

# Global Actions for Managing Cactus Invasions

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**Abstract:** The family Cactaceae Juss. contains some of the most widespread and damaging invasive alien plant species in the world, with Australia (39 species), South Africa (35) and Spain (24) being the main hotspots of invasion. The Global Cactus Working Group (IOBC GCWG) was launched in 2015 to improve international collaboration and identify key actions that can be taken to limit the impacts caused by cactus invasions worldwide. Based on the results of an on-line survey, information collated from a review of the scientific and grey literature, expertise of the authors, and because invasiveness appears to vary predictably across the family, we (the IOBC GCWG): (1) recommend that invasive and potentially invasive cacti are regulated, and to assist with this propose five risk categories; (2) recommend that cactus invasions are treated physically or chemically before they become widespread; (3) advocate the use of biological control to manage widespread invasive species; and (4) encourage the development of public awareness and engagement initiatives to integrate all available knowledge and perspectives in the development and implementation of

management actions, and address conflicts of interest, especially with the agricultural and ornamental sectors. Implementing these recommendations will require global co-operation. The IOBC GCWG aims to assist with this process through the dissemination of information and experience.

**Keywords:** biological control; Cactaceae; early detection and eradication; impacts; prevention; public awareness; public engagement

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## 1. Introduction and Methods

Humans have been introducing species to areas outside their native ranges for centuries [1,2]. Although only a fraction of the introduced taxa become invasive, invasive species can cause significant negative environmental and socioeconomic impacts in invaded areas [3–8]. Management actions are therefore underway in many parts of the world [9] to achieve one or more of three main goals: prevention (to regulate potential invaders through national and/or international policies and control their introduction at ports of entry), eradication (to find and completely remove invasive species from a region), and impact reduction (to manage invasions to contain their spread and reduce their impacts).

The funding and capacity required to manage all invasive alien species usually exceeds available resources. A useful approach for prioritising the allocation of resources is to develop management actions for groups of species with similar management requirements rather than developing and implementing separate strategies for each species [10,11]. If invasive species have similar characteristics and impacts, share common stakeholders, invade similar environments and require similar management responses, grouping them for management purposes (termed “invasion syndromes” [12]) could simplify the decision-making process. Sharing lessons, approaches, and techniques can thereby reduce management costs. Collaboration between countries can also reduce costs, since lessons gained from the successes and failures of management in one country can guide managers in others [13,14].

Here we focus on the plant family Cactaceae Juss., commonly referred to as cacti, which has a number of widespread invasive alien species in different parts of the world [15]. We review and unify knowledge on the actions implemented worldwide to manage invasive alien cacti, thereby contributing towards the development of management strategies to mitigate the negative impacts of cactus invasions. The family Cactaceae contains 1919 succulent plant species native to the American continent [16], although the native range of *Rhipsalis baccifera* (Mill) Stearn is still unclear [17]. More than 200 cactus species have been introduced outside their native range for human consumption, animal fodder, and for medicinal and ornamental purposes [18]. While many species do not become problematic, 57 cactus species are currently listed as invasive around the world, with Australia (39 species), South Africa (35) and Spain (24) representing the hotspots of cacti invasion [15]. In the invaded areas, invasive cacti cause a range of negative impacts. For example, on biodiversity, national economies, and human health [19,20]. Moreover, with 97 naturalised species reported globally, Cactaceae rank among the top 30 families with the most naturalised aliens [2].

Cactus invasions were amongst the first plant invasions to be recognised and regulated. Cacti were the first plants targeted for classical biological control, with management efforts dating back to the 1800s [21]. Some of these early interventions were extremely successful, such as the biological control programmes against *Opuntia stricta* (Haw.) Haw. in Australia and South Africa [22,23]. Management of invasive cacti has continued, stimulating increasing efforts to improve collaboration. For example, in Australia in 2009, representatives from various government biosecurity agencies, the pest management community, the Rangelands Alliance, the scientific community, and the South Australian State *Opuntia* Taskforce formed the Australian Invasive Cacti Network (AICN; <http://www.aicn.org.au>). The main aims of the national network are to raise awareness of the impacts of invasive cacti in the country and to provide a forum for exchanging information on the taxonomy,

biology and management of invasive cacti. Nowadays, the AICN consists of more than 100 members from all mainland states of Australia. Similarly, in South Africa, a national working group (the South African Cactus Working Group; SACWG) was established in 2013 [24]. The SACWG consists of representatives from all relevant organisations in South Africa involved in research, policy, and management of cactus invasions. The main aims of the SACWG are to inform ongoing research and interventions and, similar to the AICN, to exchange ideas and current knowledge among experts on cactus invasions.

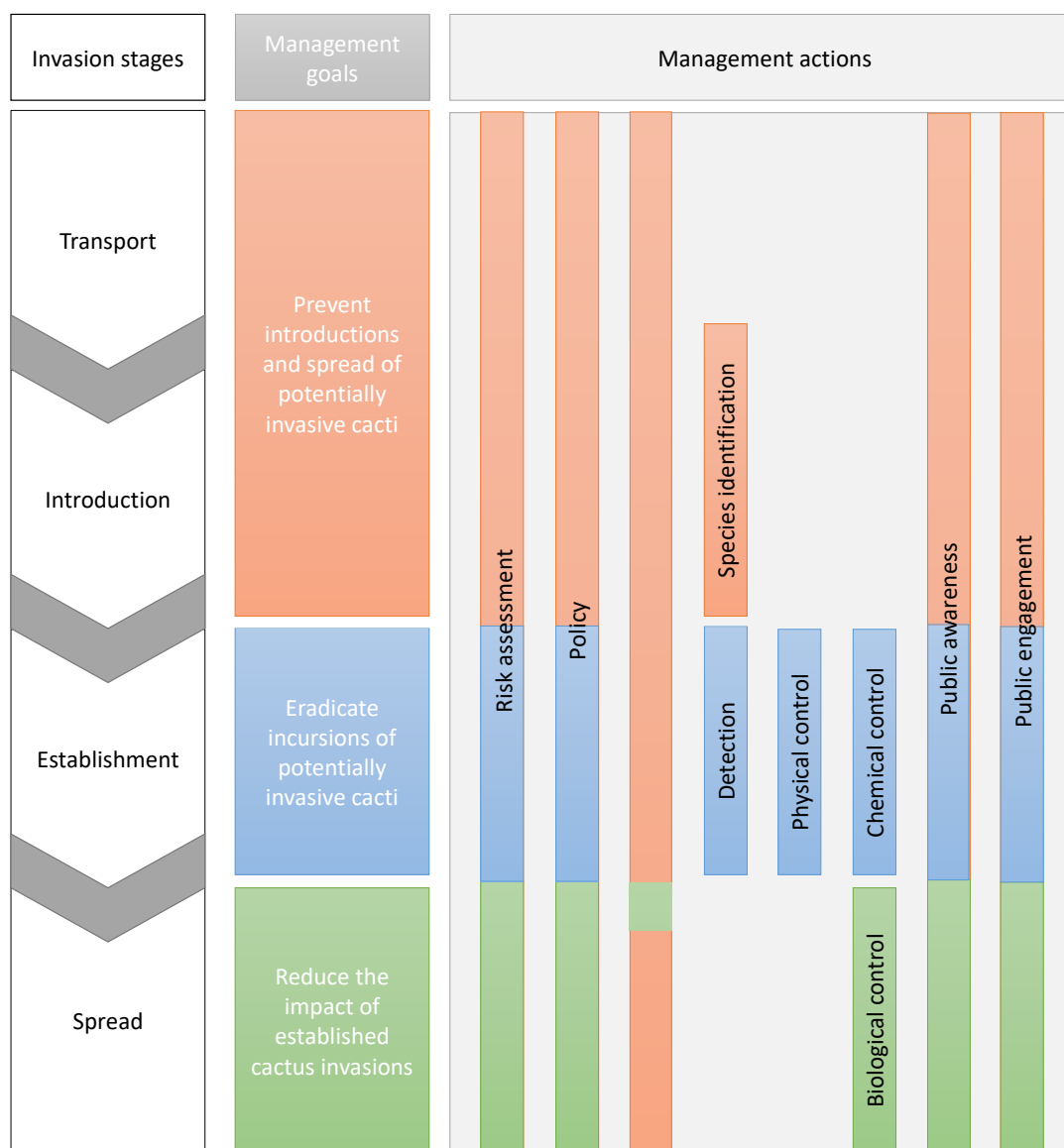
To build on these national initiatives, the International Organization of Biological Control (IOBC) launched the Global Cactus Working Group (IOBC GCWG) in 2015. The main aims of the IOBC GCWG are to share, design, discuss, and promote best management practices of cacti in their introduced ranges ([https://www.iobc-global.org/global\\_wg\\_cactus.html](https://www.iobc-global.org/global_wg_cactus.html)).

A symposium on the management of cactus invasions was held in 2015 in Waikoloa Village, Hawaii, as part of the 13th International Conference on Ecology and Management of Alien Plant Invasions (EMAPi [25,26]). As a result of discussions during this symposium, and aiming to collect available information on cactus management worldwide, members of the IOBC GCWG developed a web-based questionnaire in English, French, Italian, Portuguese, and Spanish, and distributed it to all parts of the world known to have invasive cacti (Supplementary Material). Additionally, information was collated from scientific and grey literature, online databases, and scientific reports. The collected information was then synthesised to identify a set of currently available actions to manage the invasions of alien cacti globally. We only considered invasive alien cacti here (i.e. cactus species expanding within their native ranges in the Americas are not discussed).

## 2. Results and Discussion

A total of 95 people from 13 countries / regions (Australia, Austria, France, Italy, Kenya, Lesser Antilles, Macedonia, Mexico, Pacific Islands, Portugal, South Africa, Spain and Tunisia) answered the questionnaire. However, we did not receive any responses from some countries with known cactus invasions, such as Namibia and China. Respondents included alien species managers (38.5%), invasion biologists (27.5%), property owners (8.8%), experts on biological control (7.7%), both professional (6.6%) and amateur (4.4%) horticulturalists, policy makers (4.3%) and food scientists (2.2%).

Using the information from the questionnaires and the additional sources, we identified 10 management actions, each of which can help achieve one or more of the three main goals of invasive species management (i.e., prevention, eradication, and impact reduction; Figure 1). These are discussed in turn in the sections that follow.



**Figure 1.** Overview of different actions through which goals of managing cactus invasions can be achieved. Invasion stages are based on the unified framework for biological invasions [27].

### 2.1. Risk Assessment

Risk assessments for alien species evaluate the likelihood and consequences of alien species becoming invasive. For cacti, most regions use risk assessment schemes targeting alien species in general. These general schemes were the only risk assessment methods reported by the respondents of the questionnaire. The most commonly reported scheme used was the Australian Weed Risk Assessment (A-WRA [28]), which was initially developed for Australia and New Zealand and is currently the most frequently used risk assessment scheme for alien plants [29]. The other main scheme used was the risk assessment protocol developed for central Europe by Weber and Gut [30], and tested in other European regions, such as Spain [31] and France [32].

These general risk assessment schemes assume that a similar set of factors determine the invasion success of all alien species. However, not all species share the same determinants of invasiveness [12]. This has stimulated research on correlates between invasiveness and introduction pathways, species, and habitat characteristics that can potentially predict invasions within particular groups of species, including cacti [15,18,20]. These studies revealed that cacti with detachable