Opportunities for managing the dispersal of fleshy-fruited invasive plants

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Summary Birds are the primary dispersers of the seeds of many fleshy-fruited invasive plants, with these plants successfully co-opting indigenous dispersal mutualisms. Providing that the spread of invasive plants is, at least in part, dispersal limited, manipulating the dispersal mutualism provides opportunities to limit plant invasions and their impact. We discuss five broad management approaches to manipulate dispersal at the landscape scale. First, the portions of the invasive plant population contributing most to seed spread could be identified and then removed. Second, dispersal buffer zones around important habitats or invasive plant populations could be created. Third, seed dispersal could be directed to sites inhospitable to recruitment or to where it could be managed, such as by installing perch structures. Fourth, seed dispersal could be reduced or altered through changes in fruit quantity or quality, such as that induced by biological control agents, sub-lethal herbicide application or bird repellents. Fifth, the fruit traits of invasive plants could be used to select appropriate replacement native species, which could serve to either shift the seed dispersal mutualism to favour natives or provide alternative resources when invasive plants are removed, thus contributing to conserving existing frugivore populations. We examine each approach, and identify at what stages of invasion each may be appropriate, using case studies from eastern Australia.

Keywords Frugivore, fruit, landscape, management, mutualism, seed dispersal.

INTRODUCTION

Birds play a major role in the spread of many fleshy-fruited invasive plants (Richardson *et al.* 2000, Gosper *et al.* 2005). These invasive plants have co-opted indigenous seed dispersal mutualisms by providing a new food source to frugivorous birds, who then often distribute viable seeds away from the parent plant. This mutualism can affect the population dynamics of both plant and bird species (Buckley *et al.* in press).

Bird-dispersed invasive plants present some unique management challenges. Plant fruit traits affect food choices by birds, and seed dispersal success is affected by bird morphology and behaviour (Gosper *et al.* 2005, Buckley *et al.* in press). There are often many invasive and native fleshy-fruited plants and bird species interacting at individual locations. These interactions are complex and poorly understood which makes our ability to predict rates and new locations of weed spread exceedingly difficult. This knowledge is, however, of great importance to successful management.

The management of bird-dispersed invasive plants has rarely involved explicit manipulation of the seed dispersal mutualism. Yet manipulating seed dispersal may be particularly effective, as bird-dispersed invasive plants often have diffuse sources of invasion and political constraints in applying more traditional weed management (such as biological control agents or herbicides). Most bird-dispersed invasive plants were introduced as ornamentals, with several still promoted by the nursery industry (White *et al.* 2006), or are important horticultural plants. Consequently, source plants for invasion are often widely and patchily distributed through gardens, parks and agricultural areas. In some cases, conflicts over the removal of plants can arise over the perceived or actual importance of these plants to local fauna, particularly frugivorous birds (Gosper and Vivian-Smith 2006).

Recent reviews (With 2002, Gosper *et al.* 2005, Buckley *et al.* in press) on the contribution of frugivores to plant invasions have identified several opportunities for manipulating the seed dispersal mutualism that could be applied in conjunction with more traditional techniques. Each approach is based on the assumption that the spread of invasive plants is at least partly dispersal limited, and that management actions that alter either the quantity or quality of dispersal will reduce invasive spread. In this paper, we discuss advances in testing the utility of these approaches and identify at which stages of plant invasion they are most appropriately applied.

MANAGEMENT APPROACHES

Targeting stronger seed sources Many of the studies that have compared the rates that fruits are removed between different habitats, treatments and sites have found substantial differences (Sargent 1990, Gosper *et al.* 2006). This raises the question of whether locations of invasive plants with higher dispersal success can be

identified and prioritised for control. Currently, there is uncertainty over the general principles that guide management to effectively reduce the rates of weed spread, such as targeting satellite (Moody and Mack 1988) or core (Shea *et al.* 2002) infestations, despite growing evidence that conducting invasive plant control at some sites is more effective than at others.

Gosper *et al.* (2006) demonstrate a method for identifying invasive plant population components that contribute a greater quantity of dispersed seeds. In this case, fruit-removal rates of *Ochna serrulata* (Hochst.) Walp. were greater in bushland than suburban habitats, indicating that control efforts applied in bushland would contribute to a greater reduction in the quantity of *O. serrulata* seeds dispersed. Further work is needed to determine if there are generalisations that can be drawn over habitat types or landscape contexts that predictably have greater dispersal rates of bird-dispersed fruits. This approach to invasive plant control is most suited to established plant invasions, where clearer prioritisation of management is required (Table 1).

Dispersal barrier/buffer zones Buffer zones aim to establish an area surrounding an important habitat or existing invasive plant population across which recruitment of the invasive plant is restricted. In some cases, the barrier itself (natural or anthropogenic) may be sufficient to prevent plant spread, but in others, recruiting invasive plants need to be systematically removed. In the context of frugivore-dispersed weeds, the barrier would constitute a constraint on the pattern of movement of particular vertebrates (With 2002). As such, buffer zones for invasive plant management may conflict with some ecological restoration objectives (With 2002). For example, deliberately fragmenting the landscape to restrict frugivore movement may limit dispersal of native and invasive plant seeds.

The usefulness of buffer zones in slowing the rate of spread of insect pests has been demonstrated theoretically (Sharov and Liebhold 1998), and they have been applied in the planning and management of horticultural developments to reduce invasion risk (e.g. olive (*Olea europaea* L.) plantations, APCC 1999). Evaluation of the success of this for invasive plant control is required. *Post hoc* evaluation has indicated that barriers to bird movement across the landscape (Hutchinson and Vankat 1998) and weed control zones (Anderson *et al.* 2005) can reduce invasive plant spread and seed arrival respectively. Buffer zones are likely to be useful in containing invasive plant spread at all stages of the invasion process (Table 1).

Table 1. Potential management techniques to manipulate the seed dispersal mutualism of fleshy-fruited invasive plants and the stages of invasion at which they are most suitably applied.

Technique	Naturalisation	Early spread	Widespread	Culturally significant plants
Target stronger seed sources		Remove populations contributing most dispersed seed	Remove populations contributing most dispersed seed	
Dispersal barrier/ buffer zones	Limit dispersal into sites suitable for recruitment	Limit spread from initial populations	Limit spread into new regions or to significant sites	Limit dispersal into sites suitable for recruitment
Direct seed deposition	Detect new incursions	Limit spread from initial populations and track spread rates	Limit spread into new regions or to significant sites	
Reduce fruit quality/quantity:				
Biocontrol			Reduce quantity of seed dispersed	
Herbicide/pruning	Prevent fruit-set			Prevent fruit-set
Repellents	Reduce quantity of seed dispersed			Reduce quantity of seed dispersed
Alternative resources		Reduce quantity of seed dispersed	Reduce quantity of seed dispersed	

Directing seed deposition Deposition of seed is often concentrated beneath perches and other structures frequented by birds (Ferguson and Drake 1999). Invasive plant management may be improved if a greater proportion of these seeds could be directed to sites that are more easily managed or are inhospitable for recruitment. The use of perches to enhance or direct the deposition of vertebrate-dispersed seeds is well-established in ecological restoration (Handel 1997), providing a solid theoretical basis for the application of this method in invasive plant management.

Using perches around plantations to capture seeds has been suggested for management of commercial *O. europaea* in South Australia (APCC 1999), and for other bird-dispersed invasive plants (Gosper *et al.* 2005). While there is increasing evidence that bird behaviour is influenced by environmental structure and that many species do not disperse seeds randomly (Wenny and Levey 1998), experimental testing of the effect of different types and arrangements of perches on seed accumulation is needed. Directing seed deposition is likely to be effective in reducing early spread of invasive species beyond initial populations and preventing spread to new or significant sites (Table 1). Through using seed traps to sample seeds accumulating at perches or surveying plant recruitment, this technique could be used to detect newly naturalising species or track rates of plant spread.

Reducing fruit quantity or quality Techniques that reduce either the quantity or quality of fruit have the potential to affect seed dispersal (Gosper *et al.* 2005). Surprisingly, the role of fruit-infesting biocontrol agents in affecting bird fruit choice has received little attention, although the interaction of fruit-spoiling insects and frugivorous birds has been more widely studied in natural systems (García *et al.* 1999). In a recent study by Vivian-Smith *et al.* (2006), infestation of *Lantana camara* L. fruits with the larvae of the biological control agent *Ophiomyia lantanae* (Froggatt) reduced fruit removal rates. An important question arising from this study is to determine how an agent that affects fruit choices by birds affects seed dispersal, and ultimately, *L. camara* recruitment. Biocontrol agents have the potential to be effective in reducing the quantities of seed dispersed in widespread species that would be difficult to manage otherwise (Table 1).

There are other techniques that could be used to reduce fruit quantity or quality. Sub-lethal herbicide application and pruning have been used to limit seed-set (Scanlon and The Camphor Laurel Taskforce 2001). Chemical bird repellents have been tested for use in reducing bird consumption of fruit and seed crops (Avery *et al.* 2001) and predator baits (Day *et al.* 2003). These repellents may reduce weed fruit attractiveness to birds, but this should be tested. Repellents, pruning and sub-lethal herbicide techniques are probably most useful for reducing seed dispersal from small numbers of culturally-significant plants that can't be removed, rather than from extensive weed populations (Table 1).

Providing alternative resources Increasing the abundance of native, fleshy-fruited plants can potentially assist management in two ways. First, new food resources could offset losses from weed control efforts, helping to maintain native frugivore populations, which may make weed control more culturally and ecologically acceptable. Second, it could encourage frugivores to consume fruits of native plants rather than weeds, thus re-directing the seed-dispersal mutualism to favour native species (Gosper and Vivian-Smith 2006).

This approach has been suggested as a method to manage weeds (Gosper *et al.* 2005), although the outcomes have yet to be evaluated. Gosper and Vivian-Smith (2006) outline two complimentary approaches to plant selection: a scoring system to match native fruits with those of a target invasive species according to fruit traits important in bird food choice; and using native plant frugivores to identify plants with the most similar frugivore assemblage to the target weed species. Providing alternative resources is most applicable for manipulating the dispersal of established invasive plants (Table 1).

CONCLUSION

Each of these five approaches for manipulating the seed dispersal mutualism of fleshy-fruited weeds is likely to be useful in management, although not all strategies are suitable for all plant invasion stages. Furthermore, some may be applied in combination, such as perches to capture seeds on the edge of barrier zones, increasing effectiveness overall. These approaches would be most successful applied as part of an integrated management strategy. Significant advances in testing the utility of several of these approaches have recently been made, although further testing is needed on the generality of observed responses to determine if over-arching management guidelines can be established.

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