Overview of non-vascular plants, lichens, fungi and algae in the Goulburn Broken Catchment: their status, threats and management.

A background paper for the Goulburn Broken Catchment Management Authority Regional Catchment Strategy review process.

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May 2002

Disclaimer

This report was prepared for the general purpose of assisting with the Goulburn Broken Regional Catchment Strategy review and update. An exhaustive investigation was not appropriate for this purpose. The report is based on the best readily available information. The views expressed in the report are those of the author and do not necessarily represent the views of the GBCMA.

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Table of Contents

Summary of recommendations

Recommendation 1. The GBCMA should take an active role in raising public awareness about cryptogam conservation issues in the catchment.

Recommendation 2. The GBCMA should ensure that cryptogams are ‘covered’ in strategic and policy documents.

Recommendation 3. The GBCMA should encourage and facilitate research into cryptogam status, distribution and ecology in the catchment.

Recommendation 4. The GBCMA should also encourage research into disturbance regimes and management prescriptions of native vegetation communities and revegetated habitats in the catchment and their potential impacts on cryptogam communities.

Recommendation 5. The GBCMA should work closely with its partner agencies and other land management agencies in the catchment to raise awareness about cryptogams (and other lesser-known elements of biodiversity).

Recommendation 6. The GBCMA should continue to support land use planning processes such as the Environment Conservation Councils Box Ironbark Investigation as a means of improving the reservation and protection status of biodiversity in the catchment.

Recommendation 7. The GBCMA remnant protection programs should continue and where ever possible, expanded to include areas of likely high cryptogam diversity.

Recommendation 8. The use of indigenous planting should continue to be encouraged.

Recommendation 9. **The GBCMA should continue to encourage biodiversity friendly and sustainable farming practices.**

Recommendation 10. **The GBCMA should discourage harvesting of firewood from native vegetation on private and public land and encourage the establishment of firewood plantations.**

1 Introduction

This report is a background paper for the Goulburn Broken Catchment Management Authority (GBCMA) Regional Catchment Strategy review process. As part of this review process, a number of emerging biodiversity issues have been identified, including the conservation and management of invertebrates, non-threatened flora and fauna, aquatic ecosystems and non-vascular plants (cryptogams). This report focuses on the issue of non-vascular plant conservation in the catchment and specifically on a key group within this broad classification, the cryptogams. The aim of this background paper is to provide a general overview of cryptogams in the Goulburn Broken Catchment, give some indication of their distribution, diversity and abundance in the catchment and to highlight their importance in ecosystem functioning and the provision of ecosystem services. Finally, potential threats to the cryptogam flora are identified and actions to reduce these threats are outlined.

2 Cryptogams: what are they?

Non-vascular plants lack the specialized fluid conducting tissues typical of higher or vascular plants (Scott *et al.* 1987). They are a specialized and diverse group that includes organisms as varied as single celled algae through to very large and complex colonies of lichens and fungi that may stretch over metres or even hectares. For the purposes of this report, the group of non-vascular plants of most interest are the *cryptogams*; the non-vascular plants that reproduce through the production of spores rather than seeds (Scott *et al.* 1987). Cryptogams make up the vast majority of non-vascular plants. Cryptograms include algae, lichens, bryophytes and fungi (Scott *et al.* 1987). In the strictest sense fungi, some algae and lichens are neither plants nor animals but rather are classified into several separate kingdoms. For simplicity they are all treated as ‘plants’ in this report and the diversity of cryptogams (i.e. lichens, mosses, liverworts, fungi and algae) are referred to as cryptogam(mic) flora. The cryptogram group excludes the pteridophtyes (the ‘ferns’ and their allies) as although they are spore producing, they contain vascular tissue and as such are grouped with the higher vascular plants. A brief description of each group in the cryptogram assemblage is provided below (Scott *et al.* 1987).

Algae: is a collective term for all photosynthetic organisms that do not have embryos. Although typically thought of as aquatic organisms, the also colonize terrestrial habitats including soil, bark, leaves, rocks and even animals.

Lichens: lichens are a plant-like structured compound organism composed of two symbiotic organisms; a fungi and photosynthetic algal cells - usually blue-green or green algae. The exact nature of the relationship between the two symbiotic organisms is unclear. The fungi in the lichen obtains photosynthetic compounds from the algae, while the algae may receive water and minerals via the fungi. The symbiotic relationship allows lichens to survive and grow where the individuals would be unlikely to survive on their own. They colonize rocks, soils, dead timbers and other structures such as buildings.

Bryophytes: bryophyte is a collective term for the mosses, liverworts and hornworts. Bryophytes develop from embryos enclosed by maternal tissue but lacking lignin. Bryophytes are typically associated with more moist habitats where they grow on soil, tree trunks and branches, fallen timber, debris and rocks. Some bryophytes, particularly mosses, are capable of withstanding desiccation and consequently are able to survive in very arid environments, taking advantage of infrequent rainfall events to resurrect and reproduce.

Fungi: a diverse group of organisms that cannot manufacture their own food though photosynthesis and must absorb nutrients from the surrounding environment. Many fungi are saprotrophic meaning they feed on dead plant material and play an important role in nutrient recycling. Other fungi form symbiotic or parasitic relationships with other plants and animals. Fungi range in size from microscopic moulds, mildew and rusts to macroscopic, with large fruiting bodies visible as mushrooms, toadstools and puffballs.

3 General overview of cryptogams and their ecological significance

Cryptogams are one of the most poorly known and studied groups of all organisms (Scott *et al.* 1987, State of the Environment Advisory Council 1996). This lack of knowledge is not surprising given that many cryptograms are microscopic, have cryptic life cycles and that specialist skills are required to identify and study individual species (Scott *et al.* 1987). They are also extremely diverse, with estimates putting the number of fungi species alone at 1.5 million worldwide (Dalphe 1997). The distribution, abundance and ecology of all but the most common species in Australia are largely unknown (Scott *et al.* 1987, May 2001).

Knowledge and understanding of the significance of cryptogams to the functioning of terrestrial ecosystems, including agricultural systems, is increasing (St. John 1992). Cryptogams, along with other microbial organisms, form the underlying ecological 'fabric' on which the patterns of more visible components of ecosystems are arranged. The role of cryptogams in the healthy functioning of ecosystems is fundamental to the supply of ecosystem services on which all of society depends (Scott *et al*. 1987). The economic value of cryptogams to the catchment community, given their role in soil formation and stability, nutrient cycling and increased plant production, is probably in the range of hundred of millions of dollars per annum, if not more. The fact that as a group cryptogams are not charismatic and poorly known should not diminish their status in conservation efforts or decrease their true value to the community.

4 Cryptogams in the Goulburn Broken Catchment

General estimates of cryptogam diversity in Australia are staggering. Although no comprehensive survey has been undertaken, it is estimated there are some 260,000 or more species of cryptogams of which only around 5% have been described (Scott *et al.* 1987, May 2001). Compare this to estimates of vascular flora and vertebrates (20,000 and 6,000 species respectively) of which more than 90% of species have been described (State of the Environment Advisory Council 1996). Combine the species diversity of cryptogams with their abundance and biomass and it quickly becomes apparent that cryptogams make up a huge proportion of the total Australian biodiversity (State of the Environment Advisory Council 1996).

No detailed studies of cryptogams have been undertaken in the Goulburn Broken catchment (Scott *et al.* 1987, State of the Environment Advisory Council 1996, May 2001). Survey records from a few locations, particularly in the upper catchment, are available from the Royal Botanic Gardens Melbourne herbarium collection and from the National Herbarium in Canberra. These data have not been presented in this report but can be extracted from records on request from these organisations. In general terms these collections reflect sampling effort rather than the true distribution or abundance of particular groups or species and as such provide little indication of the true diversity of cryptogams in the catchment (T. May pers. comm., S. Louwhoff pers. comm.).

Studies of wet and dry sclerophyll forests in the southeast and southwest of Australia indicate that the diversity of fungi alone could be as high as 1,000 or more species per hectare in some forest types (Scott *et al*. 1987). In another study, 25 species of one genus were found in plots with-in a 100ha area, with an estimated 181,000 fruiting bodies per hectare per month (Scott *et al*. 1987). Taking into account the other cryptogam flora (bryophytes, algae and lichens) the diversity of this group as a whole may be an order of magnitude or more higher than the diversity of vascular plants for a similar area. Extrapolated to the scale of the Goulburn Broken catchment with the environmental gradients (e.g. temperature, rainfall) and diversity of topography, habitat types and land-use, the high levels of habitat specificity and host specificity (i.e. of mycorrhizal fungi) of cryptogams it would not be unreasonable to expect cryptogam species diversity in the catchment to be in the range of 5,000-10,000 species or more. It is also highly likely that a number of regionally endemic or species with very limited ranges are present in the catchment.

Cryptogams from each group (i.e. fungi, algae, lichens and bryophytes) will be found in all habitat types throughout the catchment (Scott *et al*. 1987). A range of environmental factors; particularly at the microhabitat scale, will determine the diversity and abundance of species at any one site in the catchment. The presence of suitable substrates and host plants, suitable macro and micro-climatic conditions particularly moisture, appropriate disturbance regimes and other environmental factors will influence the diversity at any one location. In general terms, the damp sclerophyll forests of the foothills and highlands and the alpine and sub-alpine ecosystems of the catchment are likely to be particularly rich in fungi, bryophytes and algae (S. Louwhoff pers. comm.). The drier forests of the low hills, particularly where there are rocky outcrops, are likely to be richer in lichens and bryophytes. The drier vegetation of the plains is likely to support a diverse range of lichens, bryophytes and fungi, while the floodplains along major rivers and creeks are likely to support an abundance of all cryptogams (S. Louwhoff pers. comm.).

It is important to note that Ecological Vegetation Classes (EVC) as a method of classifying vascular plant communities may not correspond to cryptogam patterns of distribution (Scott *et al.* 1987). Further, traditional views of native vascular plant diversity may not be useful indicators of cryptogam diversity; even highly modified agricultural land can support highly diverse fungi flora. Studies of wheat paddocks using only limited isolating techniques to identify fungi revealed 50 genera of soil inhabiting fungi from one paddock and over 200 species from another paddock (Scott *et al.* 1987). Similarly, casual examination of a single rock on a degraded roadside in the Koonda Hill area during recent CSIRO fieldwork revealed 2-3 species of bryophyte and at least 3-4 species of lichen in an area less than $0.5m^2$ (personal obs.).

5 The role of cryptogams in ecosystem function

Cryptogams have a fundamental role in ecosystem function. They play central roles in the formation and stabilizations of soils, the decomposition of dead organic material and nutrient cycling. They form symbiotic relationships with most vascular plants and are an important food source for many other organisms. It is important to recognise that cryptogams fulfill these functions in natural *and* agricultural production systems and in so doing, they play a crucial role in the viability and sustainability of agricultural production and the local communities that depend on these industries. The key roles of cryptogams in ecosystem functions are described in more detail below.

Soil formation: cryptogams, particularly lichens and fungi play a fundamental role in soil formation (Scott *et al.* 1987, Anon. 1999, Dalphe 1997, Tommerup and Bougher 1999). Lichens are pioneer colonizers of bare rock and through chemical processes break down rock material into mineral components and soluble elements, making these available to the ecosystem. Fungi, particularly ectomycorrhizal fungi (where the mycelium of the mycorrhizal fungi attach to the outside of the host plant roots), assist in the formation of macro aggregates in soil (Anon. 1999, Dalphe 1997, Tommerup and Bougher 1999). The physical structure provided by the fungi mycelium and organic compounds such as proteins, polysaccharides and other complex carbohydrates exuded by the mycelium 'glue' soil particles together to form micro and macro aggregate soil particles, contributing to the physical structure of soil (Tommerup and Bougher 1999).

Soil stabilization: Lichen and mosses colonize bare soil, forming a visible surface crust. Under this visible surface crust, lichen and moss possess fine-root like structures (rhizines and rhizoids) that bind soil particles (Anon 1999, Tommerup and Bougher 1999). Although often less visible, fungi and algae are also present in these surface crusts (Anon. 1999). Both produce filaments that bind soils and exude sticky polysaccharides that attach to soil particles, forming larger soil aggregates (Anon. 1999). Together this network of cryptogam cover traps nutrients and organic material, assisting the build up of a humus layer (Anon. 1999). Fungi in this layer break down dead plant material and recycle nutrients, making them available for higher plants (Warcup 1986). The soil crust also provides a protective layer that slows moisture loss, while the physical structure and nutrients available in the crust creates suitable conditions for the germination and growth of higher plant seedlings (Anon. 1999). Research suggests that the presence of a soil crust increases the availability of key nutrients such as nitrogen, phosphorous, potassium, calcium and iron to plants compared to sites with bare soil (Dumaresq and Greene 2001). The micro-topography created by cryptogam crusts increases surface roughness, reducing wind and water erosion and provides microhabitats for invertebrates. This process provides the crucial first steps in the re-establishment of vegetation communities on disturbed sites.

The cryptogam crust also has important implications for other on and off site factors. The crust provides physical protection to the soil surface from rain splash erosion - an important initial step in the erosion of bare soils (Anon. 1999). The cryptogam crust also slows the flow of surface water and may increase infiltration rates and filter surface flows by trapping sediment and organic material (Anon 1999). This limits the amount of sediment and nutrients flowing off site and into waterways. The cryptogam crust also provides a protective barrier against trampling by stock and other disturbances that may damage the soil surface (Jefferies and Klopatek 1987). In drier vegetation types, lichens and mosses may provide an almost continual crust layer in the inter tussocks spaces between perennial plants. In undisturbed locations these crusts may be decades or even centuries old (Jefferies and Klopatek 1987, Anon. 1999).

Biotic relationships: Fungi form mycorrhizal associations with vascular plants, whereby fine hyphae (filaments) of the mycelium ('stem' of the fungi) form a sheath-like structure around the roots of the host plant (Scott *et al.* 1987, Tommerup and Bougher 1999). These structures allow the exchange of nutrients and water between the fungi and its host (Scott *et al.* 1987). It is believed 95% or more of vascular plants form these relationships, particularly in low nutrient systems where the mycorrhizal fungi are crucial in transporting phosphorous and nitrogen to the root system of host plants (Tommerup and Bougher 1999). In return, the fungi receive nutrients from the plant, primarily carbohydrates. They also disperse photosynthetically derived carbon from the host plant through the soil and so play an important role in increasing soil carbon stock (Tommerup and Bougher 1999).

The mycorrhizal relationship is critical to the growth and reproduction of many plant species and it is likely that plant-fungi associations have co-evolved over long periods. Many mycorrhizal fungi are host-specific and even life-stage specific. Mycorrhizal associations provide many benefits to the host plant including increased nutrients and protection against environmental stresses such as drought, salinity and pollution (Tommerup and Bougher 1999). The association may also reduce the host plant's susceptibility to disease and pathogens. Most vascular plants that typically form mycorrhizal associations show reduced vigour and often fail to survive in the absence of mycorrhiza. Studies of Eucalypt seedlings showed that seedlings inoculated with fungi were twice the size (diameter and height) of seedlings of the same species that didn't posses mycorrhizal fungi (Buchanan 1989). Anecdotal evidence suggests that difficulties with the propagation and growth of some Australian species under nursery conditions may be due to the lack of fungi in sterilized soils. The presence of mycorrhizal fungi may be essential for the recolonisation and re-establishment of some vegetation communities following major disturbances such as fire. Mycorrhizal associations may be critical in the conservation of some rare plant species and the re-establishment of some vegetation communities.

Mycorrhizal fungi also contribute to the productivity of agricultural crops, increasing the uptake of nutrients and water to plants and reducing susceptibility of crop plants to pathogens and disease (Dumaresq and Greener 2001). Research indicates that mycorrhizal colonization may reduce the need for fertilizer and pesticide applications while maintaining similar or greater yields (Dumaresq and Greener 2001). Ultimately, the development of more fungi 'friendly' agricultural practices may have wide benefits for both landowners and the wider social, economic and environmental spectrum.

Cryptogams also play other important roles in the functioning of healthy ecosystems, by providing food, shelter and other resources for a wide range of species. For example many birds use mosses and lichens in the construction of nests and many invertebrates feed and live directly in or on cryptogams (Scott *et al.*1987). The below and above ground (fruiting bodies) structures of fungi provide habitat and food for a wide range of other soil microorganisms and small mammals. Fungi play an important role in the development of tree hollows and cavities (Gibbons and Lindenmayer 2002).

Nutrient cycling: cryptogams are critical in the cycling of nutrients in all terrestrial ecosystems (Scott *et al.* 1987). Many fungi are saprotrophic, breaking down dead plant material, and making nutrients available to other organisms (Warcup 1986). Macro-fungi, such as mushrooms and toadstools, puffballs, stinkhorns and micro-fungi including mildew, moulds, rusts and yeast secrete digestive enzymes to dissolve organic material into organic molecules and minerals (Warcup 1986). The fungi absorb these molecules, while those not absorbed are available to other organisms. Lichens and bryophytes absorb nutrients from rock and soil surfaces and from dead organic material such as wood, making the nutrients 'trapped' in these substrates available to other organisms (Wacup 1989). Algae are important carbon fixers in all systems particularly aquatic systems, but also fix nitrogen in soil crusts (Anon. 1999). Through the fixing and cycling of nutrients, cryptogams are key drivers of terrestrial ecosystems (Scott *et al.* 1987).

6 Potential threats to cryptogams in the Goulburn Broken catchment.

Because of the lack of detailed information about the diversity and distribution of cryptogams in the Goulburn Broken catchment, no specific information about threats to individual species or communities of cryptogams is available. In the absence of more detailed work, it must be assumed that wherever the threats outlined below are currently active in the catchment, the cryptogam flora is being affected to some degree. Consequently, the list of threats discussed below, although not species or habitat specific, are all likely to be detrimental to the long term viability and functioning of cryptogam flora in the catchment if left unabated (Scott *et al.* 1987).

It is important to recognise that like native vascular plants and vertebrate fauna, the cryptogam flora in the Goulburn Broken catchment has already undergone a dramatic reduction. The loss and fragmentation of native vegetation associated with agricultural development and the perpetuating impacts that broad scale clearing in the catchment are likely to have had comparable or greater impacts on the cryptogam flora. As with other flora and fauna, the conversion of native vegetation to grazing or cropping land is likely to have directly destroyed the habitat of many cryptogam species (Scott *et al.* 1987).

Many cryptogam species would be unable to survive in small, degraded remnants. Weed invasion, stock grazing, timber harvesting and changed fire and flooding regimes are all likely to have severely impacted the cryptogam habitats of these small patches

(Tommerup and Bougher 1999). Given the estimates of diversity and abundance of cryptogam species outlined above, it is reasonable to assume that many species have already been lost from the catchment. Further, given that many species are very habitat-specific and in the case of mycorrhizal fungi, host specific, it is also likely that those land types and vegetation communities most altered since European settlement are also likely to contain species of cryptogam whose range and/or abundances have been similarly impacted. Conversely, as outlined earlier, the distribution of other cryptogam flora may not necessarily correspond and follow patterns of higher plant distribution. As such it is likely there are areas in the catchment that have been overlooked for conservation works (i.e. reservation, fencing) because they do not meet 'normal' significance assessment criteria that may contain highly significant crytogam floral communities. The threats to cryptogams are outlined in more detail below (Scott *et al.* 1987).

6.1 Lack of knowledge, data and awareness.

The single greatest threat to cryptogams is the lack of awareness of this group (Scott *et al.* 1987). The general public and most land managers are unaware of the fundamental role that cryptogams play in the functioning of healthy natural and production ecosystems and in the prosperity of the catchment community. It is likely that even invertebrates rate higher in the general communities awareness of the contribution different components of biodiversity make to the production of ecosystem goods and services.

6.2 Disturbance

The thresholds at which natural and artificial disturbances cause severe or irreparable damage to cryptogam flora may be far subtler than thresholds for vascular plant communities. While many vascular plant communities are able to tolerate a fairly high degree of direct disturbance, such as a once off, short duration heavy grazing and recover, the cryptogam flora at the same site may be severely damaged, taking decades or centuries to recover (Jefferies and Klopatek 1987). The long-term consequences of this disturbance may be an increased susceptibility to other threats such as weed invasion or erosion. Cryptogam communities may be more susceptible to subtle changes in environmental factors, such as increased light or wind penetration into remnant vegetation which follow the removal of a few individual trees. These subtle changes may not have any visible impacts of vascular plant communities, but may have major implications for the cryptogams narrow habitat range. The potential threats direct and indirect disturbance pose are discussed more fully below:

6.2.1 Direct disturbance

Cryptogams are very susceptible to direct physical disturbance. They are small, lack woody structures like many higher plants, and are generally fragile. Direct physical disturbance such as trampling by stock, humans or vehicles (e.g. recreation) or mechanical disturbance (e.g. cropping or logging), can impact directly on the physical structure of cryptogams (Scott *et al.* 1987, Jefferies and Klopatek 1987, Anon. 1999, Humphrey *et al.* 2002, Newmaster and Bell 2002). Some groups, particularly mosses and lichens, may be particularly susceptible during dry periods when they are desiccated and growth structures are brittle (ECC 1997). Similarly, fungi are susceptible to direct physical damage when above ground fruiting bodies are present (Scott *et al.* 1987).

Grazing of remnant vegetation is undoubtedly the major direct threat to the cryptogam flora of the catchment (Jefferies and Klopatek 1987). Uncontrolled grazing and the use of remnants as stock camps are likely to have a severe impact of cryptogrammic flora. Numerous studies on the impacts of grazing on cryptogams suggest that heavy grazing effectively destroys all visible cryptogam flora (Jefferies and Klopatek 1987). Studies on trampling of soil crusts by stock suggest that up to half the cover of cryptogams can be lost, with the resulting impacts of increased run-off and increased soil loss (by up to six times compared to pre-disturbance) (Jefferies and Klopatek 1987). These impacts may occur without apparent visible damage to the standing vegetation. Many cryptogams, such as lichens, mosses and some fungi are extremely slow growing and cannot be expected to recover rapidly from disturbance. Recovery times for cryptogrammic soil crusts following heavy grazing were from 14 to 18 years or more in some studies (Jefferies and Klopatek 1987). Research indicates that disturbance to some cryptogrammic soil crusts may take decades to centuries to recover from acute disturbances such as mechanical disturbance. Grazing may also alter microclimatic conditions through the removal of biomass, with consequences for light, wind and water penetration to the site. Grazing can alter nutrient regimes, micro topography, lead to soil pugging and compaction, introduce weed propagules and disturb litter and fine woody debris all of which are likely to have negative consequences for cryptogrammic flora (Tommerup and Bougher 1999).

Most cryptogams are killed by direct contact with fire. Inappropriate fire regimes and 'burning off' may represent one of the more widespread threats to cryptogam flora in the catchment, given the practice of fuel reduction burning on public land and roadsides (Scott *et al.* 1987). Most public land fire regimes are based on the response of vascular flora and are unlikely to take into account the requirements of cryptogams. Cryptogams have no particular fire-adapted survival strategies and consequently, frequent burning of an area is likely to result in a reduction in cryptogam diversity and abundance. Recolonization relies on the close proximity of propagules in adjacent unburnt areas and 'chance' for suitable conditions in the burnt area to allow recolonisation following fire. This represents a risk to less common species or those with patchy distributions. The severity of impact is probably linked to fire intensity. Low intensity fires leave unburnt areas and some woody debris and probably do not destroy all spores and below ground structures of fungi and other cryptogams. As with trampling, the recovery time for crytogam flora following intense fires may be very long. One study reports no recovery of a cryptogrammic crust after 19 years (Humphreys *et al.* 2002).

Although broad scale clearing has largely ceased in the catchment, habitat loss and fragmentation is probably still a major threat to cryptogrammic flora in the catchment. For organisms the size of cryptogams, habitat loss and fragmentation may literally occur with the ploughing of a firebreak, construction of a track through native vegetation, the heavy grazing of sections of a roadside or the clearing of one or two scattered trees. In general terms, cryptogams are not highly dispersive or mobile, with dispersal by individual spores likely to be in the order of centimetres to tens of metres rather than over hundreds of metres. Fragmentation not only destroys habitat directly but also results in changes in microclimatic conditions of the remaining areas of native vegetation. This may render the edges or in the case of small remnants the entire area unsuitable for the development of some cryptogams, particularly the more moisture sensitive bryophytes and fungi.

Studies suggest that conventional cropping practices reduce the diversity and abundance of beneficial cryptogams, particularly fungi (St John 1992, Dalphe 1997, Dumaresq and Greener 2000). Short cropping rotations, use of fertilizer and herbicides, fallowing and grazing to control weeds and excessive tillage are all likely to impact on cryptogam flora (and other beneficial soil biota). Comparisons between organic cropping systems and conventional cropping practices suggest that organic systems have significantly more soil fungi and other soil organisms, reducing the need for chemical and fertilizer inputs and so reducing costs (Dumaresq and Greener 2000).

6.2.2 Indirect disturbance.

Commercial and domestic harvesting of firewood is likely to represent a major threat to some cryptogam species, particularly fungi (Driscoll *et al.* 2000). A number of fungi species occur only on fallen timber and at particular stages of decay (Warcup 1986). Studies in the northern hemisphere recorded the association between particular fungi species and the size of fallen timber with some species only occurring on the largest size classes of fallen timber (Humphrey *et al.* 2002, Newmaster and Bell 2002). Similar relationships may also occur in Australia. Fallen timber may also provide a refuge for some fungi species following disturbance (e.g. following fire or during drought). Removal of woody debris may also alter the microclimatic conditions of a site. Particular vegetation types are the focus for firewood harvesting in the catchment and as such, cryptogam species associated with fallen and dead standing timber in these habitats may be at risk. The box/ironbark and riverine redgum forests in particular are targeted due to the quality of the firewood resource and large areas of these forests have little fallen timber remaining. Harvesting of bush rocks for the nursery and landscaping trade may also represent a threat to lichens and mosses (Scott *et al.* 1987).

Pasture improvement, fertilizer and herbicide application may all contribute to the loss of cryptogam flora in agricultural landscapes. Native grass communities can be particularly rich in cryptogams with well-developed lichen and moss crusts occupying the spaces between perennial grass tussocks. Cultivation and pasture improvement of these native grass communities destroy these cryptogam crusts (Anon. 1999). This shifts the previously stable native grasslands to an introduced annual system that is less efficient in terms of water and nutrient use and requires greater inputs to maintain productivity, particularly during times of environmental stress. These changes have wider implications for catchment management due to increased accessions to the water table, increased surface run-off, nutrient and sediment transport to waterways, acidification and soil structure decline. Studies of native grassland grazing systems suggest that these systems are far more resilient to environmental stresses. The cryptogrammic flora of native grasslands may be important drivers in this resilience by maximizing the use of available resources. Additionally, the introduction of some ‘weedy’ pasture species (e.g. phalaris spp.) not only impacts on the site where it has been deliberately established, but may also invade adjacent remnant habitats where the introduced species may have severe impacts on the ground layer vascular and cryptogam flora and interrupt ecological processes further modifying the site for native species.

Commercial forestry is likely to have a severe impact of cryptogam flora, however, few studies have been undertaken in Australia to quantify the impacts of forestry on cryptograms. Forestry practices destroy key substrates for cryptogams in forest habitats; standing and fallen timber, soil and litter (Driscoll *et al.* 2000, Humphrey *et al.* 2002, Newmaster ad Bell 2002). Clear-felling practices destroy soil surface integrity and can result in severe soil disturbance, erosion and loss of litter and topsoil. Further, the gross structural changes to vegetation when clear-felled and the regeneration techniques used to promote commercial timber species such as high intensity slash burning, herbicides and fertilizers in some operations and short rotation times between logging result in simplified forest and substrate structure for cryptogam flora. Additionally, changes in fungal dispersing faunal populations that result from clear-felling operations and the impacts of fragmentation on adjacent uncleared vegetation suggest that commercial forestry is generally a land-use not compatible with cryptogam conservation.

Loss of hosts may be an important threat to some mycorrhizal fungi species. Ironically it may be the loss of mycorrhizal fungi that is contributing to the decline in populations of some species of native vascular plants in the catchment. Mycorrhizal fungi increase the growth and reproductive vigour of host plants and assist the host to cope with periods of environmental stresses such as drought (Buchanan 1989, Tommerup and Bougher 1999). The loss of mycorrhiza due to other threats such as those outlined here may in turn contribute to population declines in host plants due to a lack of reproduction, regeneration and recruitment. While this may seem a 'chicken or the egg' phenomena, in the absence of detailed studies (which are not likely to be undertaken in the near future), it should be assumed that populations of rare or threatened plants also possess mycorrhizal fungi that are likely to be important for host plant's survival. Many of these fungi may be host-specific and consequently, are likely to be rare or threatened themselves. From a management perspective the only option is to maintain viable populations of native plants to 'capture' this reciprocal risk. Nursery hygiene and management practices such as soil sterilization and use of biocides may destroy fungi partners and limit abilities to propagate some rare plants under nursery conditions. *In situ* conservation is likely to be the most effective option to conserve these species and their hosts.

Physical and biogeochemical changes to soil conditions such as compaction and soil structure decline, salinisation and acidity may threaten cryptogams in the agricultural zone (Scott *et al.* 1987). Salinity in particular, may be a major risk to cryptogam flora, both directly by increasing soil and water salt concentration beyond the tolerance thresholds of cryptogam species, and also by causing more general declines in native vegetation. Rising saline ground water is likely to impact on mycorrhizal host plants with a knock-on effect to the fungi. This may cause the declines of overstorey species, changing microclimatic conditions in remnants and reducing substrates such as litter and fallen timber in the longer term.

Little is known about the impacts of exotic cryptogams. Two species of weed mosses from Europe may occur in the Box/Ironbark forests, where they have the potential to displace native species (ECC 1997). Further risks of introduction are through the nursery trade, soil movements and poor industry hygiene practices (e.g. forestry and agricultural equipment). The spread of exotic vascular plants may also be responsible for the introduction and spread of exotic cryptogam species.

The introduced fungi *Phytophthora spp.* is a serious threat to native vegetation (Environment Australia 2001). At least 14 species of *Phytophthora* have been recorded in Australia, three of these species have impacts on native vegetation and one species *P. cinnamomi* (Cinnamon Fungus) can have devastating effects on some native plant species and vegetation communities. First identified in the forests of south west Western Australia, Cinnamon fungi is now common in vegetation communities above 600mm rainfall in southeastern Australia. 'Dieback caused by the root-rot fungus' is listed as a key threatening process under the *Environmental Protection and Biodiversity Act 1999* and a threat abatement plan has been prepared (Environment Australia 2001). The pathogen fungi can have major impacts on vegetation community composition, structure and function and have knock on effects for other species of plants and animals. The fungi can have also serious economic implications for forestry operations (Environment Australia 2001).

Other fungi pathogens in the catchments can have serious impacts on agriculture. Rusts, moulds, root and parasitic fungi pathogens cause substantial impacts to agricultural crops, particularly cereal and horticulture, by reducing yields and damaging fruit. The use of chemicals to control pathogens is a substantial input cost to agricultural industries in the catchment.

7 Legislative framework for the conservation and management of cryptogams in the Goulburn Broken.

In general terms cryptogams should be included under the legislation that governs the conservation of Victoria's biodiversity, including the Federal *Environment Protection* *and Biodiversity Conservation Act 1999,* the Victorian *Flora and Fauna Guarantee Act 1988, Planning and Environment Act 1987* and to a lesser extent the *Catchment and Land Protection Act 1994, Conservation, Forests and Lands Act 1884, Environment Conservation Council Act 1997, Forest Act 1990, Water Act 1968* and *Heritage Rivers Act 1992*.

Additionally there are a range of key strategic documents including Victoria's Biodiversity Strategy, Restoring our Catchments – Victoria's Draft Native Vegetation Management Framework, the Draft Goulburn Broken Native Vegetation Management Plan and the land and water management plans which cover the catchment that determine how vegetation, land and water resources are managed and priorities set for actions to address threats to the resources.

These Acts and strategic documents all have relevance to the protection and management of biodiversity in the catchment and consequently to the management of cryptogam flora. While this legislative framework is theoretically capable of providing protection and management to the cryptogam flora of the catchment, there are a number of areas of concern. In reality the cryptogam flora is overlooked in most decision making, with the focus being more on the vascular flora, particularly trees and shrubs and to a lesser extent ground layer vascular plants. This may stem partially from the inconsistencies in the definition of native vegetation in legislative documents. It cannot always be assumed that cryptogam flora and other non-vascular plants are covered. While the *Flora and Fauna Act 1988* refers to 'all taxa' and 'flora' which encapsulate non-vascular and vascular plants alike, the *Planning and Environment Act 1987* refers to 'all indigenous plants including trees, shrubs, herbs and grasses' of the state and the *Catchment and Land Protection Act 1997* refers to 'native vegetation'. This raises the question of how fungi, lichens and some algae should be treated by legislation when they are neither plants nor animals. While this may sound pedantic, the inconsistency outlined in the terminology used in legislation and strategy documents is symptomatic of the lack of understanding and poor levels of awareness about the lesser-known elements of biodiversity. It also highlights the need to use careful language when referring to elements of biodiversity to ensure that people are aware that “biodiversity” is more than plants and animals, but rather is an all encompassing concept that incorporates the lesser known living organisms and their interactions.

8 Areas for Action

The major issues for the GBCMA to consider in relation to cryptogam flora conservation fall into two key themes, awareness building and on-ground management actions. The awareness issues should generally be focused around promotion of the role of cryptogams in catchment health and sustainability rather than on collection of scientific data. While scientific investigation is obviously important it is unlikely that any major commitment of resources can be made in the foreseeable future to study cryptogams or their ecological role in the catchment. The collection of this type of data is required, however, and the GBCMA should opportunistically encourage and facilitate research into cryptogams wherever possible.

As an emerging issue, cryptogam conservation will need to build on the strong momentum for sustainability and conservation already present in the catchment community. The fact that cryptogams are being raised as an issue suggests that the catchment community has reached a level of awareness of natural resource management that goes well beyond the ‘normal’ level of community awareness and understanding. Like all new issues, there will need to be a period of awareness raising and knowledge building before more specific priorities and more targeted actions than those outlined here can be devised to address particular threats to cryptogam flora. This process will evolve over time. Given the greatest direct threats to cryptogams lie on private land managed by thousands of landowners and public land managed by Natural Resources and Environment and Parks Victoria, the GBCMA will have to adopt a strong advocacy role if cryptogam conservation issues are to be incorporated into management activities.

Specific issues for consideration are outlined below:

9 Awareness raising.

Recommendation 1.

The GBCMA should take an active role in raising public awareness about cryptogam conservation issues in the catchment.

The GBCMA should highlight the role of cryptogams in catchment health and sustainability and their economic importance to agriculture. Where appropriate, descriptions and explanations of the role of cryptogams should be included in documents, brochures and other communication material produced by the GBCMA that have reference to vegetation in the catchment. It would be useful to obtain some high quality images of cryptogams for use in publications, talks and media contacts. A brochure on the ‘forgotten flora’ (and fauna, the invertebrates!!) may be a first step. A field day and training session for agency staff may be useful in encouraging Catchment Management Officers to take a greater interest in the other components of biodiversity.

Recommendation 2.

The GBCMA should ensure that cryptogams are ‘covered’ in strategic and policy documents.

In particular cryptogams and other non-vascular plants should be specifically included in the Native Vegetation Retention Controls.

Recommendation 3.

The GBCMA should encourage and facilitate research into cryptogam status, distribution and ecology in the catchment.

Opportunities to include cryptogam issues in existing studies such as CSIRO’s Heartlands and Ecosystem Services projects should be explored with the research partners. The GBCMA could also advocate the inclusion of cryptogams into other biological surveys undertaken in the catchment, particularly pre-logging surveys and any surveys undertaken for developments such as road construction. This opportunistic data collection, while not systematic, will at least begin to develop a base level of knowledge about cryptogam distribution in the catchment.

Recommendation 4.
The GBCMA should also encourage research into disturbance regimes and management prescriptions of native vegetation communities in the catchment and their potential impacts on cryptogam communities.

For example, there would appear to be conflicts between management prescriptions such as ‘crash’ grazing to reduce weed invasions in grassy woodland remnants and cryptogam conservation. Further research into the impacts of fuel reduction burning, timber harvesting and grazing on public land on the cryptogam flora should be encouraged when opportunities arise.

Recommendation 5.
The GBCMA should work closely with its partner agencies and other land management agencies in the catchment to raise awareness about cryptogams (and other lesser-known elements of biodiversity).

In particular issues such as grazing of public land, fuel reduction burning, roadside maintenance, construction of irrigation infrastructure and drainage schemes all have potential to destroy cryptogam communities, introduce pathogen cryptogams and impact on adjacent areas of native vegetation. Use of Best Practice wherever and whenever works are undertaken in or near native vegetation should be encouraged.

Recommendation 6.
The GBCMA should continue to support land use planning processes such as the Environment Conservation Council’s Box-Ironbark Investigation as a means of improving the reservation and protection status of biodiversity in the catchment.

10 On-ground Management Actions

Recommendation 7.

The GBCMA remnant protection programs should continue and wherever possible, be expanded to include likely areas of high cryptogam diversity.

The information presented here creates an even stronger case for continued focus on remnant vegetation protection as opposed to revegetation. The policy of remnant fencing protects cryptogam flora within remnants and encouraging revegetation in and around remnants has merit by creating the best opportunities for inoculation of planted vegetation with mycorrhizal fungi and colonization of other cryptogams. The remnant fencing programs should give some consideration to allocation of resources toward protection of scattered trees and small clumps of vegetation in paddocks that may provide important points for recolonisation of mycorrhizal fungi in revegetated areas. Some sites, such as those with large amounts of fallen timber and rocks, diversity of land forms and micro-topography and moist areas such as drainage lines may be particularly rich in cryptogam flora. Some consideration should be given to protecting sites with potentially high cryptogam diversity. These they may not be considered priorities under existing remnant scoring systems.

Recommendation 8.

The use of indigenous plantings should continue to be encouraged.

The use of the most 'locally' available seed and planting stock in revegetation may be very important for the conservation of host specific mycorrhizal fungi and for the conservation of threatened flora species. The role of mycorrhizal fungi in the long-term success of revegetation activities strengthens the case for continuation of the Goulburn Broken Seed Bank program, continued awareness raising of the need to plant indigenous and local seed collection efforts. The GBCMA could also investigate increasing incentives for revegetation efforts that use locally collected indigenous seed (i.e. revegetation projects that use seed collected on site could be funded more than projects that use regionally indigenous seed).

Recommendation 9.

The GBCMA should continue to encourage biodiversity friendly and sustainable farming practices.

Leaving fallen timber, litter and debris in remnants and the encouragement of sustainable farming practices such as minimum tillage, reduced herbicide use and conservation grazing, are likely to benefit cryptogams, landowners and the wider catchment community in the long term.

Recommendation 10.

The GBCMA should discourage harvesting of firewood from native vegetation on private and public land and encourage the establishment of firewood plantations.

Firewood harvesting impacts on a range of flora and fauna, particularly cryptogams. Unless private (or public) firewood plantations are established at some point, the reliance on public forest for firewood will continue. The GBCMA should consider the opportunities for firewood production and the benefits to native vegetation, in land use change scenarios being considered for different areas of the catchment.

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