and complete responses.

DO YOU HAVE TO PARTICIPATE?

Participation in this research is entirely voluntary, and you may withdraw from the study at any time without providing a reason. Similarly, if you do not want to answer questions during the interview, you are free to decline without any consequences.

ARE THERE ANY RISKS IN PARTICIPATING?

There are no economic, legal, physical or social risks associated with participating in this study. Your anonymity and confidentiality will be fully maintained throughout the entire process. However, emotional responses may occur depending on the participant’s connection to the topic.

No personal information will be requested. If at any point during the interview you feel uncomfortable with any question, please remember that your participation is entirely voluntary, and you are free to skip any questions you prefer not to answer

ARE THERE ANY BENEFITS IN PARTICIPATING?

There are no direct benefits to participating in this research, nevertheless your involvement will contribute to this research, by having a clearer understanding of management strategies. This may, in turn, prove beneficial for future conservation and management efforts and indirectly prove valuable to you. be valuable for you in future conservation and management strategies.

HOW WILL INFORMATION YOU PROVIDE BE RECORDED, STORED AND PROTECTED?

If consented by the participant, the interview will be recorded to refer back to your responses. The transcripts will be accessible only to the researcher.
During the whole process confidentiality and anonymisation will be ensured, by excluding your name and any reference to your position in the research paper. Identification IDs (e.g. P1, P2, etc.) will be used throughout the whole process. A list with the real names and IDs will be stored in a private separate document.

The gained information will be used for our research purposes only. The researcher is the only person with access to the data. All data will be stored on a secure platform provided by the University of Groningen. All information will be safely stored until the completion of the research, in July 2025. Afterwards the data will be disposed of.

WHAT WILL HAPPEN TO THE RESULTS OF THE STUDY?

The research findings will be shared with the two examiners evaluating the final report. The findings will be presented in the Capstone presentation, which will be open to fellow students, faculty, and friends and family. It will also be presented at the Campus Fryslan Conference, which is open to the general public. Finally, the results will be shared with the participants of the study.

WHO SHOULD YOU CONTACT FOR FURTHER INFORMATION?

This study is being conducted by Kira Gloxin. I am a Global Responsibility and Leadership bachelor student at Campus Fryslan, University of Groningen, Netherlands.

In case of any questions or comments, you can contact me via email k.gloxin@student.rug.nl or via WhatsApp (+491705264688).

ETHICAL APPROVAL

This research study adheres to relevant ethical guidelines, and potential ethical considerations have been addressed with the assistance of the ethical checklist provided by the Campus Fryslan Ethics Committee.

INFORMED CONSENT FORM

By signing the consent form, you are agreeing to participate in this research and consent to the terms outlined above. However, you have the right to withdraw your consent at any time, without providing an explanation.

Appendix 4: Informed Consent Form

Title study: Management strategies for Hedychium coronarium

Name participant:

Assessment

- I have read the information sheet and was able to ask any additional question to the researcher.
- I understand I may ask questions about the study at any time.
- I understand I have the right to withdraw from the study at any time without giving a reason.
- I understand that at any time I can refuse to answer any question without any consequences.
- I understand that I will not benefit directly from participating in this research.

Confidentiality and Data Use

- I understand that none of my individual information will be disclosed to anyone outside the study team.
- I understand that my identity will be kept anonymous, and no personal information will be included in the report.
- I understand that the information provided will be used only for this research and publications directly related to this research project.
- I understand that any pictures provided to the research team in the frame of this research may be included in the report.
- I understand that data (consent forms, recordings, interview transcripts) will be stored until completion of the researcher's course, and then permanently deleted at the latest in July.

Future involvement

☐ I wish to receive a copy of the scientific output of the project.

☐ I consent to be re-contacted for participating in future studies.

Having read and understood all the above,
I agree to participate in the research study: yes / no

Date

Signature

To be filled in by the researcher:

- I declare that I have thoroughly informed the research participant about the research study and answered any remaining questions to the best of my knowledge.
- I agree that this person participates in the research study.

Date

Signature

Appendix 5: Ethical Checklist

1. Participants

- Does the study involve participants who are unable to give informed consent (i.e. people with Learning disabilities)? If yes: Discuss why and what measures you will take to avoid or minimize harm.
    - NO
- Does the research involve potentially vulnerable groups (i.e. children, people with cognitive impairment, or those in dependent relationships)? If yes: Discuss why and what measures you will take to avoid or minimize harm.
    - NO
- Will the study require the cooperation of a gatekeeper for initial access to the groups or individuals to be recruited? (i.e. students at school, members of self-help group, residents of nursing home)? If yes: Who is the gatekeeper? What agreement have you made, and which expectations do you share? Discuss whether and how this cooperation may influence your results.
    - NO
- Will it be necessary for participants to take part in the study without their knowledge and consent at the time (i.e. covert observation of people in non-public places)? If yes: Discuss why and how, and provide a risk analysis if applicable.
    - NO
- Will any dependent relationships exist between anyone involved in the recruitment pool of potential participants? If yes: Explain why and how, and provide a risk analysis
    - NO

2. Research design and data collection

- Will the study involve the discussion of sensitive topics? (i.e. sexual activity, drug use, politics) if yes: Discuss which topics will be discussed or investigated, and what risk is involved? What measures have you taken to minimize any risk, if applicable?
    - NO

- Are drugs, placebos, or other substances (i.e. food substances, vitamins) to be administered to the study participants? If yes: Discuss the procedure and the cost - benefit analysis.
    - NO
- What measures have you taken to minimize any risk, if applicable?
- Will the study involve invasive, intrusive, or potentially harmful procedures of any kind? If yes: Discuss the procedure and the cost-benefit analysis. What measures have you taken to minimize any risk, if applicable?
    - NO
- Could the study induce psychological stress, discomfort, anxiety, cause harm, or have negative consequences beyond the risks encountered in everyday life? If yes: Discuss the procedure and why no alternative method could be used. If necessary, discuss the cost -benefit analysis. What measures have you taken to minimize any risk, if applicable?
    - NO
- Will the study involve prolonged or repetitive testing? If yes: Discuss the procedure and how the interests of the participants are safeguarded.
    - NO
- Is there any form of deception (misinformation about the goal of the study) involved? If yes: Discuss the procedure and provide a rationale for its use.
    - NO
- Will you be using methods that allow visual and/or vocal identification of respondents? If so: Discuss what you will do to guarantee anonymity and confidentiality?
    - I will ask respondents for their consent to record the interview. If consented by the participants, I will record the interview in order to come back to the data and aid the analysis process. If desired by the participants, anonymity and confidentiality will be ensured throughout the whole process. I will be the only person that will have access to the audio recordings and transcripts. The files will be stored on the University of Groningen drive.
- Will you be collecting information through a third party? If yes: Discuss your choice for this party and the procedure.
    - NO

- Will the research involve respondents on the internet? If yes: Discuss how you plan to anonymize the participants.
    - NO
- How will you guarantee anonymity and confidentiality? Discuss the procedure and estimate the risk of a breach of confidentiality.

    - I will guarantee anonymity and confidentiality by making sure that the interview is conducted in a safe, comfortable and private space for the participants. If consented by the interviewees, I will audio record to be able to come back to the data. If desired by the participant, they will be completely anonymous throughout the study. I will, however, include their roles in my thesis but I will try my best to minimize this identification. Unless someone manages to access my emails, the risk of a breach of confidentiality is minimal.
- What information in the informed consent will participants be given about the research? Please consult the template for information sheets and informed consent sheets for further guidance. Adjust the template to your situation and discuss it with your supervisor. Which procedures are in place in case participants wish to file a complaint?
    - An information sheet and consent form will be shared with the participants.
- Will financial compensation be offered to participants? Discuss the compensation being offered and the rationale for it.
    - Participants will not receive any financial compensation due to the financial limitations of this study.
- If your research changes, discuss how consent will be renegotiated?
    - If the research changes, participants will be informed and asked for consent before any further actions. If not content the participant cna withdraw from this research.

3. Analysis and interpretation

- What is the expected outcome of your research? Discuss what you would consider a significant result?

- The expected outcome of my research is gaining insights from stakeholders perspectives and complementing the literature review.

- During the course of research, discuss how unforeseen or adverse events will be managed (i.e., do you have procedures in place to deal with disclosures from vulnerable participants)?
    - The interview procedure will be carefully designed and taken out in order that unforeseen situations are minimal. If any vulnerable participants are discovered throughout the process, I will personally assess their risk and ability to participate in this study and if necessary withdraw them from the research if necessary.

4. Dissemination

- Discuss how you plan to share your research findings. Which audience do you intend to target?
    - The findings will be shared via email with the participants of this study. They will also be included in my thesis, therefore, they will be shared with the University of Groningen. Likewise, I will share my findings during the Campus Fryslan Conference which is open to the general public, students and teachers. My findings will also be shared with two examiners who will assess my thesis.

5. Data storage

- Discuss: where your data will be stored and which measures you have taken to make sure it is secure?Which safety precautions have you arranged for in case of data leakage?, whether your data be disposed of. If yes: When? (date) if no: Why not?
  Whether your research involves the sharing of data or confidential information beyond the initial consent given (such as with other parties)? What specific arrangement have you made and with whom?

    - The data will be only stored on my personal device to which no one else can access it. Throughout the whole process data will not be shared with anyone. After the completion of the research on the 23th of June, the recordings and other personal data will be deleted from the device.

Appendix 6: Statement of Academic Integrity

This thesis was written with the help of my supervisor who gave me insightful guidance throughout this thesis. Although all interpretations, analysis and writing were done individually, AI tools were used to enhance grammar, clarity and translate texts with the use of DeepL and ChatGBT. All arguments were based on information received through the interviews or exploratory review.