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Overcoming Restoration Barriers in a Degraded Coastal Environment

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Abstract
Restoration techniques that naturally accelerate regeneration by removing ecological barriers, such as limited seed dispersal, could reduce the need for expensive and labour-intensive methods. One potential method to overcome this barrier is the strategic placement of artificial perches in degraded areas. These perches encourage frugivorous birds to fly out from remnant areas to rest and defaecate seed in degraded areas, thereby increasing seed dispersal. This technique has been extensively tested in tropical systems but is yet to be explored in coastal systems. We aimed to determine the success of artificial perches in a degraded coastal environment by investigating: (1) their ability to attract fruit-consuming birds from nearby remnant vegetation; (2) their potential to increase seed rain in comparison to the open landscape, and (3) the seasons in which they are most effective. In this study, nine bird species that consume fruit as part of their diet visited the perches. The most frequent of these visitors were *Gymnorhina tibicen* (Australian magpie), *Acanthagenys rufogularis* (spiny-cheeked honeyeater), *Sturnus vulgaris* (common starling) and *Corvus coronoides* (Australian raven), which are all greater than 20 cm in size. Smaller fruit-consumers may be less inclined to rest in open areas and risk predation. Artificial perches effectively increased the seed rain of several native fleshy-fruited species in degraded paddocks and were most effective in summer–autumn, when the majority of native species were fruiting. The restoration ability of perches was reduced in some months owing to the abundant defaecation of invasive species. Potential modifications to the restoration technique may overcome this limitation.

Introduction
There is increasing interest in the restoration of abandoned lands for the recovery of biodiversity and ecosystem function (Bradshaw 2002). For restoration of vegetation communities to occur, critical ecosystem processes such as seed dispersal, seed germination and plant recruitment must be present. Without these processes restoration is limited. Common strategies for overcoming recruitment limitations include direct seeding and planting seedlings. These methods, however, can be expensive and labour-intensive, restricting the scale of restoration and associated outcomes. These limitations have led to the development of novel restoration techniques that are both cost-effective and more natural means of restoration. Artificial perching structures are one such technique that has been developed for this purpose. Perches work by encouraging frugivorous birds to rest while flying between areas of remnant vegetation, where they may defaecate the seeds of fruit they have consumed and ideally increase seed dispersal and plant recruitment (Robinson and Handel 1993).

Currently, restoration using perching structures has been thoroughly trialled in inland tropical and temperate systems (Holl 1998; McDonnell and Stiles 1983), but has not been tested in coastal systems. Coastal systems are ideal for the use of artificial perches as many of the plant species are fleshy-fruited and require seed dispersal by frugivorous animals, as opposed to dispersal via wind or water (Castley *et al.* 2001). We aimed to determine the success of artificial perches in a degraded coastal environment by investigating: (1) the ability of perches to attract fruit-consuming birds from nearby remnant vegetation; (2) their potential to increase seed rain in comparison to the open landscape, and (3) the seasons in which they are most effective.

Methods
Field research was conducted in paddocks of Cantara Homestead (36.3393°S, 139.7378°E), located approximately 800 m inland from the ocean on the Younghusband Peninsula, South Australia. Twelve perches were erected in cleared paddocks at Cantara at distances between 50 to 250 m from remnant vegetation. Perches consisted of a dead branch wired to a metal stake, resulting in a structure approximately 2.5 m in height. A 1 × 1-m square-shaped seed trap constructed from fibreglass mesh was placed beneath each perch to collect seed rain. Twenty-five seed traps of the same design were also established at sites without perches in both the paddocks, as well as in open areas in the surrounding dunes, to measure the rates of seed rain in open areas. Traps were collected at the same time each month from September 2015 to August 2016. Collected seeds were then counted and identified.

Bird observations were made from dawn to dusk (total 108 hours) in October to December in 2015. Four perches were observed simultaneously for 2-hour periods. Bird observations were also carried out during December and January of 2016 using remote cameras aimed at the perches and set to trigger with detected motion. The two methods each recorded bird species and abundance at perches, allowing datasets to be combined for analysis.

Results
From the two bird observational methods a total of 302 observations were recorded with 697 bird visits to perches (Table 1). A total of 17 bird species visited the perches, where common visitors tended to be insectivorous birds. Although the most frequently observed perch visitor, *Acanthagenys rufogularis* (spiny-cheeked honeyeater), was a frugivore. Eight other species that consume fruit as part of their diet visited the perches. Over 12 months, a total of 25,919 seeds (mean 2160 seeds/m^2) were dispersed to sites with perches. During the same period 138 seeds were dispersed to traps in open dune areas (mean 6 seeds/m^2) and 22 seeds to traps in open paddock areas (<1 seed/m^2). Sites with perches accumulated more seeds than those without perches (Analysis of Variance, Tukey's Honestly Significant Difference test, $P < 0.05$). The numbers of seed counts in traps at open sites in dunes was

also higher (but not significantly different; $P = 0.99$) than the numbers counted in traps placed in nearby open paddocks. Seasonal variation was observed in the abundance and species richness of seeds collected under artificial perches. The abundance of native seed dispersed to perches, as well as overall species richness, was greatest during summer and autumn (Fig. 1). Seeds of invasive plants, in particular *Lycium ferocissimum* (African Boxthorn), were abundant in traps under artificial perches in November–December and April–May (Fig. 1).

Table 1. Common perch visitors based on the number of observations and bird visitors determined by perch observations and remote camera photography.

Scientific Name	Diet	No. of obser-vations	No. of bird visits
Acanthagenys rufogularis	F, N, I	62	74
Anthus novaeseelandiae	I, G	41	46
Corvus coronoides	C, I, F	11	13
Cracticus tibicen	I, F	54	92
Hirundo neoxena	I	41	336
Falco berigora	C, I	11	11
Rhipidura leucophrys	I	29	30
Sturnus vulgaris+	I, G, F	11	47
Zosterops lateralis	F, N, I	9	11

Diet code: C = carnivore, F = frugivore; G = granivore; I = insectivore; N = nectarivore. Dietary preferences listed in order of presumed importance. + = invasive species.

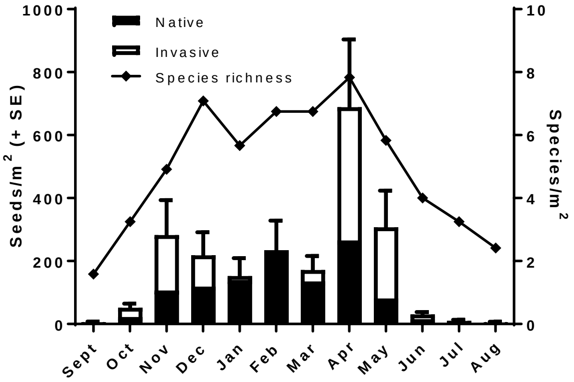

Fig. 1. Mean seed abundance and mean species richness of native and invasive species whose seeds were dispersed to artificial perches during the 12-month study.

Discussion

Fruit-consuming bird species that commonly visited the perches tended to be omnivores, which consume smaller proportions of fruit compared to frugivores. These bird species often frequent open areas and are all medium to large in size. Holl (1998) and Ferreira and Melo (2016) also found omnivorous birds to be common perch visitors in tropical systems. Smaller fruit-consumers such as *Zosterops lateralis* (silvereye), the most abundant bird during the fruiting season, may be less inclined to rest on simple-structured perches in open areas where predation risk is elevated. Perch of greater structural complexity that provide protection may be required to attract these species.

The provision of perches was successful at increasing the quantity of seed dispersal, and this is consistent with studies conducted in both tropical and temperate systems (Holl 1998; McDonnell and Stiles 1983). A substantial amount of seed was dispersed to perches; however, not all of this seed was suitable for restoration. A large proportion of the seed was from the invasive species, *L. ferocissimum*, which is able to fruit and germinate seed at any time of the year. Therefore removal of the perches at certain times of the year may not necessarily be a solution in reducing its dispersal. Rather, control of this species may be required particularly close to perches to minimise its dispersal and to improve the effectiveness of perches as a restoration technique.

Although artificial perches successfully attracted fruit-consuming birds and increased the dispersal of native seed to open areas, this does not necessarily mean that the perches were successful as a restoration technique. Rather success should be measured by the extent to which the dispersed native species seed germinates and establishes new recruits. Numerous factors including herbivory, seed predation and weed competition can prevent germination and seedling establishment. A recent study by Elgar *et* al. (2014) found enhanced recruitment under artificial perches when weed competition was suppressed by the use of herbicides. In future restoration, the use of supplementary techniques in association with artificial perches may be necessary to increase plant recruitment.

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