Containment: the state of play

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Summary 'Containment' is a common strategic objective for invasive plants and the term is widely used in strategy documents. It is commonly prescribed as a 'fall-back' option when eradication is deemed not feasible but we challenge the implied assumption that containment is easier than eradication. The use of the term 'containment' is often not supported by a rigorous definition or it is assumed that an intuitive understanding is both universal and adequate. Containment is often advocated without a systematic analysis of the prospects of success. Some references in the management literature just propose containment as a broad objective; others provide some conceptual context. Some strategies incorporate the all-important spatial element but without reference to scale. The most advanced containment strategies are those built on a clear definition, covering the introduced range but making provision for delimitation and addressing individual infestations. A more rigorous approach to containment would encompass all infestations of a targeted species; tailor an approach to that species and the situations in which it is growing; define containment units that are centred on individual infestations or populations; and provide for the likelihood that those units will be breached by the plant's dispersal capacity.

Keywords Containment, objective, strategy.

INTRODUCTION

Weed management planners and strategists use various terms to describe aims and activities in the strategies they develop. The Australian weed management literature includes: 'prevention' (e.g. Barker 2004), 'eradication' (Groves and Panetta 2002), 'local eradication', 'extirpation', 'containment' (Panetta 2007, Grice 2009), 'active containment', 'partial containment', 'total containment' (Cacho 2004), 'asset protection', 'suppression', 'impact reduction' and 'control' (Grice *et al.* 2011). Often, terms are used without a definition, implying that an intuitive definition is adequate and generally applicable. In many cases, a subset of terms is presented, explicitly or by implication, as mutually exclusive options for strategic objectives with 'containment' featuring prominently. 'Containment' is widely advocated in both Australian strategy documents (e.g. Cherry *et al.* 2006) and the scientific literature (e.g. Panetta 2007). A clear definition is often lacking but the universal intention is to restrict where an invasive species grows so that it is deliberately prevented from occupying its potential distribution.

We briefly review use of the term 'containment' in Australia's weed management literature, and the ecological basis for achieving containment in practice. We propose an explicit definition of containment and put a case for more rigorously addressing it as a strategic option.

CONTAINMENT IN AUSTRALIAN WEED MANAGEMENT STRATEGIES

The strategy documents for Australia's Weeds of National Significance (WoNS) (Thorp and Lynch 2000) illustrate the use of the term 'containment' in Australian weed management literature. Of the 20 documents for the original WoNS, only two do not employ the term. We have grouped them into six categories according to their use of the term.

(1) No explicit reference to containment—*Tamarix aphylla* (L.) H.Karst. (Athel pine) (ARMCANZ 2000a) and *Salvinia molesta* D.S.Mitch. (salvinia) (ARMCANZ 2000b). The strategy for *S. molesta* incorporates an aim of minimising further spread.

(2) Refer to containment but provide no conceptual context or detail as to what might be involved—*Rubus fruticosus* L. (blackberry) (ARMCANZ 2000c), *Nassella neesiana* (Trin. & Rupr.) Barkworth (chilean needle grass) (ARMCANZ 2000d), *Hymenachne amplexicaulis* (Rudge) Nees (olive hymenachne) (ARMCANZ 2000e), *Mimosa pigra* L. (mimosa) (ARMCANZ 2000f), *Lantana camara* L. (lantana) (ARMCANZ 2000g), *Salix* L. spp. (willows) (ARMCANZ 2000h). The term is used in the aims, general objectives, vision statement or performance indicators but no further reference is made.

(3) General reference to containment as an objective with some conceptual context— *Prosopis* L. spp.

(mesquite) (ARMCANZ 2000i), *Ulex europaeus* L. (gorse) (ARMCANZ 2000j), *Alternanthera philoxeroides* Griseb. (alligator weed) (ARMCANZ 2000k). Containment is related to terms and concepts such as 'core' areas and 'non-core' areas (ARMCANZ 2000i), generally defined in terms of the feasibility of control options.

(4) Containment related to particular scales, sometimes multiple scales, but without specific locations—*Cabomba caroliniana* Gray (cabomba) (ARMCANZ 2000l), *Annona glabra* L. (pond apple) (ARMCANZ 2000m).

(5) Refer to containment and provide broadscale (regional and/or national) context—*Chrysanthemoides monilifera* (L.) Norlindh (bitou bush/boneseed) (ARMCANZ 2000n), *Cryptostegia grandiflora* R.Br. (rubber vine) (ARMCANZ 2000o), *Parthenium hysterophorus* L. (parthenium) (ARMCANZ 2000p), *Nassella trichotoma* (Nees) Hack. ex Arechav. (serrated tussock) (ARMCANZ 2000q), *Acacia nilotica* (L.) Delile (prickly acacia) (ARMCANZ 2000r), *Asparagus asparagoides* (L.) W.Wight (bridal creeper) (ARMCANZ 2000s).

(6) Refer to containment and provide fine-scale spatial context—*Parkinsonia aculeata* L. (parkinsonia) (ARMCANZ 2000s). Containment is related to individual infestations or zones.

This analysis indicates that containment is generally seen as a valid and worthwhile objective for important weeds in Australia. It is advocated even for species that are already widespread and abundant (e.g. *L. camara*, *C. monilifera*, *C. grandiflora*).

Though containment is widely advocated, strategy documents often lack a useful conceptual context. For example, the concept of 'core' and 'non-core' areas (ARMCANZ 2000i) could relate to areas of higher and lower abundance, respectively, or to areas that are peripheral versus central to the overall current distribution. The concepts may be useful if they can be related to dispersal processes but if they are defined only in terms of relative abundance they may relate more to habitat quality or invasion history. Increases in the area covered by an invasive species are obviously linked to dispersal capacity and mechanisms. Given that containment is about preventing increases in the area covered, it seems logical to relate containment efforts to the specific dispersal processes of a target species but often this is not done explicitly.

Strategy documents do not always thoroughly consider the scale at which containment is to be attempted. The strategies for *C. monilifera* and *C. grandiflora*, for instance, focus principally at a whole-of-range scale, a scale that is, perhaps, 2–3 orders of magnitude above that at which dispersal typically takes place. This is not to deny that a very small proportion of propagules could be dispersed very long distances. There is a need for the scale at which containment efforts are made to be reconciled with the scale at which dispersal processes occur. It also seems that many references to containment in strategy documents are not backed by sufficient analysis of whether containment is feasible or what it might look like in practice. Scale and dispersal capacity are again key considerations.

In summary, containment as a general objective is commonly proposed but there is a lack of detail connecting the objective to the biology of the invader and its environment. The lack of detail may be partially attributable to the broadly strategic nature of the documents that we reviewed. However, most strategies that identify containment as an objective give little guidance as to how it is to be achieved in practice. In line with this there are few, if any, well documented cases of containment.

A SYSTEMATIC APPROACH

Previously, Grice *et al.* (2010) proposed the concept of a containment unit, consisting of a zone occupied by the weed, a buffer zone into which propagules would be dispersed, and an unoccupied zone. Under such a model an effective containment program would be one that ensures that the target species does not reproduce in the buffer zone or disperse to the unoccupied zone. The outer limit of the buffer zone reflects the plant's maximum dispersal capacity. The concept assumes that there is an absolute limit to a plant's dispersal capacity that lies well within the area the containment program is designed to defend. However, dispersal kernels are probability functions, reflecting the fact that, statistically, there is no such absolute limit. This means that there will be a probability >0 that dispersal units will reach beyond any practical, pre-determined outer boundary of a 'buffer zone'.

To be effective, a containment program must incorporate all of the features of a sound eradication program. The containment unit(s) must be defined at a scale that reflects the plant's dispersal capacity. Moreover, all linked populations/infestations must be considered simultaneously. It is likely to be unproductive to attempt containment of one infestation but ignore others from which it is separated by suitable habitat. This is illustrated by the recently proposed strategy for *H. amplexicaulis* in Australia, involving geographical differentiation of management objectives. Extensive zones are assigned for containment but the containment units relate to all the individual infestations within those zones (Grice *et al.* 2011).

It is vital to prevent vegetative and sexual reproduction of any plants that occur outside the 'occupied zone'. The most effective and efficient way of doing this is likely to be to kill them. To kill or prevent reproduction of all plants in the buffer and 'unoccupied' zones requires that they be detected and treated. While it is conceivable that this could be achieved through biological control or other broadscale techniques that do not require specific detection of every individual, such techniques are unlikely to provide the necessary 100% effectiveness.

Eradication programs are often jeopardised by the fact that infestations are not reliably delimited because either the extent of the infestation(s) or the plant's dispersal capacity is underestimated. Expediency may also play a role. An eradication effort may cover the area that the budget allows rather than an area that the biology indicates would be more effective. These same factors operate for containment programs. While the cost of an eradication program is always a function of the total area occupied by the weed, the cost of a containment program will be a function of the area of the buffer zone. Where there are multiple containment units, cost will depend on the sum of the areas of their buffer zones. This assumes a 'minimalist' approach to containment in which all the effort is concentrated on the areas that receive or could receive propagules from the 'occupied' zone. It may also be effective and efficient to direct some effort at the occupied zone in order to reduce propagule pressure on the buffer zone (Lockwood *et al.* 2005). It is important to consider the optimal distribution of effort between 'occupied', 'buffer' and 'unoccupied' zones in a given circumstance.

CONCLUSIONS

In general, containment involves restricting a species to a part of its potential range. We propose a more explicit definition:

> ***Containment is deliberate action taken to prevent establishment and reproduction of a species beyond a predefined area.***

In practice, containment involves some combination of reducing (i) reproduction of the source population; (ii) dispersal from the source population; and (iii) establishment and reproduction away from the source population. Although dispersal is the critical ecological process, our definition focuses on establishment and reproduction because it is difficult to manage many dispersal processes and pathways.

We advocate that containment efforts should be built around units of containment that centre on individual infestations or populations, not simply at a whole-of-range scale. They should simultaneously cover all infestations or populations that are separated from one another by suitable habitat for the species. The buffer zones associated with each containment unit should be scaled to suit the species' dispersal capacity in the specific environment in which it is growing. The spatial distribution of effort must consider the fact that there is no absolute upper limit to the species' dispersal capacity. There will always be a probability >0 that some dispersal units will spread beyond whatever outer limit is established for the buffer zone. This presents a challenge for detection and requires a capacity to kill all individuals that arise from such events: failure to do so means that containment has failed (Grice *et al.* 2010). Some attention to the 'unoccupied zone' is required: education to increase the probability that incursions into this zone are detected and identified, reporting systems to facilitate a co-ordinated approach and rapid response capacity to maximise the chance of eliminating incursions (Panetta 2012).

If a containment unit is breached through plants establishing and reproducing outside the 'occupied zone' (Grice *et al.* 2010) the options are to kill all 'escapees' (in effect, an eradication exercise), redefine the containment unit or abandon containment as the objective.

Containment is not necessarily an easy fall-back when eradication is deemed not feasible. Delimitation, scale and spatial distribution of effort must be addressed, by definition, an effort over an indefinite period of time. There can be no end-point while containment is the objective.

It would be valuable to more systematically document containment efforts, including (i) the strategy and how and why it is modified over time; (ii) the nature of the containment units; (iii) how they are delimited and how different units relate to one another; (iv) actions taken to achieve containment and their timing; and (v) the consequences of those actions.

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