Scientific approaches to selecting weed replacement plants for use by frugivorous birds

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Summary  Invasive plants can be a source of conflict for conservation management. While the detrimental impacts of plant invasions on biodiversity and ecosystem function are well known, in some cases, invasive plants perform important roles in supporting fauna. For example, fleshy-fruited invasive plants can provide food that subsidises native frugivores. How can such conservation vs. invasive weed control conflicts be managed? We suggest that for frugivorous birds, one approach is to provide replacement native food sources. We use two methods to best match native and invasive plant species. First, the fruit characteristics of the native and invasive plant are matched using functionally important traits. We used a scoring model of fruit traits using all native fleshy-fruited plant species from a region relative to a target invasive species. Highly ranked species were found to be used by more of the target invasive species’ frugivores than a random selection. Using a second approach, a cluster analysis of frugivory records of all the native plant species was performed to identify those native plants with the most similar frugivore assemblages to the invasive species. The native plant species derived from both methods can then be used as part of a restoration strategy to provide replacement food resources, and favour future seed dispersal of native, rather than invasive species.

Keywords  Invasive plant, mutualism, seed dispersal, fruit functional traits, Lantana camara, restoration ecology.

INTRODUCTION  Invasive plants can be a source of conflict for conservation management (Buckley et al. in press). While the detrimental impacts of plant invasions on biodiversity and ecosystem function are well known (Vitousek et al. 1996), positive interactions with native species occur, or are at least perceived (Westman 1990, Buckley et al. in press). Some of the best researched examples of positive invasive plant contributions to conservation outcomes are the fruit sources they provide to frugivorous birds. In northern New South Wales, Australia, invasive camphor laurel (Cinnamomum camphora (L.) Nees) provides the principal food source for several rainforest pigeons for part of the year. Camphor laurel may have helped buffer these pigeon populations from the broad-scale destruction of their natural habitats (Date et al. 1996). Concerns over the importance of the resources provided by invasive plants for fauna can lead to public opposition to invasive plant management (Westman 1990).

One approach to managing such conflict from both a social and ecological perspective is the provision of alternative or replacement (if combined with invasive plant control) food for fauna (Williams and West 2000, Gosper et al. 2005, for another approach see Lawrie 2002). However, no clear, science-based methodology has been developed to guide appropriate species selection.

Invasive plant management and research has taken two broad approaches; either weed- or species-led (aimed at eradication or containment), or site-led (aimed at protecting or restoring key sites from multiple weeds) (Williams and West 2000). We advocate a third management approach, ‘process-led’, that identifies the key processes driving invasion and develops methodology to intervene or redirect them. Seed dispersal mutualisms of fleshy-fruited plants are one such process, as birds consume the fruits of many invasive plant species and effectively disperse their seeds (Gosper et al. 2005). The dispersal mutualism has, for example, been successfully manipulated in other systems to attract seeds to sites (Handel 1997). Providing replacement resources aims to redirect dispersal processes to maintain frugivore populations and favour native seed dispersal mutualisms.

We demonstrate two complimentary approaches to selecting replacement native plant species for frugivorous birds. First, we use a functional approach using plant and fruit traits to identify those native plants most similar to the target weed species, from the perspective of frugivores. Plant and fruit traits are well known to affect fruit choices by birds (Gosper et al. 2005, Buckley et al. in press). Second, we use the frugivore assemblages of native plant species to identify those most similar to the invasive plant species
under consideration. Each of these approaches results in a list of native plant species suitable for replacing the target invasive plant for use in a variety of ecological restoration settings.

We investigate these two approaches using lantana, the most significant invasive plant problem in south-eastern Queensland (Batianoff and Butler 2002), as a test species. Lantana fruits are consumed by many native bird species (Stansbury and Vivian-Smith 2003), and Low (1999) regards lantana as ‘a keystone species for many animals’.

**MATERIALS AND METHODS**

**Study region**  We conducted this study in south-eastern Queensland and north-eastern New South Wales. The climate is subtropical, and lowland rainforest and sclerophyll habitats in the region support at least 427 fleshy-fruited (including arillate seeds and elaiosomes attractive to frugivorous birds) native plant species (from Stanley and Ross 1983–9, Harden 1990–3).

**Plant trait model**  Fruit morphology and phenology of lantana were measured as per methods in Gosper et al. (2006). For native plant species, values for these traits were obtained from the literature (mainly Floyd (1989), Stanley and Ross (1983–9) and Harden (1990–3); other sources used are available from the authors).

Information on native plants severely limited the variety of traits that could be included in the following model. Native species were ranked by summing scores for three sets of traits that affect bird fruit choice (Gosper et al. 2005): phenology (measuring when fruits are available); morphology (measuring physical constraints on consumption), and conspicuousness and accessibility (measuring traits relevant to fruit location by birds) (maximum score = 24) (Table 1). Phenology affects fruit choice in terms of both the period of the year that fruits are available and fruiting season length. Morphology is important in terms of both fruit size and the number of hard bodies in the pulp. Conspicuousness and accessibility are important via fruit colour, fruit type and plant growth form. In all cases, higher scores were allocated to species with similar values to lantana for those traits (as shown in Table 1).

**Testing the model** We tested if the plant species that were most highly ranked in the model were used by more of the same frugivores that use lantana fruits than a random selection of fleshy-fruited plants. This outcome is expected if birds are responding to the fruit and plant traits as predicted and is a test of the ability of the model to select suitable replacement plants for frugivores. A database of records of frugivory of native birds was compiled, primarily from the Handbook of Australian, New Zealand and Antarctic Birds series (Volumes 1–6: Oxford University Press, Melbourne), with other sources used available from the authors.

We tested if plants with the top two (scores of 21 and 22) and three (20, 21 and 22) totals were used by more of the frugivores of lantana than a random selection of species using a R × C likelihood ratio test, with a Monte Carlo sample of 10,000 from the reference data set to obtain an unbiased estimate of the exact P-value. P-values of 0.05 were considered significant. This test was performed using StatXact-6 (CYTEL Software Corporation, Cambridge, Mass.).

**Frugivore assemblage** The frugivory database was used in cluster analysis (R version 2.1.1) to identify those native plant species with the most similar

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**Table 1.** Scoring system for ranking native plant species as suitable replacements for lantana for frugivores. Higher scores are allocated to plants with similar traits to lantana (shown in column 2).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Lantana</th>
<th>Score 4</th>
<th>Score 3</th>
<th>Score 2</th>
<th>Score 1</th>
<th>Score 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit phenology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- period and % overlap</td>
<td>Jan-May</td>
<td>100%</td>
<td>80%</td>
<td>40–60%</td>
<td>&lt;40%</td>
<td>0</td>
</tr>
<tr>
<td>- length (months)</td>
<td>5</td>
<td>&gt;5</td>
<td>4–5</td>
<td>2–3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fruit morphology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- size: length/diam. (mm)</td>
<td>4–7/4–7</td>
<td>4–7 and 4–7</td>
<td>4–7 or 4–7</td>
<td>&lt;20 and &lt;10</td>
<td>&gt;20 or 10–15</td>
<td>&gt;/&gt;15</td>
</tr>
<tr>
<td>- no. endocarp/seed</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3–5</td>
<td>&gt;5</td>
<td></td>
</tr>
<tr>
<td>Conspic./Accessibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- colour</td>
<td>Black</td>
<td>Black</td>
<td>Part black</td>
<td>Red, yellow or blue</td>
<td>White, green or brown</td>
<td></td>
</tr>
<tr>
<td>- fruit type</td>
<td>Drupe</td>
<td>Berry/drupe</td>
<td>Shrub and climber</td>
<td>Shrub and climber</td>
<td>Shrub or climber</td>
<td>capsule</td>
</tr>
<tr>
<td>- growth form</td>
<td>Shrub and climber</td>
<td>Shrub and climber</td>
<td>Shrub and climber</td>
<td>Shrub or climber</td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

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frugivore assemblage to lantana. A dissimilarity matrix from binary data was produced and agglomerative hierarchical clustering with the Euclidian dissimilarity measure used.

RESULTS

Plant trait model None of the native fleshy-fruited plant species scored the maximum possible in the plant trait model. Even on the basis of the limited variety of traits considered here, no native plant species had identical fruits to lantana. The most highly ranked species are shown in Table 2.

Native plants ranked highly by the model were used by more of the frugivores of lantana than randomly (top two scores Likelihood ratio test statistic = 9.84, df = 3, P = 0.026; top three scores Likelihood ratio test statistic = 9.23, df = 3, P = 0.031).

Frugivore assemblage Lantana has a frugivore assemblage of at least 23 native bird species in the study area. These frugivores also feed on the fruits of many native plant species, although no native species is known to be used by all the frugivores of lantana. The native species with the most similar frugivore assemblages to lantana are on the same branch of the dendrogram (Figure 1).

DISCUSSION

We have trialled two methods for selecting native plant species to replace the weed lantana, on the basis of providing continued suitable food for frugivorous birds. Both approaches have identified a suite of potential replacement species, although only one species, red ash (Alphitonia excelsa (Fenzl) Benth.), was ranked highly by both approaches.

Plant trait model The model successfully selected species used more by the frugivores of lantana than randomly, suggesting that this approach is worthy of further investigation. These investigations could include expanding the study to more biogeographic regions, invasive plant species, re-testing the model with different trait combinations and weightings, and field-testing the use of the replacement species by frugivores. Certainly the model could be improved if further information on important fruit traits, such as pulp nutrient content and inter-annual variability in fruit production (Gosper et al. 2005), becomes available for native plant species. The lack of such information has resulted in species that are obviously different to lantana in these traits being scored as suitable replacements, such as climbing panax (Cephalaria cephalobotrys (F.Muell.) Harms), which, unlike lantana, does not fruit reliably each year (Innis 1989).

Table 2. Native plant species with similar fruit characteristics to lantana.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulmaceae</td>
<td>Trema tomentosa</td>
</tr>
<tr>
<td>Araliaceae</td>
<td>Cephalaria cephalobotrys</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>Enchylaena tomentosa</td>
</tr>
<tr>
<td>Eparicadaceae</td>
<td>Trochocarpa laurina</td>
</tr>
<tr>
<td>Oleaceae</td>
<td>Jasminum dallachii</td>
</tr>
<tr>
<td>Oleaceae</td>
<td>Jasminum didymum</td>
</tr>
<tr>
<td>Ripogonaceae</td>
<td>Ripogonum discolor</td>
</tr>
<tr>
<td>Rhamnaceae</td>
<td>Alphitonia excelsa</td>
</tr>
<tr>
<td>Thymelaeaceae</td>
<td>Pimelea neo-anglica</td>
</tr>
</tbody>
</table>

Figure 1. Cluster analysis of plant species by frugivore assemblage. Only branches of the dendrogram close to lantana are shown.

Frugivore assemblage The native plant species clustered close to lantana not only share many of the same frugivores, but probably also have the common characteristics of a wide distribution and being abundant, which undoubtedly influences documented frugivore richness.

Comparing the two approaches The two approaches used here to identify suitable replacement plants have advantages and constraints in wider application. Furthermore, each may be more suited to particular circumstances, depending on the aims of
the weed management program, site constraints and the degree of knowledge of fruit traits and frugivore interactions.

The frugivore assemblage approach has the advantage of directly using knowledge of the foods of the target group in plant selection. However, it is constrained by the general lack of knowledge of frugivory and a large amount of bias in the amount of observation effort per plant species (due to distribution, abundance, observer interest etc.). Using fruit traits avoids this bias, but does have problems due to uncertainty in the fruit traits that are actually driving food choices in birds (Levey and Martinez del Rio 2001) and the lack of data on important fruit traits for native plant species.

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REFERENCES


