The influence of dwarf cherry (*Exocarpos strictus*) on the health of river red gum (*Eucalyptus camaldulensis*)

Steve J. Sinclair[1,2]

[1]Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, 123 Brown Street, Heidelberg, Victoria 3084, Australia
[2]Email: Steve.sinclair@dse.vic.gov.au

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Summary

Recent studies suggest that river red gum health is declining across much of the Murray floodplain. Some anecdotal reports assert that localised but severe declines in river red gum health are related to the increased abundance of the hemi-parasitic shrub dwarf cherry. To investigate this, river red gum health was measured by canopy cover in 548 trees on the Murray floodplain downstream from Swan Hill, in areas with varying amounts of dwarf cherry. Trees were slightly but significantly less healthy where dwarf cherry was present. However, river red gums in poor health were widespread in the study area, suggesting that decline is largely due to broad-scale ecological changes. Dwarf cherry appears, at most, to play a secondary role in localised river red gum decline.

Keywords: parasitic plants; forest health; haustoria; flooding; drought; ecological disturbance; Santalaceae; *Exocarpos strictus*; *Eucalyptus camaldulensis*

Introduction

River red gums (*Eucalyptus camaldulensis* Denh. Myrtaceae; hereafter 'red gums') are conspicuous in riverine environments throughout much of Australia. In some inland areas, such as the lower Murray region, much of the water required by red gums is not derived from local rainfall, but comes from ground-water, flood-water or river water (Young 2001; Chisholm *et al*. 2003). Agricultural activities have altered flooding regimes across the Murray Basin (Mitchell 1839; Dexter *et al*. 1986; Bren *et al*. 1987; Bren 1988; Walker and Thoms 1993), and massive changes in vegetation have taken place (Chesterfield 1986; Bren 1992). Declining red gum health has been reported for decades across much of the Murray-Darling Basin and is apparently worsening (Brett Lane and Associates 2005). Observations suggest that drought and alterations in flood regime are ultimately responsible for some decline in red gum health, although no studies have addressed this exhaustively and relatively few have demonstrated a spatial relationship between flood history and red gum health (Bren and Acenolaza 2000; Chisholm *et al*. 2003).

In some areas, anecdotal reports have suggested that red gum decline is often accompanied by the rapid spread of the hemi-parasitic shrub dwarf cherry (also commonly known as pale-fruit ballart, *Exocarpos strictus* R.Br., Santalaceae, hereafter 'cherry'). Cherry naturally occurs across much of south-eastern Australia, often on the banks of inland rivers (Cunningham *et al*. 1992). Its identity as a hemi-parasite has been inferred from the other members of its genus, which have long been known to appropriate xylem fluid from their hosts by means of haustorial connections (Rao 1942; Fineran 1963a,b). Little is known of the ability of *Exocarpos* species to cause harm to their hosts. Many basic theoretical predictions of host–parasite interactions (e.g. summarised in Whittaker 1975 and Begon *et al.* 1996) are of limited value in the case of cherry, due to the partial nature of the parasitism and the shrub's ability to parasitise multiple host individuals simultaneously. Apparently only one previous study has shown a spatial relationship between the abundance of an *Exocarpos* species and tree decline (Jehne 1972). In a recent review of eucalypt decline, Jurskis (2005) concluded that parasites including *Exocarpos* species contribute to eucalypt decline, but are generally symptomatic of broader ecological changes.

In north-western Victoria, local landholders and other concerned community members have been seeking support from local land and water management agencies to address the spread of dwarf cherry, on the assumption that it is causing tree decline. This study was initiated in order to investigate whether cherry parasitises red gum, and whether it contributes to tree decline.

Materials and methods

Study area

The study area encompassed the floodplain, on the Victorian side of the Murray, between Nyah and Tooleybuc. The soil is generally cracking grey clay, occasionally topped by aeolian sand (Woorinen formation) (Land Conservation Council 1974; White *et al*. 2003). The climate is semi-arid (350–450 mm rainfall y^{-1}, Chesterfield 1986; Parsons *et al*. 1991).

Investigating cherry parasitism

Shallow excavations (~50 cm) were carried out where cherry and red gum occurred in close proximity. Searches were made for cherry haustoria that were physically attached to red gum roots. Excavations were carried out in heavy clay on the river bank at the 'Piangil pump' and just upstream of the Tooleybuc bridge. A third excavation was carried out where the two species occurred in an area topped by Woorinen sand on the Murray Valley Highway roadside, between Piangil and Wood Wood. Root sections were stored in plastic bags in moistened paper towel, and small haustoria were stored in 70% ethanol at ambient temperature. Samples were photographed using a dissecting microscope at Monash University several days later.

Investigating the association between cherry and red gum health

Eighty-three plots, 10 m × 10 m, were visited in March and April 2004. Sixty plots were selected by generating random co-ordinates and eliminating those which fell in un-forested areas or on farms to which no access had been arranged. Another 13 were generated by travelling random distances along the river bank track, in order to ensure that certain known large riverbank cherry stands were adequately sampled, to make a total of 73 'random' plots. A further 10 plots were situated in areas 'of concern' to landholders who perceived cherry as a threat to red gum health, and which tended to include defoliated red gums and thick patches of cherry. These were used in only some analyses. The plots fell in several land tenures including state forest, private land and roadsides.

'Red gum health' and the abundance of cherry were measured. The assessment of red gum health was based on canopy cover and the current 'foliage health' only, not the probability of a tree's survival in the long term, since red gums may recover from severe defoliation (Young 2001). Health was scored on a 0–10 scale, modified from the Forest Health Surveillance technique employed by the Forest Science Centre (DSE), and closely resembling the scoring system used in other studies (e.g. Reid *et al*. 1994). A score of 0 was assigned to 'dead' trees without leaves, a score of 1 to trees with 0–10% canopy cover (in practice often an apparently-dead tree which retains small twigs and some discoloured foliage), and a score of 10 to trees with 90–100% healthy canopy cover. 'Healthy canopy cover' is defined as the foliage cover that would be present on a densely foliated tree of a given stature. Thus, any red gum stand would inevitably contain many trees with scores < 10 as a result of normal tree decline. All trees within a plot (or dissected by the plot boundary) were assessed as long as they attained a diameter at breast height (dbh, at 1.4 m) of 1 cm. All observations were made by the author.

I took 64 photographs of different red gums in or near the study area, in various stages of health, before the study began. Before field work commenced, I scored these photographs according to the red gum health scale. After all field work was completed several months later, I shuffled and re-scored these photographs. After rescoring, 47% were scored the same, 41% scored one point higher or lower, and 12% scored two points higher or lower. Thus the technique was shown to be repeatable to an acceptable level.

Red gum health in plots with and without cherry was compared using basic statistics (95% confidence intervals on the differences in the means of these two groups, and one-way *t*-tests; Genstat 6th edn, VSN, UK).

Results

Cherry parasitises red gum

Excavations revealed that cherry was parasitising red gum, as haustoria were found connected to red gum roots (Fig. 1). Cherry

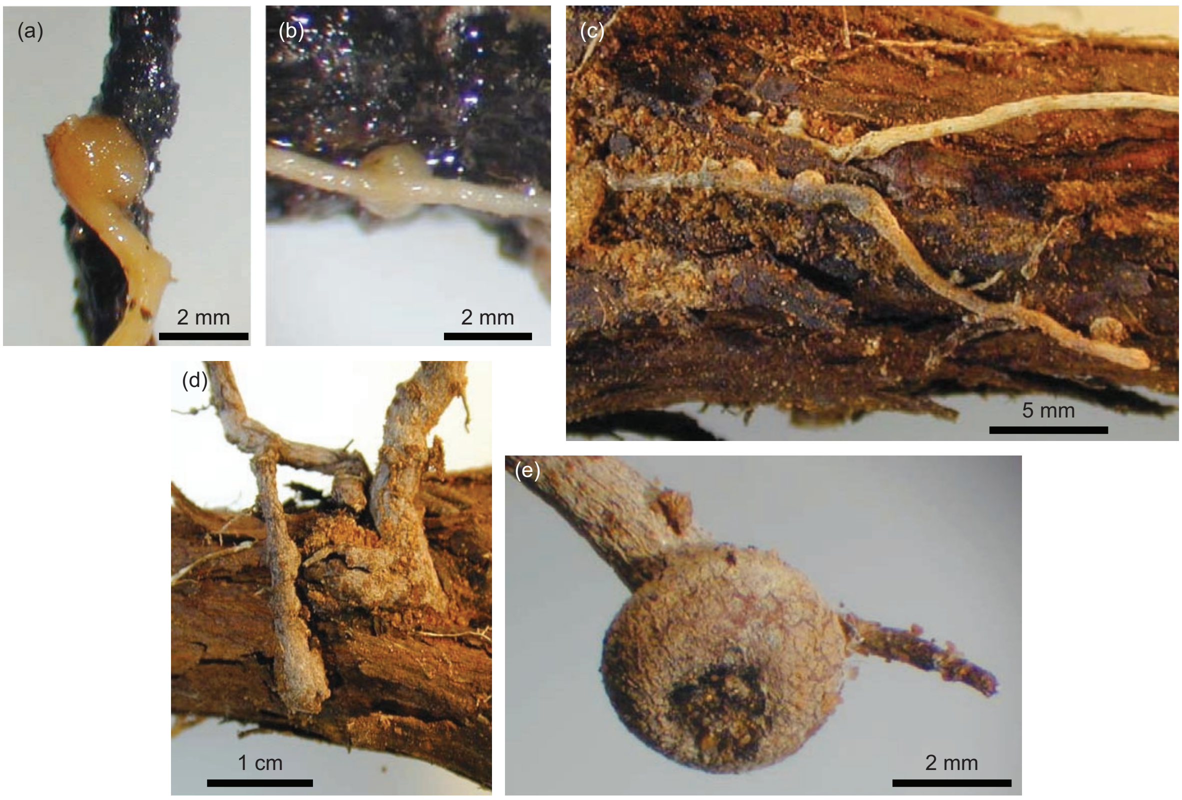

Figure 1. Haustorial connections between cherry and its hosts. Panels (a) and (b) show young cherry roots (self attack), with new haustoria forming. Panel (c) shows young cherry roots travelling across the surface of a red gum root, forming numerous haustoria between the fissures in the 'bark'. Panel (d) shows established haustoria on a red gum root. The haustorium in panel (e) has been removed from its host. The withered cherry root tip is visible to the right, along with the (broken) central peg of penetrative tissue that was inside the host root.

conformed to the general pattern reported from other Santalaceous hemi-parasites, featuring many small flattened haustoria, each with a central 'peg' of penetrative tissue entering the host root (Benson 1910; Coleman 1934; Fineran 1962, 1963a,b,c,d, 1965a). The haustoria were numerous, developing laterally from the small roots to form many connections with the root systems of host plants. Thus the connections were peripheral, with cherry possessing its own branching root system, rather than being connected firmly by the stem to a host (cf. mistletoe). Haustoria were observed on red gum and cooba (*Acacia salicina* Lindl. in T.Minch., Mimosaceae). 'Self attack' between nearby cherry roots was also very common, as noted in other *Exocarpos* species (Fineran 1965b).

Red gum health and cherry

Across the 83 plots, 538 red gums were recorded, at an average density of 6.5 red gum stems per plot (650 ha^{-1}), with many small trees, and progressively fewer large trees (for analysis, split into size classes; saplings (1–5 cm dbh, n = 144), small trees (6–20 cm dbh, n = 153), established trees (21–50 cm dbh, n = 133) and large trees (>50 cm dbh, n = 108)) (Fig. 2). The largest tree encountered had a diameter of 240 cm.

Red gum health was highly variable. The mean health score across all trees was only 2.8 (SD = 1.81). The highest score given was 8, in only 5 trees of a total sample of 538. Cherry was present in 34 of the 83 plots (these 34 plots contained 212 trees).

Red gums were less healthy where cherry was present (mean = 2.3, SD = 1.6) than where it was absent (mean = 3.0, SD = 1.9) (one way t-test, $P < 0.001$; 95% confidence interval (CI) on difference of means 0.45 to 1.06). This situation remained when the 10 'subjectively chosen' plots were removed (one-way t-test, $P = 0.001$; 95% CI 0.18 to 0.90), and was true for all size classes when these were analysed in isolation separately. The same trend was apparent in respect to the 'sickest' and 'healthiest' trees in each plot. These data are summarised graphically in Figure 3.

There were proportionally fewer saplings in plots with cherry (mean = 0.11, SD = 0.19, n = 34) than in plots lacking cherry (mean = 0.23, SD = 0.28, n = 49) (95% CI for differences in means 0.013 to 0.217). Similarly, absolute numbers of saplings were less in plots with cherry than plots without cherry, but this difference was not significant.

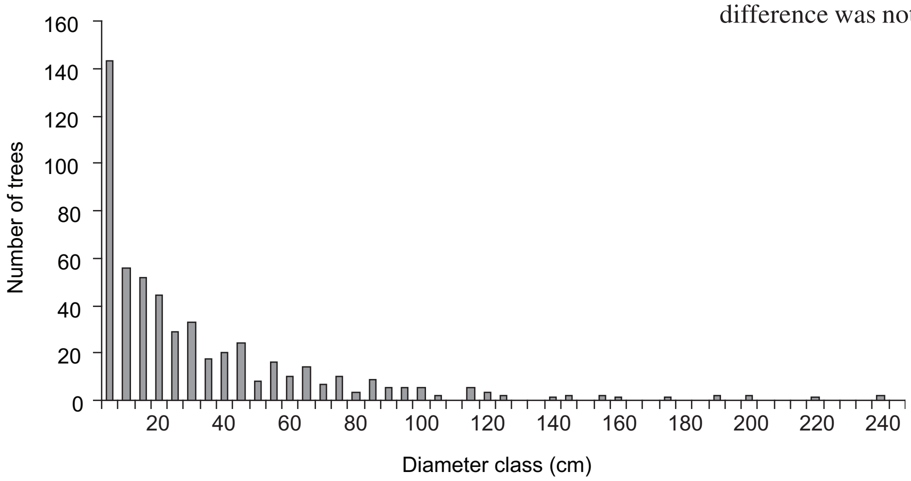

Figure 2. Red gum size distribution. Each bar represents the number of stems in each diameter class (0–5 cm, 6–10 cm, etc).

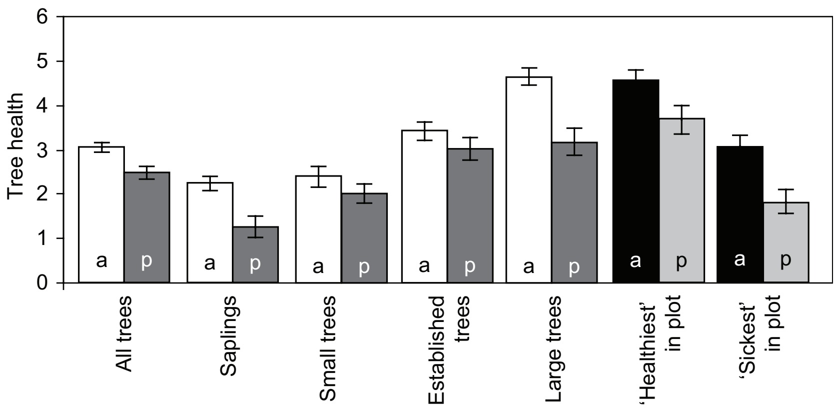

Figure 3. Red gum health in plots with and without cherry. The two columns on the left labelled 'all trees' show the mean health (±SE) in plots where cherry was present (p) and absent (a). The pairs of columns labelled 'saplings', 'small trees', 'established trees' and 'large trees' show the same data, separated according to tree diameter. The two pairs of columns on the right show plot-wide tree health in plots where cherry was present (p) and absent (a), using two different plot-wide health measures ('healthiest tree in plot' and 'sickest tree in plot').

Discussion

Red gum health was lower in plots where cherry was present. Given that cherry was shown to be parasitising red gum, it is likely to have been the cause of some stress. The haustoria of dwarf cherry are essentially the same as those of other Santalaceous species, involving only the xylem in the host-parasite connection (Rao 1942; Fineran and Bulluck 1979) and it is reasonable to assume that the major effect of cherry on its host is the appropriation of water. The length and severity of water deficit is believed to influence the long-term health of red gums (Chisholm *et al.* 2003), and it is reasonable to conclude that cherry is contributing to red gum decline by exacerbating water stress. The data also show that there were proportionally fewer red gum saplings in plots where cherry was present, suggesting that the cherry may also be associated with reduced establishment of red gums.

It remains unclear how much of the observed association between cherry and red gum decline is explained by cherry proliferation directly adversely affecting red gums. Other studies suggest that eucalypt parasites such as mistletoes increase in response to eucalypt stress, possibly due to water potentials and nutrient levels in declining trees favouring parasites (Jurskis 2005; Jurskis *et al.* 2005). Similarly, part of the association may result from red gum and cherry each independently responding to external factors. For example, red gum regeneration and cherry proliferation may tend to occur in different ecological niches, contributing to the measured association between cherry and reduced red gum establishment. Red gum regeneration is known to occur after flooding (Parsons *et al*. 1991; Ashton 2000), while cherry thickets may be disadvantaged in areas recently inundated.

Importantly, unhealthy red gums were widespread in the study area in areas with and without cherry. This strongly suggests that the important causes of red gum decline are widespread. During field assessments, other data measuring soil type, elevation, disturbance and distance from water features were collected. Multiple linear regression modelling was used in an attempt to explore patterns in red gum health (response variable) with these other variables, but the dataset was not sufficient to investigate these landscape-scale factors with adequate statistical rigour (data not shown). Further studies are required to properly identify the major ecological factors causing red gum decline, but some ecological changes that are candidates are obvious.

The most obvious change experienced by the lower Murray region over the last few decades has been an alteration of flood regime. The frequency, extent and duration of winter floods have been reduced substantially, while minor summer floods are more frequent (Dexter *et al*. 1986; Bren *et al*. 1987; Bren 1988; Walker and Thoms 1993). Flooding plays a major role in determining local vegetation patterns (Bren and Gibbs 1986; Bren 1992; White *et al*. 2003), and this alteration in flood regime has caused major vegetation changes (Mitchell 1839; Bren 1992). A lack of flooding, particularly during drought, may lead directly to red gum decline due to water stress (Chisholm *et al*. 2003) or changed saline ground-water conditions. Altered flood regimes are considered the prime cause of red gum decline in several areas (Bren and Acenolaza 2000; Chisholm *et al*. 2003). Flooding may also have a direct role in controlling the abundance of cherry.

Other ecological changes may also be relevant, including alterations in fire regime. Other studies have drawn together evidence that in some cases altered fire regimes have led to changes in soil nutrient conditions, which have in turn contributed to tree decline (Jurskis 2005; Jurskis *et al*. 2005). The study area has not experienced an extensive fire in living memory, and historical fire regimes are difficult to infer. The study area once held a far higher fuel load than at present (Mitchell (1839) describes extensive reed and grass beds), but it is unlikely that the area regularly experienced massive fires since red gums are relatively fire-sensitive (Chesterfield 1986; Askey-Doran 2002; Lunt 1995). Chesterfield (1986) speculates that regular, low-intensity fires would once have occurred, encouraging the formation of open woodlands rather than forests. Unfortunately, data are not available to assess the combined effects of altered fire and flood regimes on soil conditions relevant to tree decline. It is likely, however, that an increased density of young stems has resulted from a lack of fire (Jacobs 1955; Chesterfield 1986). The consequent increased competition among young trees, in combination with reduced access to water, may be causing the decline observed in many trees. Fire presumably also has direct effects on cherry, as it does on *Exocarpos cupressiformis* which suckers readily after the main stem has been burnt (Coleman 1934; Jehne 1972). Infrequent fire may allow *E. strictus* to form large thickets, while once-regular fires may have limited its growth.

Another obvious ecological change in the area is the alteration in grazing regime, which is known to have had major impacts in riparian areas in inland Australia (Robertson and Rowling 2000). Stock have been removed from many riverfront areas over the last decade. Cherry is very palatable to domestic stock, as seen along certain fencelines, although its palatability to native herbivores is unknown. It is quite clear that the recent removal of stock has contributed markedly to a spectacular increase in abundance of cherry over recent years in certain areas; it is far less clear whether grazing has had any effect on the health of red gum.

Results of this study suggest that controlling cherry proliferation will have, at best, a minimal effect on red gum health, which is largely influenced by factors operating at a broader scale.

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