28 Management of Invasive Australian *Acacia* Species: Contributions from Citizen Science, Volunteer Groups and Public Awareness Raising

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Abstract

The engagement of citizens and stakeholders in the management of invasive Australian *Acacia* species ('wattles') through diverse strategies can make a valuable contribution to decrease the threats posed by these species to biodiversity, habitats and human values. For this to happen, these groups must be aware of invasive wattles and the problems they cause. Such awareness and perception (or the lack thereof) can influence the likelihood of citizens to get involved in, and support, management. Effective public engagement with invasive wattle management is happening in several countries (notably in Portugal and South Africa) but is very limited in others where these species are present and invasive (e.g. Chile, Spain). Such engagement ranges from: (i) active participation in data collection (mostly through mapping apps that are substantially increasing knowledge of the distribution of *Acacia* species; but also monitoring their phenology or the establishment of biocontrol agents); (ii) volunteer involvement in wattle control (mostly in Portugal and South Africa, from informal groups to structured and funded projects, including combinations of control actions with training activities promoted by researchers); to (iii) participation in outreach activities aimed at raising awareness about invasive wattles and engaging citizens, such as talks, workshops, exhibitions and social media. Lessons learned from all these practices reinforce the notion that citizen involvement is an important part of any national or local strategy to achieve better management of invasive wattles. Reporting and exchanging successes (e.g. citizens' contribution to wattle control and mapping in South Africa and Portugal) and failures (e.g. the apparent lack of these types of activities in other regions where wattles are invasive) is critical to improve these strategies globally.

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28.1 Introduction

Prevention, early detection and rapid response are crucial steps in invasive plant management (Chapter 26, this volume). However, the rapid rate at which invasive Australian *Acacia* species ('wattles') spread (due to long-lived seed banks in the soil, clearing operations along roads that stimulate germination, resprouting, seed dispersal in water and by animals, etc; Gibson *et al*., 2011) makes it difficult for researchers, managers and other stakeholders to collate distribution and biometric data, to monitor every new population (i.e. to meet all surveillance needs; Kruger *et al*., 2022) and to control these species. Engaging citizens and stakeholders is thus crucial to ensure more timely surveillance and the effective management of invasive wattles. Involvement of decision makers is also needed to ensure more successful policies and the effective implementation of national and regional invasive alien species (IAS) legislations (e.g. EU Regulation No. 1143/2014 that lists *A. saligna*) that requires accurate and up-to-date information on the distribution of IAS. After a brief overview on why it is important to involve citizens in the management of wattles, and how their perceptions influence their willingness to be involved, different approaches to promote more successful citizen engagement with IAS are discussed in this chapter. The approaches range from face-to-face and hands-on activities to more general outreach initiatives. In the end we present some final considerations with some reflections and lessons learned.

Despite the great diversity of wattles (Chapters 2–4, this volume) and the wide scope of this book (Chapter 1, this volume), this chapter deals only with wattles in territories where they are non-native and invasive (*sensu* Richardson *et al*., 2000). Wattles are among the most widespread invasive alien plants (IAPs) in Mediterranean-climate areas of the world, namely Chile, Portugal and South Africa (Richardson, 2018; Chapters 9, 10, 12, 13, 26 and 27, this volume); we therefore focus on these regions. We focus on these three countries because for most other countries where wattles are invasive, we could not find much information, despite literature searches and communication with colleagues in those countries. Similar citizen engagement approaches with non-*Acacia* are common in other regions of the world (e.g. Australia or New Zealand; Kruger *et al*., 2022).

28.1.1 Why is it important to involve citizens in the management of wattles?

As with other IAS, the introduction, spread, prevention and control of wattles depend on human actions, including research and management undertaken by professionals, but also actions involving the public. The latter is the focus of this chapter. People may enhance the spread of wattles intentionally (e.g. planting them as ornamentals, for wood or for binding sand) or accidentally (e.g. by spreading seeds on shoes or in soil). On the other hand, citizens may help to manage wattles when they are properly informed, by preventing their introduction and spread (e.g. avoiding planting them), actively controlling them (e.g. in volunteer groups) or contributing to the collection of data needed for research, surveillance and management (e.g. via citizen science initiatives; Chapter 30, this volume).

Collection of occurrence records of IAS, such as geolocation data, by citizens is an important component of surveillance (Pawson *et al*., 2020). Cardoso *et al*. (2017) highlight that the contributions of citizen scientists to IAS mapping not only add to the number of records, but also raise awareness and increase public support for IAS regulations and management. The difference between someone contributing positively (i.e. reducing invasions) or negatively (i.e. promoting invasions) often depends on the level of awareness about IAS, and this is true also for wattles (Cordeiro *et al*., 2020). Citizens who are 'wattle blind' will not avoid their use and will probably not support management efforts. Conversely, when citizens are aware of the negative environmental, social and economic impacts of invasive wattles, they are likely to prevent introductions or further spread, and control them. In this case, it is important to know species' characteristics and recognize actions that can help disseminate such information. For example, after clearing, some wattles resprout more vigorously (e.g. *A. dealbata* and *A. mearnsii*) than others (e.g. *A. longifolia*) and therefore knowing how to identify the species is crucial for effective control (Chapter 10, this volume). Knowledge of the ecology of IAS is also important.

For example, knowing which species are dispersed by ants (*A. longifolia*) or birds (e.g. *A. melanoxylon* or *A. cyclops*; Gibson *et al.*, 2011; Marchante *et al.*, 2014; Chapter 17, this volume) is important for making decisions about their management: bird-dispersed species are likely to produce more distant invasion foci than are ant-dispersed species (Holmes, 1990) and, as such, bird-dispersed species should be prioritized for control.

28.1.2 Do perceptions of citizens regarding invasive wattles influence their willingness to promote and/or participate in management activities?

The level of knowledge, awareness and perception may influence the contribution of citizens (and stakeholders in general) towards invasive wattles and other IAS, as shown in several recent assessments (Sharp *et al.*, 2011; Urgenson *et al.*, 2013; Marchante and Marchante, 2016; Cardoso *et al.*, 2017; Novoa *et al.*, 2017). These studies shed light on the factors that affect the willingness of citizens to contribute proactively to IAS management and on options for raising awareness of problems associated with biological invasions in general. In Portugal, this subject has sparked interest from several researchers. To set the social context, several *Acacia* species were introduced to Portugal before 1900 (Chapters 10 and 27, this volume) and some are used, especially as ornamentals or for firewood, but there is no major dependency by people on these species. Cordeiro *et al.* (2020) analysed the knowledge and perceptions of 'environmentally aware' citizens about IAPs, including *A. dealbata*, the most widespread wattle in the country (Marchante *et al.*, 2014). The invasive status of *A. dealbata* was often recognized by respondents (when the species was found among other common IAPs and native plants), who were able to name it correctly in *c.*60% of the cases, rising to *c.*80% for respondents with formal training in environmental areas (from a total of 735 respondents). More interestingly, while around 90% of people with formal training in environmental sciences agreed that the species should be removed, only around 60% of respondents without such training supported control. This suggests that when citizens are informed about the invasive status of a species, they are more willing to support its control. Another finding of that study was that knowledge of the project INVASORAS.PT (used as a proxy for higher awareness/informal education) increased knowledge and altered the perceptions of citizens about IAPs, corroborating findings from other studies (Novoa *et al.*, 2017; Phillips *et al.*, 2021) and stressing the importance of public awareness in IAS management. INVASORAS.PT is a Portuguese science communication platform, led by researchers from the Centre for Functional Ecology (from both the University of Coimbra and the Coimbra Agriculture School), and targets Portuguese citizens in general. It aims to raise awareness and to engage citizens and different stakeholders on issues pertaining to IAPs. To this end, INVASORAS.PT provides information on the identification and control of IAPs, includes a WebMapping platforms (with associated Android and iOS apps "Plantas Invasoras" and project invasoras.pt at iNaturalist) that engage citizens in mapping the distribution of IAPs in Portugal, and supports scientific research and management. It also boosts numerous outreach activities and social media profiles (Marchante *et al.*, 2017) and reaches a wide audience (see Section 28.4, 'Final Considerations').

In northern Portugal, Vaz *et al.* (2020) assessed the perceptions of stakeholders (people responsible for making and/or implementing land-management decisions) about wattles (mostly *A. dealbata*, *A. longifolia* and *A. melanoxylon*), the invasion process, social-ecological impacts and management. Key findings were that about 40% of stakeholders (from a total of 65 respondents) could not accurately identify individual *Acacia* species, especially in areas where they are not common. Many stakeholders were unable to identify the drivers of dispersal and did not know which management methods were appropriate. Stakeholders had different perceptions regarding the benefits (acknowledged by only 22% of all respondents) and negative impacts (recognized by 97%) on natural resources provided by wattle species. The authors recommended the implementation of technical training and outreach strategies to address effective management actions and proposed that engagement should be promoted in the design and implementation of biosecurity efforts (i.e. actions aimed at reducing the risk of introducing or

spreading the alien species). Land managers generally agreed that management responsibilities should be shared among landowners, associations and municipalities.

A contrasting example comes from South Africa, where people are more dependent on wattles (Kull *et al*., 2011; also see Chapter 16, this volume). Ngorima and Shackleton (2019) analysed the benefits and costs of *A. dealbata* to rural communities in the Eastern Cape province and reported that all respondents recognize the species (although they were not aware that it was alien). The negative perception towards *A. dealbata* among respondents emerged as it became more abundant in the landscape and because of education campaigns coordinated by the country's Working for Water programme, which clearly labels IAPs as detrimental for the environment and ecosystem services (van Wilgen *et al*., 2011). Despite several benefits attributed to the species (e.g. firewood, fodder, fencing) by all 150 respondents, over 60% did not want *A. dealbata* near their home because the roots cause the foundations of buildings to crack. Yet, apart from areas that are directly used by residents, such as fields and surroundings of houses, local communities do not remove *A. dealbata*, assigning control responsibility to external agencies (e.g. government agencies and private consultancies). Ngorima and Shackleton (2019) conclude that greater effort is needed to raise awareness if government agencies are to gain local support for IAS management. Although there is still some dependence on *A. dealbata*, as housing conditions and the availability of electricity increase in the country, reliance on the species for firewood and building material is likely to decrease in the medium term.

In urban environments around the city of Cape Town in South Africa, Potgieter *et al*. (2019) explored perceptions of the impacts of IAPs (including the widespread *A. saligna*). They found that 83% of urban residents (out of a total of 158 respondents) perceived IAPs negatively, although 37% recognized some positive benefits. The provision of fuelwood was the most widely perceived benefit for *A. saligna*, while the negative impacts included the displacement of native species and high consumption of water. When it came to management, 91% of respondents agreed that IAPs need to be controlled to conserve the environment and protect biodiversity. However, such management actions were not perceived as a high priority, with only 39% of respondents assigning 'high management priority' to them compared to the other environmental problems; 49% assigned 'medium management priority' and 12% 'low management priority'.

In Chile, although wattles are increasingly recognized as invasive and problematic by researchers and conservation institutions (Chapter 13, this volume), the public remains largely unaware about their status as invaders and their potential negative impacts. In fact, one of the most widespread species in Chile, *A. dealbata*, is known by the public as 'aromo chileno' (Chilean wattle) to differentiate it from the second most widespread wattle species, *A. melanoxylon*, which is called 'aromo australiano' (Australian wattle). There have been efforts to raise awareness, especially in areas heavily invaded by these two species. For example, the group Naturaleza Intrusa, a student organization with the aim of communicating the risk posed by invasive species, has produced material with information on *A. dealbata*, which is one of the emblematic species used in education seminars, fairs and social media (S. Benavides, Concepción, October 2022, personal communication). Some characteristics of this species resonate with the public and may hinder management efforts, for example it has very bright yellow blossoms in winter and an intense aroma that are appreciated by most citizens (Pauchard and Maheu-Giroux, 2007). Similarly, both *A. dealbata* and *A. melanoxylon* produce high-quality firewood and, because of their vigorous resprouting, can provide a long-term energy source for rural and peri-urban communities (Fuentes-Ramírez *et al*., 2011). Restoration efforts are probably the best example in Chile of how perceptions of local stakeholders regarding wattles may change, as they see wattles competing strongly with the native species targeted for re-establishment. This is the case in Nonguén National Park, where restoration has required intensive control of the two wattles (C. Echeverria, Concepción, October 2022, personal communication). Similarly, in wetland areas in the Concepción metropolitan area, wattles have been controlled along the margins and native trees have been planted. Unfortunately, no monitoring has been conducted to assess whether native trees can outcompete regenerating wattles.

In conclusion, as illustrated by the examples discussed above, public perception regarding wattles as invaders may significantly influence the ways people support their management, are willing to participate in such management, or support it financially or in other ways. Such perceptions depend on the context, specifically on dependencies that may exist with the species and/or on the recognition of benefits and/or costs associated with the species. Although wattles are invasive in Chile, Portugal and South Africa, the contexts and perceptions are different, with wattles being controlled over large areas and for several decades in Portugal (Chapter 27, this volume) and South Africa (Chapter 26, this volume) and less so in Chile (Chapter 13, this volume), and this is reflected in citizen participation (see below).

28.2 Initiatives Involving Citizens that May Contribute to Wattle Management

The involvement of citizens in IAS-related activities – from citizen science to control actions by volunteer groups, reporting on IAP biocontrol agents, or outreach activities – is generally more common among environmental volunteers, naturalists, researchers, conservation technicians, biology/science teachers and their students, etc. However, other groups such as beekeepers, farmers, foresters, birdwatchers or gardeners are also good targets to involve, as they may have good knowledge of their environment, are frequently committed to nature conservation and are frequently less 'plant blind', which is crucial for identifying and recognizing IAS (Cardoso *et al.*, 2017), including wattles.

28.2.1 Citizen science projects that collect data on wattles: occurrence records

With the rapid expansion of wattles in many regions outside their native ranges (see Chapter 9, this volume), accurate and up-to-date distribution data are increasingly important in formulating strategies for effective management (Chapter 26, this volume). However, it is not easy for researchers, technicians and other professionals to obtain occurrence data for all the species and territories. In recent decades, the number of citizen science platforms that collect biodiversity and IAS data has increased (Johnson *et al.*, 2020; Price-Jones *et al.*, 2022; Chapter 30, this volume); such platforms are becoming increasingly useful for complementing data collected by professionals.

Citizens have been involved in the recording of species for more than a century (Silvertown, 2009). However, the role of these citizen scientists in early detection and monitoring of IAS has emerged only in the last few decades, catapulted by the development of Internet and smartphone applications or 'apps' (Dehnen-Schmutz and Novoa, 2022). Various mapping platforms hosting different forms of data on biodiversity, including alien species, have emerged, and have become useful for studying IAS and for their management around the world (Cardoso *et al.*, 2017; Johnson *et al.*, 2020; Howard *et al.*, 2022; Price-Jones *et al.*, 2022). iNaturalist is one of the most popular and globally adopted citizen science platforms but many others exist (Howard *et al.*, 2022; Price-Jones *et al.*, 2022), including 'Invasive Alien Species in Europe' (European Union; Schade *et al.*, 2019) and 'Plantas Invasoras' from the platform INVASORAS.PT (Portugal; Marchante *et al.*, 2017) which also collect geolocation data. All these platforms are useful for increasing our knowledge of the distribution of wattles by providing accurate occurrence data (Chapter 30, this volume; see Table 28.1).

iNaturalist is open to the public for reporting observations of all organisms across the world. Protocols for data collection entail participants capturing and uploading pictures and videos of species along with metadata, such as GPS coordinates, to the online database. The submitted images, or at least some of them, are identified and vetted by the iNaturalist community of experts, which increases identification accuracy (iNaturalist, 2022). Yet, records are not always deeply scrutinized, which may lead to misidentification of some species. In their non-native ranges, wattles are relatively easy to detect in the landscape due to their size and typical showy blooms, although some identification challenges do exist at the species level. This makes them excellent targets for such platforms and there are both iNaturalist projects with wider taxonomic targets that include wattles

Table 28.1 Observations (on 17 February 2023) of Australian *Acacia* species in selected citizen science projects outside Australia.

	iNaturalist projects								App Plantas Invasoras (Portugal)[b]
	Australian *Acacia* species in…			ALIEM (Italy/ France)	*Acacia s.l.* in Sardinia (Italy)	Invasoras.pt (Portugal)	Invasive Plants of California (USA)	iNaturalist (general; includes Australia)	
Acacia species	South America	South Africa[a]	Africa						
A. dealbata	413	362	400	275	8	2944	1475	8560	3225
A. melanoxylon	505	1189	1197	8	3	1232	1597	8402	1302
A. longifolia	92	1545	1545	11	4	766	1524	7798	1114
A. mearnsii	8	3794	3885	4	2	337	–	6451	167
A. saligna	11	3358	3368	92	82	270	108	5043	550
A. pycnantha	–	412	412	6	6	86	129	3477	106
A. paradoxa	–	18	18	–	–	–	19	3321	–
A. cyclops	–	1896	1901	2	–	7	821	3015	19
A. verticillata	–	–	–	–	–	4	–	2150	–
A. confusa	1	–	–	–	–	–	–	2070	–
A. baileyana	76	192	192	6	–	11	613	1781	–
A. auriculiformis	2	–	23	–	–	–	–	1596	–
A. ulicifolia	–	5	5	–	–	–	–	1561	–
A. retinodes	110	1	3	21	8	36[c]	–	1361	87[c]
A. acinacea	–	3	3	–	–	–	–	1160	–
A. podalyriifolia	5	314	319	–	–	–	–	1004	–
A. fimbriata	–	1	1	–	–	–	–	894	–
A. implexa	–	128	128	–	–	–	–	795	–
A. decurrens	16	152	153	–	–		–	769	–
A. redolens	1	–	–	–	–	–	–	678	–
A. mangium	41	–	21	–	–	–	–	489	–
A. floribunda	1	–	–	–	–	–	–	476	–
A. elata	2	223	223	–	–	–	–	455	–
A. stricta	–	26	26	–	–	–	–	399	–
A. provincialis	–	3	3	–	–	66	–	263	–
A. binervata	–	6	6	–	–	–	–	153	–
A. falciformis	–	42	42	–	–	–	–	121	–
A. cultriformis	–	8	8	–	–	–	–	77	–
A. viscidula	–	15	15	–	–	–	–	40	–

A. schinoides	–	1	1	–	–	–	–	34	–
A. vestita	1	–	–	–	–	–	–	30	–
A. adunca	–	4	4	–	–	–	–	25	–
A. crassiuscula	–	5	5	–	–	–	–	14	–
A. piligera	–	12	12	–	–	–	–	12	–
A. minutifolia	–	–	1	–	–	–	–	3	–
Total no. of species with observations	16	27	30	9	7	11	8	d	8

Note: Projects with a larger geographic range include observations from projects with smaller geographic ranges (e.g., all observations on 'Australian *Acacia* species in South Africa' are part of 'Australian *Acacia* species in Africa').

[a]Observations 'shared' with the project 'Australian trees and shrubs in South Africa'.

[b]Values from December 2022. App associated to the INVASORAS.PT platform.

[c]At least part of these observations is probably *A. provincialis*.

[d]On iNaturalist there are many more *Acacia* species with observations, notably in Australia; only species with observations in projects outside Australia are included in this table.

and more dedicated projects to groups of *Acacia* species or even a single species.

A typical iNaturalist project is 'Australian *Acacia* species in South Africa' which was launched in 2019 and includes all verified (Research Grade) observations of wattles in that country. As of 17 February 2023, the project had 12 members (participants who have formally joined the project), 1101 observers (participants who submit observations but may not join the project) and 412 identifiers. Observations have greatly increased the knowledge of the distribution of wattles in South Africa, providing not only first detections but also additional observations that have improved the knowledge of the distribution of these species. The project contributed 15,303 observations of 27 *Acacia* species, out of the 33 Australian wattle species confirmed in the country (Magona *et al*., 2018; Chapter 12, this volume). It also collates distribution data on seven biocontrol agents released in South Africa: *Dasineura dielsi* Rübsaamen (on *A. cyclops*), *Dasineura rubiformis* Kolesik (on *A. mearnsii*), *Melanterius maculatus* Lea (on *A. mearnsii* and *A. dealbata*), *Melanterius servulus* Pascoe (on *A. cyclops*), *Trichilogaster acaciaelongifoliae* (Froggatt) (on *A. longifolia*), *Trichilogaster signiventris* (Girault) (on *A. pycnantha*) and *Uromycladium morrisii* Doungsa-ard, McTaggart, Geering & R.G. Shivas (on *A. saligna*) (also see Chapter 21, this volume). Most records (76%) are from the Western Cape province (Fig. 28.1). This province is the most invaded terrestrial area in South Africa (Richardson *et al*., 2020), including by wattles, and is also where most research on biological invasions has been conducted (van Wilgen *et al*., 2020) and where citizen scientists have made the greatest contribution to the mapping and management of IAS in South Africa (Jubase *et al*., 2021). Another iNaturalist project in South Africa that collates records on wattles is 'Australian trees and shrubs in South Africa', which lists records of 126 species; five wattles are in the list of the top-ten taxa with the most observations. The list of the species recorded in these projects with corresponding observations is provided in Table 28.1.

Other iNaturalist projects include observations on wattles, for example: (i) 'Major invasive plant species in protected areas globally', created in 2020, including 58 of the most widespread and well-studied IAP species in protected areas globally (as listed by Foxcroft *et al*., 2017). This project includes two *Acacia* species, with 5665 observations of *A. mearnsii* and 4172 of *A. saligna* (17 February 2023) and has records from many areas, mostly from regions with Mediterranean-type climate; (ii) the '*Acacia s.l.* in Sardinia' project includes ten species, seven of which are Australian *Acacia* species, on the small Italian island in the Mediterranean. It was created in 2020 to increase public awareness of these species in urban landscapes and coastal areas within the island and by 17 February 2023 it had collated 82 observations of *A. saligna* while all the other Australian *Acacia* species had fewer than ten observations; (iii) 'Invasoras.pt' was created in 2019 to complement Plantas Invasoras from the INVASORAS.PT platform and includes observations of IAPs in Portugal, including wattles, accumulating 5759 observations of 11 *Acacia* species (Table 28.1).

The level of *Acacia* species misidentification for iNaturalist records is low because the scientific community voluntarily corrects some initial misidentifications. Formal projects such as those mentioned above help to focus attention on identification queries (e.g. by tagging experts to assist with identification) which are usually rapidly resolved. It is interesting to observe heterogeneous 'ID skills' in different regions. For example, in Portugal *A. mearnsii* is frequently misidentified as *A. dealbata* but the genus *Acacia* is almost always indicated correctly from the beginning. In some regions of South America, other genera with yellow flowers, including both native and alien genera, are sometimes misidentified as *Acacia* or wattles are not correctly identified at species level. Some of these identifications are later corrected by experts. Other platforms only make records available online after validation by experts, and while this may increase identification accuracy it also increases the requirements for project maintenance. One such example is INVASORAS.PT in Portugal, which includes several outreach tools including a geolocation platform and associated Android and iOS apps (Plantas Invasoras), that has been available since 2013 (Marchante *et al*., 2017). Although not focused on wattles, it includes data on eight species – the most invasive and widespread species in Portugal – and on 31 December 2022 listed 6570 observations of

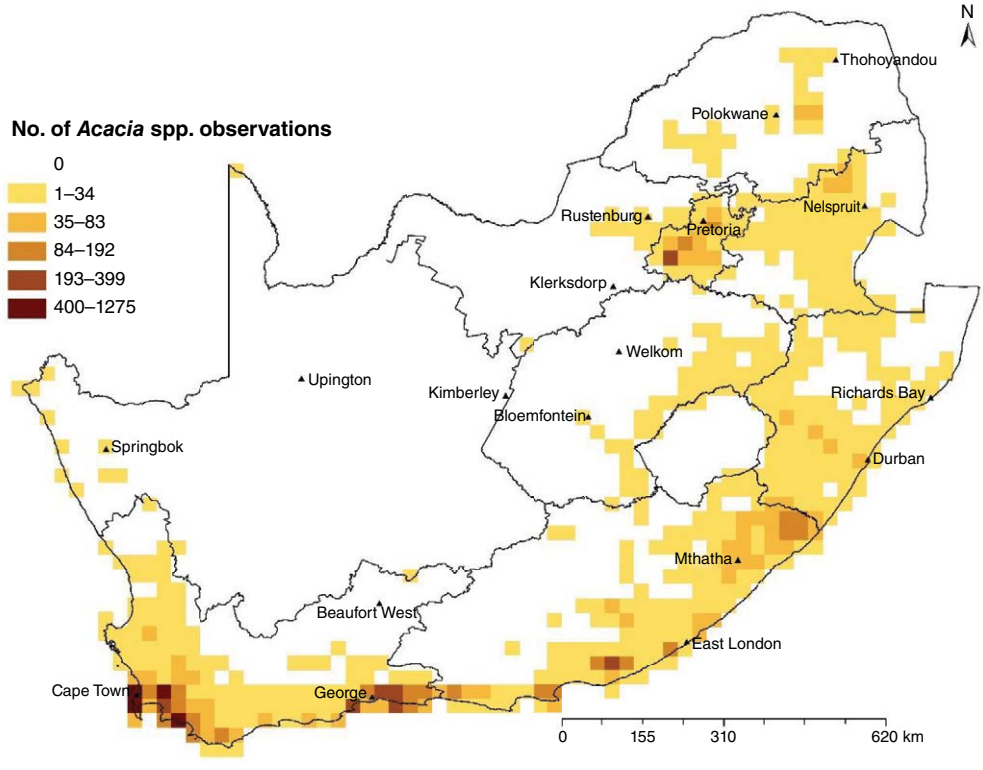

Fig. 28.1. Citizen science observations (on 12 August 2022) of Australian *Acacia* species in South Africa at the scale of quarter-degree grid cells. Data were collected by citizen scientists using the platform iNaturalist.

wattles submitted by 501 users (Table 28.1). In this platform, all submitted records are verified by experts, who either accept or reject them, and only accepted records become visible on online maps.

Another crowdsourcing platform that is contributing important data on the distribution of alien wattles is Pl@ntNet (https://identify.plantnet.org/, accessed 17 February 2023). On 2 August 2022, Pl@ntNet held records for 16 Australian *Acacia* species for Western Europe; species with more than 500 records include *A. dealbata* (3730), *A. longifolia* (570), *A. mearnsii* (676), *A. melanoxylon* (632) and *A. retinodes* (1269).

While effective early detection of IAS is logistically challenging and limits effective management, public participation through citizen science mapping platforms has amplified efforts of detection and thus promises a better future for management decision making.

28.2.2 Citizen science projects that collect data on wattles: monitoring of invasive plant phenology and other data collection

While most citizen science projects involving wattles focus on recording species observations, there are other types of projects on wattles, although not focused on the genus, that may engage citizen scientists with their management. In Portugal, three projects associated with the platform INVASORAS.PT targeting school communities and volunteer groups are worth mentioning: (i) 'Monitor IAP phenology', where citizen scientists are asked to photograph a selected IAP once a month, using a project (Desafio2) in the free app Epicollect5, aiming to gather data on IAP life cycles (Fig. 28.2). This is a long-term project that aims to identify trends in IAP phenology; (ii) 'Spread the word', where citizen scientists are invited to develop creative ways (videos,

Fig. 28.2. Example of sequential life-cycle photographs of *Acacia longifolia* (A) and *A. dealbata* (B), collected in the citizen science project 'Monitor IAP phenology' in Portugal. Such data add knowledge on the phenology of invasive alien plants in the country.

posters, songs, memes, exhibitions, etc.) to communicate aspects related to biological invasions, aiming to raise awareness about them; and (iii) 'Control – get to work!', where citizen scientists select an invaded area to control an IAP (wattles are among the most common targets) and report about it. The citizen scientists' participation in these latter three projects is (still) minimal when compared with the above-mentioned mapping apps, probably due to their high specificity and mainly because of the lack of 'tradition' in their use and of their wide recognition.

Data collected by citizen science projects can be used for scientific research (e.g. modelling studies to better understand species distributions; Dinis *et al*., 2020; Chapter 30, this volume), for management and/or implementation of legislation, for instance 'feeding' surveillance platforms and species action plans (César de Sá *et al*., 2019). César de Sá *et al*. (2019) showed that models trained with data collected by citizen scientists increased the predicted spatial distribution of three wattle species (*A. dealbata*, *A. longifolia* and *A. melanoxylon*) in Portugal and facilitated the identification of areas with the highest surveillance priority (both for citizen scientists and researchers) for these species (Chapter 30, this volume).

Despite the increasing volume of data collected by citizen scientists, in most cases such data remain virtually unexplored for official surveillance (e.g. by filtering records of *Acacia* species in regions where they were previously absent – early detection – and taking the necessary control measures) and for reporting on the status of invasions. This is partly attributable to issues pertaining to the potential lack of reliability and quality of some of the data, difficulties in accessing the data (Cardoso *et al*., 2017; Price-Jones *et al*., 2022), lack of knowledge about its existence by some parties, or (most problematically) difficulties in harmonizing platforms that collect and manage data effectively. New initiatives should always consider utilizing existing tools, exploring possibilities to avoid duplication of effort or should at least ensure cross-platform compatibility (e.g. with iNaturalist or the Global Biodiversity Information Facility; GBIF). It is also crucial that these data sets should be easy to use, and not time-consuming (Cardoso *et al*., 2017). A few promising examples show how citizen science projects that generate data on IAS distribution are already working as supplementary tools in official surveillance systems. For example, the 'Invasive Alien Species in Europe' project is used for implementation of EU Regulation No.

1143/2014, and the INVASORAS.PT platform complements surveillance associated to the Portuguese national legislation, Decreto-Lei no. 92/2019, by sharing the collected observations, and data are shared with land managers and other stakeholders.

In general, wattles could serve as a model group for developing a standardized approach for fine-tuning citizen science projects as an aid to IAS research and management. Invasive wattles have important traits that make them very suitable for engaging citizen scientists; these include their conspicuous nature in most habitats they invade (unusual 'leaf' (phyllode) morphology, distinctive flowering patterns, seed pods, etc.) and their well-documented impacts that resonate with the informed public.

28.2.3 Citizen science monitoring of biological control: *Trichilogaster acaciaelongifoliae* as an example

Since late 1970s in South Africa, and since 2015 in Portugal, the control of invasive wattles has included biological control (Chapter 21, this volume). Post-release monitoring of biocontrol agents is crucial to evaluate their spread and effectiveness, as well as to assess direct non-target effects. However, long-term post-release evaluation programmes are often neglected or underfunded (Schaffner *et al.*, 2020). The scale of monitoring can be substantially expanded if the contribution of citizen scientists is included, even if monitoring protocols need to be simplified (Morin *et al.*, 2009). In Portugal, citizen scientists have been collaborating with researchers from the INVASORAS.PT platform to gather data on the establishment of the bud-galling wasp *T. acaciaelongifoliae*, a biocontrol agent of *A. longifolia* (López-Núñez *et al.*, 2021). The project 'Registo de *Trichilogaster acaciaelongifoliae*' was created using the free app Epicollect5 to register establishment of the agent, including the presence and absence of its galls, and other parameters. To confirm the expected high host specificity, the absence of galls on non-target plants is also requested. With over 810,200 galls recorded by 9 August 2022, the project at Epicollect5 has been successful in engaging 110 citizen scientists to monitor both the presence (3205 records) and absence (2275) of galls on *A. longifolia*, and their absence on non-target plants (596 records). Most records are reported by conservation technicians, researchers, teachers and their students, and land managers (Marchante *et al.*, 2023). Citizen scientists may also report galls using the iNaturalist project '*Trichilogaster acaciaelongifoliae* in the Iberian Peninsula' (1017 observations, 50 observers, on 9 August 2022), by email and by Facebook, but these alternatives generally include less information than the dedicated Epicollect5 project. As the populations of *T. acaciaelongifoliae* increase and spread, the participation of citizen scientists is expected to grow, allowing a more complete follow-up of the establishment success and the effects of this biocontrol agent. This will allow an increase of data in areas not sampled in detail by researchers and indicate new regions of agent expansion, helping to guide detailed future surveys by researchers. This also raises awareness about the benefits of biocontrol, a management approach that is currently limited in Portugal.

28.2.4 Volunteer groups actively controlling wattles

Short-duration actions involving citizens in controlling wattles (and other IAPs) are regularly organized in Portugal and South Africa. These actions frequently include uprooting young plants, cutting plants with saws, shears or other manual equipment, and debarking trees – which is considered adequate even for beginners, i.e. volunteers with no experience in such tasks. Such activities probably exist in other countries too, but online searches and contacting researchers/conservation agencies to gather information on such initiatives, specifically focused on wattles, yielded no results. In Chile, efforts to control IAPs have not yet included volunteers; control efforts currently rely mostly on forestry and agricultural workers, including personnel hired as firefighters or temporary workers in social programmes. The use of tools that pose significant safety risks (e.g. chainsaws, machetes) and the lack of training in using such tools have hindered citizen involvement in wattle control, limiting volunteer work to the planting of native trees after the control of invasive species (A. Pauchard, October 2022, personal observation).

In Portugal, control actions involving volunteers include a variety of contexts and organizations: (i) actions are organized by academic institutions, researchers, environmental non-governmental organizations (ENGOs), governmental agencies and other entities; (ii) some actions form part of long-term funded projects and others are organized completely informally; and (iii) some are sporadic, whereas others are regular and are maintained over several years. Many have emerged in the last decade, probably inspired by successes and publicity of the first initiatives. Within these diverse contexts, a few examples illustrate aspects of this form of public participation:

- Since March 2018, different groups of volunteers (ten to 20 people working one Saturday per month), led by a small core group of researchers with logistical support from the University of Coimbra, control wattles (and sporadically other IAPs) on the campus of the University, where *A. dealbata* and *A. longifolia* are abundant. Thirty-nine such meetings had been convened by February 2023, with 213 unique volunteers (total of 615 participations, but 34% of volunteers involved more than once; around 1850 person-hours) and these are ongoing.
- Between 2014 and 2020 the project LIFE Biodiscoveries (Invasive species control through public participation, LIFE13 BIO/PT/000386, led by the Municipality of Barreiro) involved volunteer groups in IAP control (mostly debarking seven *Acacia* species), and other tasks, at a nature reserve near Barreiro. A small group of workers, consisting of prisoners and a technical team, was also involved. The aim was to create long-term bonds between people, IAP control and management of natural areas to guarantee the long-term maintenance after conclusion of the project. A small but strongly committed group of volunteers have remained involved and continue to encourage additional volunteers to maintain the work after the formal project ended (Câmara Municipal do Barreiro, 2020).
- Between 2018 and 2021 the LIFE Volunteer Escapes (European Solidarity Corps for Activities in Portugal with Ecological Sense, LIFE17 ESC/PT/00003), involving nine organizations (ENGOs, local and national administrations, media, enterprises), deployed long-term volunteers to carry out different nature conservation and environmental-protection activities. Such engagements regularly included control of several wattle species at several locations over 69 ha.
- From 2011 to 2018, the project 'FUTURO Projeto das 100.000 árvores na Área Metropolitana do Porto' proactively involved volunteers from the municipalities included in the metropolitan area of Portugal's second largest city (Porto) in planting trees and increasing the area of peri-urban forests. Invasive alien plants are a major threat to these areas, and wattle control became part of the regular activities to maintain the plantations. For the programme, great effort was put into training of different groups, including municipal technicians, who then tutored the volunteers, mainly on debarking and hand-pulling of wattles.
- Since 2005, a landowner with a long-time commitment (over 20 years) to convert areas of under *Eucalyptus* L'Hér. plantation and areas with dense invasions of *A. dealbata*, *A. longifolia* and *A. melanoxylon* to natural habitats, organized small groups of volunteers. These efforts included substantial wattle control, including cutting, debarking and hand-pulling. The area is in a remote rural zone (Cabeço Santo, Aveiro, Portugal) and management is partially supported by a pulp company and collaboration with an ENGO. The project is notable because of its ensured long-term commitment to the control of wattles. Some sections are now entirely cleared and restored with native vegetation. Despite this initiative's successes, sustaining the momentum of volunteer groups has been a challenge.

In South Africa, Jubase *et al.* (2021) estimated the range and value of inputs made by volunteer groups to IAP management in the Western Cape province (Fig. 28.3). They documented activities of 52 volunteer groups ranging in size from two to 50 people. The oldest volunteer groups were initiated as early as 1980. Most groups were triggered by the expansion of IAPs and are sustained by the members recognizing the need to halt further spread. Most groups concentrated their

Fig. 28.3. One of the many active volunteer groups (the 'Rhodes Mem Hack Group') removing various invasive alien plants, including *Acacia* species (*A. paradoxa* is an important focus), in the Western Cape province, South Africa. Photo credits: (A) Liz Sparg; (B) Bianke Fouché.

efforts on controlling and reducing the spread and impact of the most widespread invasive wattles in the province such as *A. cyclops*, *A. longifolia*, *A. mearnsii* and *A. saligna*. Jubase *et al.* (2021) estimated that half of the groups that participated in the survey cleared nearly 5300 ha per year, amounting to estimated labour contributions of R5.1 million (US$0.32 million). Volunteers play an important role in IAP management and are likely to continue doing so into the future. However, improving the effectiveness of these actions demands better coordination and engagement between volunteers and mandated authorities on science, policy and long-term management goals. To keep volunteers motivated about managing IAP is also important. Volunteers gain physical exercise and psychological fulfilment and build their social capital by meeting new people.

In Galicia, Spain, the 'Brigadas Deseucaliptizadoras' (http://verdegaia.org/brigadas/, accessed 17 February 2023), led by the Galician association Verdegaia, began in 2018 a network of civic intervention in areas at high risk of forest fires which is contributing to the control of several IAPs, including wattles, mainly *A. dealbata*, but also *A. longifolia* and *A. melanoxylon*. Under this initiative, groups of volunteers gather several times a month in different localities and are organized by environmental associations and the public civil-society groups in the territory. This brings together around 1300 volunteers, who contribute to the control of wattles, mainly on communal land but also on private land.

The activities described above, although contributing in varying ways to the control of wattles (from limited to relevant, depending on context), also function as valuable awareness-raising and training tools that reinforce the importance of involving citizens in management. A key point that could eventually be more explored is the ability for volunteer groups to engage in efforts beyond the scope of funded projects; this is essential because the long-lived seed bank of wattles will frequently persist and keep germinating, and several species vigorously resprout after control. For this, keeping volunteers motivated is important for ongoing monitoring efforts (Anđelković *et al.*, 2022; see Section 28.4, 'Final Considerations').

28.2.5 One-week field camps to control wattles

Annual one-week field camps, focusing on IAP control and training of volunteer participants, have been organized in Portugal since 2003 by the INVASORAS.PT platform team and different local entities. By 2022, 19 field camps had been organized, in nine different locations, mostly protected areas but also other areas. More than 380 volunteers contributed to the control of mostly *A. dealbata* and *A. longifolia*, but also *A. melanoxylon* and sporadically other IAPs. These field camps are mainly aimed at university students and professionals in areas related to environmental, forestry and biological sciences, and include three main approaches: (i) IAP control; (ii) training on the identification, impacts and

control methods of IAS, and nature conservation; and (iii) small projects involving IAPs, namely scientific experiments, and awareness-raising activities (Fig. 28.4). The philosophy behind these field camps is to strongly engage the public with IAS through learning, hands-on control activities, and stimulating a healthy and fun working/learning environment.

When the first field camp was organized the public was very receptive and enthusiastic. In 2013, a questionnaire was sent to participants and non-participants aiming to assess the effectiveness of this approach. The results highlighted that fieldwork participants: (i) had more knowledge about IAS concepts and general information; (ii) were more motivated to participate/organize activities or work with IAS; (iii) talked to more people about IAS; (iv) correctly identified more IAPs; and (v) considered themselves to have changed behaviours and attitudes towards IAS (Marchante and Marchante, 2016). In fact, after participating, several volunteers became involved in IAS projects, and some of them now work professionally in the fields of IAS research and management. These camps have thus proved very effective and successful in training people and raising awareness and in motivating staff working in protected areas to publicize their work in IAP management.

Over time, several other entities (mostly ENGOs, but also some municipalities) have organized similar field camps, many of which are focused on IAP control (often including wattles), namely: the municipality of Lousada and Montis – Association for Nature Management and Conservation, which organizes several one- or two-week camps with volunteers, generally focused on conservation actions and often involving wattle control; or the Parque Serras do Porto (bringing together three municipalities from the Porto Region), which organizes field camps, generally of shorter duration (two or three days), more centred on control actions in the field, also including wattles.

28.3 Outreach Initiatives to Raise Awareness about Wattles

Besides the above-mentioned activities, several other approaches have been used to promote public participation in the management of wattles (and other IAS), especially regarding prevention. Traditional media (e.g. national or regional press, television, radio) and popular science publications are important avenues for raising awareness and engaging the public. Social media (Twitter, Facebook, Instagram, YouTube, etc.) are currently key tools for reaching wide audiences, although recruiting new followers and maintaining their engagement is often challenging for very specific subjects such as IAS. The organization of face-to-face events, such as workshops, field campaigns, training or even newsletters, can be used to increase the engagement of citizens and encouraging their longer-term participation (Cardoso *et al*., 2017).

In Portugal, the INVASORAS.PT platform is a good example of an initiative that has organized many activities, targeting a range of audiences, aimed at dissemination activities around IAPs (almost always including wattles) since 2003 (Marchante and Marchante, 2016). For school students, these include short talks, hands-on activities, control of IAPs, identification games and other activities (Schreck *et al*., 2013). The effectiveness of some of these workshops was

Fig. 28.4. Snapshots of the three approaches included in each INVASORAS.PT field camp to control invasive alien plants in Portugal: control activities, including wattle debarking (A); training session (B); and scientific experiments, e.g. quantification of seed banks (C).

assessed using questionnaires that targeted students who attended the workshop and a control group who did not. Results showed that, one year after the workshop, participants knew significantly more than non-participants about IAS, including recognizing them (Schreck *et al.*, 2013). Further dissemination of information on IAPs, more regularly since 2007, was accomplished through participation in diverse initiatives (over 230 workshops, participations in science and nature forums and fairs, environmental conferences and talks, hands-on activities, etc.) that target diverse members of public: citizens in general, school children, university students, foresters, horticultural trade, conservation experts, ENGOs, etc. (Marchante and Marchante, 2016). As a result, over the past 15 years many citizens in Portugal are better informed about issues pertaining to IAPs, including wattles. In addition, around 100 training workshops have been organized, targeting professionals (e.g. conservation and forest technicians and operatives, teachers) and other interested citizens, which contributes directly to better management of IAPs, including wattles. Although not quantified, numerous other entities in Portugal, from the academic institutions, ENGOs, municipalities, schools, etc., promote initiatives that involve citizens to prevent and control IAPs such as wattles.

With the aim of increasing awareness about biological invasions nationally, the first IAS National Awareness Week was promoted in Portugal in 2020. The INVASORAS.PT platform team, with researchers from Centre for Functional Ecology, University of Coimbra and Coimbra Agriculture School, joined more than 90 entities in organizing about 150 initiatives on IAS management, e.g. control actions, face-to-face and online training, and citizen science IAP mapping. These initiatives were held across Portugal and involved over 1500 participants. In 2021 and 2022 this dedicated IAS week extended to Spain, being organized by the INVASORAS.PT platform, InvEco (Portuguese Network for the Study and Management of Invasive Species, associated to the Portuguese Ecological Society, SPECO), INVASAQUA and STOP Cortaderia (two Iberian LIFE projects) and leading to a surge in participation (e.g. over 230 entities organizing more than 250 activities in 2022). In Portugal, a substantial component of activities included control and monitoring of *A. dealbata* and *A. longifolia*.

Similar types of public engagements have also been organized in other countries, albeit less frequently than in Portugal, particularly when considering invasive wattles. For example, in Italy, between 2016 and 2020 the project LIFE ASAP (Alien Species Awareness Program; https://www.lifeasap.eu/, accessed 17 February 2023) focused on increasing awareness, encouraging citizen engagement with IAS, and promoting better management of IAS by public entities involved in implementation of the EU Regulation No. 1143/2014. This project included *A. saligna* and initiatives that targeted actions for schools, visitors to parks and travellers, through citizen science events such as educational games, Smart apps, the organization of awareness events and photographic contests.

In Chile, efforts to raise awareness about wattle invasions have been sporadic, but the experience of Naturaleza Intrusa may inspire future initiatives. Naturaleza Intrusa was founded in 2017 by students at the University of Concepción with sponsorship from the Laboratorio of Invasiones Biológicas (LIB). They have conducted numerous in-person and online activities, including in social networks (Fig. 28.5), educating groups about the most invasive species in Chile and the threats they pose to biodiversity. While referring to invasive wattles, the importance of conserving and recovering native tree species and other ecosystems (e.g. wetlands) displaced by wattles was always emphasized. Their approach is characterized by a direct dialogue about the pros and cons of these species and a careful approach to avoid over-generalization or counter-productive negative reactions towards non-native species.

Target audiences are diverse and there is a strong focus on elementary and high school students when raising awareness in Chile. People's reaction to wattles being invasive, spreading and causing impacts, is frequently one of surprise or even rejection. In fact, most citizens in Central Chile see wattles as part of the Chilean landscape and they appreciate their flowering in winter and the firewood they produce. However, giving further information and discussion allows them to understand the complexity of the problem and recognize the positive and negative impacts these species have in human well-being and nature, as well as the opportunity to restore native ecosystems (S. Benavides and A. Lara, Concepción, October 2022, personal communication).

Fig. 28.5. Outreach activities with local communities, in Chile, organized by the group Naturaleza Intrusa and the Laboratory of Biological Invasions (LIB), including educational games (A), exhibitions (B) and informative pamphlets (C).

28.4 Final Considerations

Initiatives involving and engaging citizens in different ways have contributed to improved prevention and control of invasive wattles (and other IAS). However, such engagement is not yet in place in all areas where wattles are invasive. We have reviewed the examples that emerged from our literature search and from communication with many researchers and ENGOs we contacted in Europe, South America and South Africa. We offer some final reflections on the contributions we have reviewed and make some suggestions for how engagement with citizens could be made more effective.

1. Citizen science mapping apps are one of the most common and widespread forms of citizen involvement in IAS. They are already contributing data to scientific research and to surveillance and monitoring schemes applied in wattle management (Chapter 30, this volume). However, to maximize their usefulness, data must be of high quality, easily accessible, interoperable (i.e. possible to share data between different platforms) and reproducible. A higher level of awareness about the existence of these data is also needed, particularly among stakeholders who could use them. Although some training courses are held in countries such as Portugal, there is scope for more of these to improve not only the capacity of volunteers to identify wattles correctly and how to submit records that are most useful (accurate locality, with multiple images that can be useful for determining habitat, density, adding records of biocontrol agent presence if applicable, etc.), but also to promote data utilization by stakeholders. Greater sharing of experiences and information from different species and territories (e.g. Australia, where wattles are not invasive; Kruger *et al*., 2022) will undoubtedly be useful to improve surveillance programmes.

2. Volunteer contributions to controlling invasive wattles benefit management strategies, but tangible initiatives seem to be currently confined to Portugal and South Africa. Given the need to use herbicides and mechanical equipment in some facets of wattle control, options for involving citizens are limited. However, time-consuming manual methods such as debarking, hand-pulling of seedlings and uprooting of saplings and younger plants are key contributions to overall management actions to deal with wattle invasions. Such activities need to be carefully coordinated with overall management actions. A key challenge in this regard is to retain the efforts of volunteers over time and especially at critical times to ensure effective project management (Ricciardi *et al*., 2017). It is important to keep volunteers motivated, for example by emphasizing the importance of long-term project goals such as habitat restoration and biodiversity rather than simply eliminating IAPs from the landscape (Pagès *et al*., 2017). Setting specific contests, e.g. competitions, may be useful in this regard. The long-lived seed banks of invasive wattles also pose an important challenge. A solution is to engage formally with area-focused interest groups (e.g. the many 'Friends of…' groups in South Africa, several ENGOs in Portugal) to commit to long-term management objectives, actions and monitoring. The need for a

multi-decade focus for managing wattle invasions at a site also calls for integration of volunteer efforts with other tenets of land stewardship.

3. The involvement of volunteers in wattle management can also raise awareness and have a multiplier effect, confirming that face-to-face and hand-on initiatives are frequently very efficient, as demonstrated by others (Schreck *et al.*, 2013; Verbrugge *et al.*, 2021). Involving citizens should always include careful and strategic planning and support (including financial), and preferably be embedded within broader regional or even national IAS management strategies (Dechoum *et al.*, 2019). Indeed, multilevel governance is essential, including local, regional, national and global initiatives and interactions between these different levels (Cardoso *et al.*, 2017).

4. A recent meta-analysis (Anđelković *et al.*, 2022) found that the main motivations of volunteers for participating in IAS citizen science and control initiatives reflect environmental concerns, social motivations and personal reasons; some motivations are unique to the IAS context, namely supporting IAS management, protecting native species and habitats, and livelihood/food/income protection or opportunities. These motivations are only supported if people are aware of IAS and understand their impacts. Our experience and the examples above show that raising public awareness of wattles is crucial if people are to understand their impacts and consequently be willing to contribute to their management. In this sense, increasing public awareness about wattles can promote people's participation in voluntary efforts to monitor and control them.

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