The Victorian Naturalist

Volume 129 (5) October 2012

Published by The Field Naturalists Club of Victoria *since 1884*

From the Editors

The 2011 FNCV Biodiversity Symposium, held on 19/20 November, focused on forests. In the International Year of Forests, the subject was a fitting one. In this issue, the Editors are pleased to publish some of the papers presented at that event, by Moore, Harley and Mueck.

The papers making up the remainder of this issue of *The Victorian Naturalist* do not form any unity of theme, area, or indeed subject matter. They do, however, serve to remind us that the field of natural history encompasses a broad spectrum of interests and activities. Because of this wide tolerance, articles focusing on fungi, historical botany and phytoplankton can appear together in the pages of this journal. It is a feature that, as one reader has remarked, makes *The Victorian Naturalist* 'of immense value'. A further valuable aspect of this particular issue is the publication of a couple of 'firsts' — the first Australian record of a fungus species, and a first collection of a Dinoflagellate bloom from the ice surface of an Australian lake.

The Victorian Naturalist
is published six times per year by the

Field Naturalists Club of Victoria Inc
Registered Office: FNCV, 1 Gardenia Street, Blackburn, Victoria 3130, Australia.
Postal Address: FNCV, Locked Bag 3, Blackburn, Victoria 3130, Australia.
Phone/Fax (03) 9877 9860; International Phone/Fax 61 3 9877 9860.
email: admin@fncv.org.au
www.fncv.org.au

Patron: His Excellency, the Governor of Victoria

Address correspondence to:
The Editors, *The Victorian Naturalist*, Locked Bag 3, Blackburn, Victoria, Australia 3130.
Phone: (03) 9877 9860. Email: vicnat@fncv.org.au

Yearly Subscription Rates – The Field Naturalists Club of Victoria Inc

(As of October 2012)

Membership category		Institutional	
Single	$75	Libraries and Institutions	
Concessional (pensioner/Senior)	$55	- within Australia	$140
Additional Concessional	$20	- overseas	AUD150
Family (at same address)	$95		
Junior	$25		
Additional junior (same family)	$10	Schools/Clubs	$85
Student	$30		

All subscription enquiries should be sent to
FNCV, Locked Bag 3, Blackburn, Victoria, Australia 3130.
Phone/Fax 61 3 9877 9860. Email: admin@fncv.org.au

The

Victorian Naturalist

Volume 129 (5) 2012 October

Editors: Anne Morton, Gary Presland, Maria Gibson

Editorial Assistant: Virgil Hubregtse

ISSN 0042-5184

Front cover: Forest scene near Marysville, Victoria. Photo by Dan Carey Photography.
Back cover: Forest scene near Marysville, Victoria. Photo by Dan Carey Photography.

The fungus *Leucopaxillus cerealis* newly recorded from Australia

Virgil Hubregtse and Jurrie Hubregtse

6 Saniky Street, Notting Hill, Victoria 3168

Abstract

Since June 2007, *Leucopaxillus cerealis* (Fungi: Agaricales) has been observed growing under eucalypts in garden beds at the Monash University Clayton campus, in suburban Melbourne, Victoria. A description of the fungus is given, which represents the first record of the species from Australia. Significant variation in the appearance of the fruit-bodies was observed between occurrences in different years, possibly because of different weather conditions. The antibiotic properties of this species could have important implications for Australian environments. (*The Victorian Naturalist* **129** (5) 2012, 160–166)

Keywords: Leucopaxillaceae, *Leucopaxillus albissimus*, Eucalypts, Tricholomataceae, *Phytophthora cinnamomi*

Introduction

Leucopaxillus is a genus of agarics (gilled fungi) characterised by the fleshy fruit-bodies lacking a partial or universal veil; often with decurrent lamellae and with a white spore print. Microscopically, spores are amyloid in Melzer's reagent, and smooth or with a warty ornamentation. Molecular studies have shown that *Leucopaxillus* belongs to the tricholomatoid clade of the Agaricales (Matheny *et al.* 2006), and is considered to be saprotrophic, not mycorrhizal (Tedersoo *et al.* 2010).

Three species of *Leucopaxillus* have been reported from Australia (May *et al.* 2006): *L. amarus* (Alb. & Schwein) Kühner, *L. eucalyptorum* (Cleland) Grgur. and *L. lilacinus* Bougher. These three species all have a brown, grey or purple pileus (Bougher and Syme 1998; Fuhrer 2005). Incidentally, *Leucopaxillus amarus* as used by most authors is more correctly called *L. gentianus* (Quél.) Kotl. (Knudsen & Vesterholt 2008).

A fungus with a white pileus matching *Leucopaxillus cerealis* (Lasch) Singer was first observed in June 2007 growing under eucalypts and other plants in a garden bed at the Monash University Clayton campus, in suburban Melbourne, Victoria. This is the first record of this species from Australia. Members of the *L. cerealis* complex are usually found in the Northern Hemisphere where they are widespread but uncommon, generally growing under conifers or broad-leaved trees, including exotic eucalypts (Arora 1986, as *L. albissimus* (Peck) Singer). We report below on the characters and identification of the Australian material and discuss the significant variation in appearance that we observed over different years.

Materials and methods

Macroscopic descriptions were made from fresh specimens. Microscopic characters were examined by standard techniques, using a Motic BA200 optical microscope with a trinocular head, and a Canon D1000 digital camera. The microscope was calibrated by using an Olympus objective micrometer with 10 μm divisions. Mounts for microscopical examination were made from dried and fresh material; measurements were made in 5% potassium hydroxide solution or in Congo Red with 10% ammonia. Melzer's reagent was used to determine the amyloid reaction of the basidiospores. All measurements were carried out on digital images using a public domain software package called ImageJ. The drawings of spores, basidia, and cystidia were made by tracing over digital micrographs in Photoshop™. In 2008, 2010 and 2011, specimens were collected and some of the material was deposited in the National Herbarium, Royal Botanic Gardens, Melbourne. No fruit-bodies emerged in 2009, because of the dry weather.

Taxonomic description

Pileus 50–100 mm or more broad; when young convex with an inrolled margin, expanding to nearly plane, with age it can become centrally depressed (Fig. 1), margin frequently ribbed on young fruit-bodies (Fig. 2); surface dry, dull, glabrous when young and moist, becoming scaly, tomentose or fibrillose and cracking when dry and with age; colour when very young

Fig. 1. Fruit-bodies can be over 100 mm across with uplifted margin, and centrally depressed.

Fig. 2. Young white caespitose fruit-bodies, with ribbed margins.

pure white, with age becoming tinted yellowish brown, darker in the centre, and occasionally turning light tan (Fig. 3); context white, becoming cream-coloured with age, does not bruise.

Lamellae attachment subdecurrent to decurrent; often with decurrent lines or ridges extending down the stipe (Fig. 4); close or crowded, thin, sometimes forked, sometimes anastomosing; can be separated easily from the stipe (Fig. 5) and also from the context of the

Fig. 3. Pileus becoming light brown to tan with age.

pileus; colour white at first, becoming buff with age or on drying out. Lamellulae present.

Stipe central; generally up to 60 mm or more long and 30 mm thick; stout, cylindrical but often enlarged at the base or in the middle; surface smooth to finely scaled or fibrillose; colour white when young, becoming pale buff with age; growing from copious white mycelium that combines with the mulch and soil to form a thick, firm mat.

Flesh up to 17 mm or more thick in large specimens, white, firm.

Odour when fresh, none to very mild but unpleasant; dried material has a very strong unpleasant odour.

Taste VH found the taste to be very bitter and unpleasant, while JH thought that it was only mildly bitter.

Basidiospores 6.3–7.5 × 4.7–5.3 µm (excluding ornamentation), ellipsoid to almost oval, hyaline, often with one oil drop, with ornamentation of scattered, strongly amyloid warts (Fig. 6).

Basidia 35–43 × 8–9 µm, narrowly clavate, four-spored, often with a clamp connection at the base (Fig. 6).

Cystidia cheilocystidia and pleurocystidia present, filamentous, often with short branches, often septate (Fig. 6); not easy to find in some specimens, but abundant in others.

Pileipellis consisting of appressed interwoven hyphae with clamp connections. Clamp connections were found in all tissue.

Fig. 4. Clitocyboid fruit-body.

Fig. 5. Swelling of stipe due to rain after a short dry period.

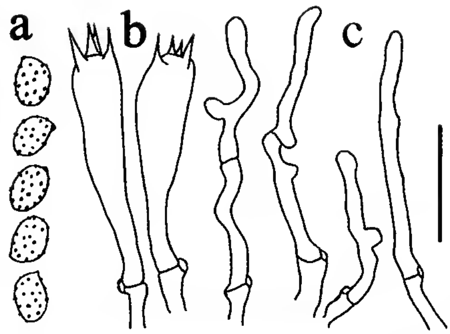

Fig. 6. (a) Spores (b) Basidia (c) Cheilocystidia. Scale bar = 20 µm.

Fig. 7. Naucoroid/clitocyboid fruit-body.

Growth habit solitary, scattered or in caespitose clusters in a 'fairy ring' in thick (up to 100 mm deep) leaf litter or mulch under eucalypts and other plants; stature naucoroid/clitocyboid (Fig. 7) or clitocyboid (Fig. 4).

Growing season generally April to June if weather conditions are suitable; however, in 2011, for the first time, a few new fruit-bodies emerged as late as 26 August.

Habitat and phenology of *L. cerealis*

The original location at Monash University was near the south-east corner of the intersection of Normanby Road and East Ring Road. The vegetation in this garden bed consists principally of *Eucalyptus* spp., *Grevillea* spp. and Gymea Lily *Doryanthes excelsa*. Most of the eucalypts in this area are Spotted Gum *E. maculata*, and it is under this species that the *L. cerealis* grows. No conifers are present.

A large 'fairy ring' of *L. cerealis* was first observed in deep leaf litter under one *E. maculata* in June 2007. There had been significant rainfall and the fruit-bodies had grown to a diameter of more than 100 mm. No collection was made because all fruit-bodies were old when discovered.

In 2008 there was initial good rain, allowing the formation of a number of naucoroid/clitocyboid fruit-bodies (Fig. 7), but then the season stayed dry, causing the fruit-bodies to become stunted and deformed. In the same year a single small fruit-body emerged under a second *E. maculata*, but dried out before it had a chance to mature.

In 2009 conditions were much drier, and although some mycelium developed amongst the leaf litter under the first *E. maculata*, no fruit-bodies were observed.

In 2010 there was some rain but the fruit-bodies stayed small and developed predominantly in several caespitose clumps, forming a 'fairy ring' (Fig. 8) under the first *E. maculata*. Fruit-bodies also emerged under a third *E. maculata*. In the same year, a 'fairy ring' of *L. cerealis* fruit-bodies was observed in mulch in a second garden bed, on the south side of the multi-level car park, about 730 m south-west of the first site. The vegetation at this new site consists of various *Eucalyptus* spp., *Kunzea baxteri* and a Cypress-pine *Callitris* sp.

In 2011 rain fell much more frequently, and several fruit-bodies, some more than 100 mm in diameter, developed under the eucalypts at the first site. However, dry periods between rain events again caused most fruit-bodies to become stunted and contorted, with cracked yellowing pilei (Fig. 9) and split or swollen stipes (Fig. 5). Some *L. cerealis* fruit-bodies, along with *L. eucalyptorum*, were observed at the second site. In the same year, fruit-bodies of *L. cerealis* were found at two new sites on the north side of the Campus Centre, about 360 m south-east of the second site, where no conifers were present. One group of fruit-bodies was

Fig. 8. 'Fairy ring' of caespitose clumps of fruit-bodies.

Fig. 9. Pileus becoming severely cracked in dry weather.

growing under a Red Flowering Gum *Corymbia ficifolia* and the other about 30 m away under a Warted Yate *E. megacornuta*.

In all cases, the *L. cerealis* fruit-bodies were slow growing and lasted for at least two months. When young they were white, but with age they became yellowish, then finally rusty brown; their smell became disagreeable, and the surface of the pilei became cracked as they dried. From these observations it is evident that the fruit-body size, coloration, growth habit and smell are highly dependent on environmental factors.

Discussion

The micro-morphological characteristics of the Australian collection (particularly the amyloid nature of the warts on the spores, and the filamentous cheilocystidia), as well as the macro-morphological features, match the description of *Leucopaxillus cerealis* by Singer and Smith (1943: as *L. albissimus*) and Knudsen and Vesterholt (2008). Singer and Smith (1943) had treated *L. albissimus* as a very variable species, including several forms and varieties. Singer (1986) updated the correct name of *L. albissimus* to *L. cerealis*, and listed numerous synonyms. Knudsen and Vesterholt (2008) regarded *L. cerealis* as a species complex, including *L. albissimus*, *L. paradoxus* (Costantin & L.M.Dufour) Boursier and *L. piceinus* (Peck) Pomerl. In addition, Knudsen and Vesterholt (2008) treated *L. cutefractus* Noordel. as a similar but distinct species, separated by the pileus cracking with age. Another species that belongs to the *L. cerealis* complex is *L. monticola* (Singer & Smith) Bon (Vizzini and Contu 2009).

A revision of *Leucopaxillus* was carried out by Singer and Smith (1943) who recognised species based primarily on fruit-body structure, taste, odour and subtle variations in microscopic characters. Since then, no other major taxonomic studies have been carried out on the genus. In particular, there are no studies describing the boundaries of various *Leucopaxillus* species using molecular data.

While the Australian material matches well to the *L. cerealis* complex, difficulty arises when trying to place it into one of the recognised taxa within that complex. Some of these taxa are recognised at varietal level, for example by Singer and Smith (1943), and some as independent species. Microscopic characters are all very similar in members of the *L. cerealis* complex (Table 1). In particular, for most species within this complex, spore and basidia sizes, and the cheilocystidia and pleurocystidia are virtually identical. This leaves the macro-morphological features as the main criterion with which to place the Australian material within particular taxa in the *L. cerealis* complex.

***Leucopaxillus cerealis*.** As described by Singer and Smith (1943: as *L. albissimus* var. *typicus*) *L. cerealis* in the strict sense is characterised by its convex to expanded white pileus with a ribbed but sometimes smooth margin. The pileal surface is smooth or rarely faintly rimose-areolate in age. The odour is aromatic or sweet, and the taste farinaceous-bitter. The lamellae are white, crowded or subcrowded, sometimes forked at the base, mostly anastomosing, adnate with a decurrent tooth or simply decurrent, some with short rib-like proliferations down the apex of the stipe, ribs not anastomosing, moderately broad (to 6 mm), lamellulae abruptly rounded at inner extremity. The stipe is 40–70 mm long, 7–15 mm thick, and the base often bulbous with adherent remnants of leaves, white-myceloid, not strigose, solid, white, subglabrous or somewhat fibrous-scabrous, especially at the apex. Cheilocystidia are rare or lacking, and pleurocystidia are absent.

In many of the Australian specimens, the macro-morphological features match closely with those of *L. cerealis* in the strict sense, although none of the specimens had an aromatic odour. Cheilocystidia and pleurocystidia were

Table 1. Spore and basidia sizes for some *Leucopaxillus* spp. belonging to the *L. cerealis* complex. (1) Singer and Smith 1943, (2) Noordeloos 1995, (3) Singer and Smith 1947, (4) Vizzini and Contu 2009

Species	Spore size µm	Basidia size µm
Australian collection	6.3–7.5 × 4.7–5.3	35–43 × 8–9
L. cerealis (as *L. albissimus* var. *typicus*) (1)	5.5–7.5(–8.5) × 4.2–5.5	24–36 × 6.5–8.5
L. paradoxus (as *L. albissimus* var. *paradoxus*) (1)	5.0–7.5 × 3.3–4.8	21–41 × 4–8
L. piceinus (as *L. albissimus* var. *piceinus* (1)	5.5–8.0 × 4.5–5.0	33–41 × 6–8
L. cutefractus (2)	6.5–8.0 × 4.5–6.0	24–52 × 8–11
L. monticola (3)	6.5–8.0 × 4.5–5.0	20–50 × 4–5
L. monticola (4)	7.0–8.0 × 4.5–5.2	30–40 × 8–10

present in all specimens, but in some samples examined they were very rare. The density of cheilocystidia and pleurocystidia seems to vary significantly, and may be influenced by environmental conditions.

L. paradoxus. This taxon, as described by Singer and Smith (1943: as *L. albissimus* var. *paradoxus* (Costantin & L.M.Dufour) Singer & A.H.Sm.) is recognised mainly by its convex to plane, sometimes centrally depressed pileus with the central area coloured creamy white, or tinted with an ochraceous cream colour. The pileal surface is sometimes faintly rimose-areolate, the space between the areolae being paler. The taste is also significant in that it is mildly bitter or unpleasant. The stipe is white and fibrillose. Cheilocystidia and pleurocystidia are absent.

Morphologically, some of the Australian specimens fitted this description, the main difference being that cheilocystidia and pleurocystidia were present, though very rare in some samples.

L. piceinus. Diagnostic features that differentiate this taxon, as described by Singer and Smith (1943: as *L. albissimus* var. *piceinus* (Peck) Singer & A.H.Sm.), from other members of the complex are the disagreeable, pungent odour, strong bitter or unpleasant taste, surface of the pileus appearing matted-fibrillose under a lens, margin frequently ribbed or grooved, and stipe often with anastomosing ridges at the apex. Cheilocystidia and pleurocystidia are very scattered.

It can be seen from our species description that the Australian specimens match the morphological characters of *L. piceinus*.

L. cutefractus. The important features considered by Noordeloos (1995) to differentiate this species from others in the complex are the numerous cheilocystidia, the cracking of the ochraceous tomentose pileal surface with age, and the normally mild and/or unpleasant taste. Many of the Australian specimens (e.g. the specimen in Fig. 9) have features that match those of *L. cutefractus*.

L. monticola. According to Singer and Smith (1947: as *L. albissimus* var. *monticola* Singer & A.H.Sm.) and Vizzini and Contu (2009) this taxon has a very similar macro-morphology to that of *L. cerealis* var. *piceinus*. However, it is separated by its pleasant aromatic odour and mild taste when fresh, and the disagreeable and distinctive odour when dried, and also its abundant cheilocystidia.

At various times, many of the Australian specimens matched the morphology of this species very well, although none had an aromatic odour when fresh.

Conclusion

Leucopaxillus cerealis has been observed growing in the same general location for four years, during which the climatic conditions have varied significantly. It is clear that the morphology of this species is affected by environmental factors. When there is plenty of rain, the fruit-bodies are usually large, white and smooth. When a period of significant growth is followed by dry weather, the pilei become areolate-cracked. When there is little rain during early growth, the fruit-bodies normally stay small, smooth and whitish. Weather alternating between dry and wet periods causes the fruit-bodies to become quite distorted, and often the stipe swells up. A lot of variability in the abundance of cystidia has also been noted, and the taste seems to depend to some extent on the taster. Because this species is very variable, and the form is so dependent on the weather conditions and age of the fruit-bodies, a chance sighting of any one of its various forms could easily place it in one of the species mentioned above.

The lack of any DNA sequence data means that the best that can be done at present is to call the Monash species *L. cerealis* because most of the observed specimens match the characteristics described for this species. Our observations over several years suggest that some names for members of the *L. cerealis* complex may represent variation caused by environmental factors.

Much research on species belonging to the *L. cerealis* complex has been carried out by molecular chemists attracted to this fungus because of the wide range of compounds that are in its tissue. It has been shown that some of the compounds produced by this fungus have medically useful antibiotic and anticancer properties (Sakai *et al.*1955; Pfister 1988). The fruit-bodies are slow to grow and even slower to decay (Arora 1986), possibly because the antibiotic substances they produce prevent, or slow down, attacks by invertebrates and bacteria. Marx (1969a, 1969b) found that *L. cerealis* var. *piceinus* produces antibiotics antagonistic to *Phytophthora cinnamomi*; this could have important implications for some Australian environments.

Acknowledgements

Our grateful thanks go to referee Dr Tom May, Senior Mycologist, Royal Botanic Gardens Melbourne, for many helpful suggestions which improved the manuscript.

References

Arora D (1986) *Mushrooms demystified: a comprehensive guide to the fleshy fungi.* 2nd edn. (Ten Speed Press: Berkeley, CA)

Bougher NL and Syme K (1998) *Fungi of Southern Australia.* (University of Western Australia Press: Nedlands)

Fuhrer B (2005) *A field guide to Australian fungi.* (Bloomings Books: Melbourne)

Knudsen H and Vesterholt J (eds) (2008) *Funga Nordica.* (Nordsvamp: Copenhagen)

Marx DH (1969a) The influence of ectotrophic mycorrhizal fungi on the resistance of pine roots to pathogenic infections I. Antagonism of Mycorrhizal Fungi to Root Pathogenic Fungi and Soil Bacteria. *Phytopathology* **59**, 153-163.

Marx DH (1969b) The influence of ectotrophic mycorrhizal fungi on the resistance of pine roots to pathogenic infections II. Production, identification, and biological activity of antibiotics produced by *Leucopaxillus cerealis* var. *piceina* [sic]. *Phytopathology* **59**, 411-417.

Matheny PB, Curtis JM, Hofstetter V, Aime MC, Moncalvo J-M, Ge Z-W, Yang Z-L, Slot JC, Ammirati JF, Baroni TJ, Bougher NL, Hughes KW, Lodge DJ, Kerrigan RW, Seidl MT, Aanen DK, DeNitis M, Daniele GM, Desjardin DE, Kropp BR, Norvell LL, Parker A, Vellinga EC, Vilgalys R and Hibbett DS (2006) Major clades of Agaricales: a multilocus phylogenetic overview. *Mycologia* **98**, 982-995.

May TW, Milne J, Wood AE, Shingles S, Jones RH and Neish P (2006) Interactive Catalogue of Australian Fungi, version 3.0. Australian Biological Resources Study, Canberra/ Royal Botanic Gardens Melbourne.

Noordeloos ME (1995) *Leucopaxillus.* In *Flora Agaricina Neerlandica*, Vol. 3. Ed C Bas, ThW Kuyper, ME Noordeloos, EC Vellinga, R van Crevel and J Van Os (Balkema: Rotterdam)

Pfister JR (1988) Isolation and bioactivity of 2-aminoquinoline from *Leucopaxillus albissimus. Journal of Natural Products*, **51**, 969-1470.

Sakai S, Minoda K, Saito G, Akagi S, Ueno A and Fukuoka F (1955) On the anti-cancer action of quinoline derivatives. *Gann* **46**, 605-617.

Singer R (1986) *The Agaricales in Modern Taxonomy* 4th edn. (Koeltz Scientific Books: Koenigstein)

Singer R and Smith AH (1943) A monograph on the genus *Leucopaxillus* Boursier. *Papers of the Michigan Academy of Science Arts and Letters* **28** (1942), 85-132.

Singer R and Smith AH (1947) Additional notes on the genus *Leucopaxillus. Mycologia* **39**, 725-736.

Tedersoo L, May TW and Smith ME (2010) Ectomycorrhizal lifestyle in fungi: global diversity, distribution, and evolution of phylogenetic lineages. *Mycorrhiza* **20**, 217-263.

Vizzini A and Contu M (2009) The North American *Leucopaxillus monticola* (*L. cerealis* complex) newly recorded from Italy. *Mycotaxon* **109**, 469-475.

Received 24 November 2011; accepted 12 July 2012

Eighty-nine Years Ago

POLYPORUS MYLITTAE ... For fifty years or so the substance known as Native or Blackfellows' Bread had been discussed, but no definite conclusion had been come to regarding it until October, 1892, when Dr. M. C. Cooke, the well-known mycologist, announced in the Gardeners' Chronicle that at last the complete plant had been received, and that he intended to name it as *Polyporus mylittae.*

... It seems to me that the fungus may be more common than is usually supposed, as from its mode of growth it might often be gathered, even by a field naturalist, without any suspicion that it was attached by perhaps a rather long stem to the underground substance known as Native Bread. The specimen exhibited to-night grew from a broken sclerotium which was soft when I got it, and was put on a shelf as a curio. I did not happen to notice the growth, which is of velvety appearance and lemon-coloured, for about a fortnight afterwards, so whether it grew while the mass was soft, or after it had hardened, cannot say. As it is so rare, it is my intention to hand the specimen to the National Herbarium, which, I understand, does not possess a specimen.—F. G. A. BARNARD.

From *The Victorian Naturalist* **XXXIX**, pp. 159–160, March 8, 1923

The importance and value of urban forests as climate changes

GM Moore

Burnley College, The University of Melbourne,
500 Yarra Boulevard, Richmond, Victoria, 3121

Abstract

The aesthetic value of trees in the avenues, boulevards, parks and gardens of Australian cities is often widely appreciated, but their economic value is often under-valued. Trees provide services and fulfil functional roles in cities. They are significant components of urban infrastructure and have a real and calculable economic value. An urban forest of 100 000 trees can save $1million per annum because their shade reduces electricity consumption. Shade can prolong the life of tarmac, and carbon is sequestered as the trees grow. A single large tree growing in a school may provide the equivalent shade of four shade sails, returning a value of about $2000 per annum, while five trees can stabilise a steep suburban block which would otherwise require about $50 000 of engineered piling to secure building insurance. Calculation of the economic contributions of trees can change the economic algorithms upon which decisions are made in cities. (*The Victorian Naturalist* **129** (5) 2012, 167–174)

Keywords: urban trees, climate change, economic value, ecological services, carbon sequestration

Introduction

Mature trees are significant assets to our environment and our society regardless of where they occur or whether they are native or exotic. A great deal of effort has gone into establishing, managing, conserving and preserving them. Considerable human labour and time have been expended on the trees as well as real energy in the form of fossil fuel that has underpinned their maintenance. Significant quantities of water have been allocated to their growth and development. They are community assets in every sense. Society has invested resources in their establishment and management, and they have matured as assets and are providing many and diverse benefits to society in return (Moore 1997).

While costs, damage and nuisance values attributed to trees are widely known, the benefits they provide are often subtle and under-appreciated. A monetary value should be assigned to trees using an acceptable amenity tree valuation formula. This value raises the status of the tree to that of an asset, and allows for the proper recognition of trees in the decision making processes.

There are also benefits that the urban forest provides for improving human health, extending life spans, reducing violence and vandalism, lowering blood pressure and providing economic savings on medical and social infrastructure costs (Tarran 2006; Tapper 2010). Tapper (2010) notes that use of water during heat waves could reduce ambient temperatures by both surface evaporation and transpirational cooling, and that such cooling could reduce the number of extra deaths that occur, particularly among elderly people. In its submission on water use, the Victorian Department of health noted that one of their objectives was promoting health and wellbeing outcomes through promoting the use of alternative water resources such as stormwater to maintain green spaces, thereby enhancing physical activity and liveability (Dedman 2010).

Cities are biodiversity hot spots (Daniels and Tait 2005) due to the variety of habitats that are available in public and private open space. In the past decade, tree populations in many Australian cities have declined, particularly with the loss of private open space (Mullaly, 2000). At a time of climate change, it is worrying that both private and public open spaces are threatened by urban renewal and development, which puts at risk long-term sustainability (Moore 2009). In many of these situations there is insufficient open space—public or private—for the planting of large trees and so the opportunities for the role of vegetation in ameliorating the heat island effect, reducing wind speed, providing shade and reducing energy use are reduced. This outcome raises questions about the economic viability of such developments, as well as their long term environmental sustainability.

The impact of climate change on urban trees
Many parts of south eastern Australia recorded below average rainfall for the 14 years between 1997 and 2010. There have been major storm events (often described as 'one in a century' or 'one in 50 year' events) annually and sometimes two or three times annually in most States in each of the years 2005 to 2010 inclusive. There has not been a similar dry period in recorded history and the frequency of major storm events has increased. These events are consistent with climate change models and they are likely to become a permanent part of our environmental conditions (Table 1).

Regardless of how things eventuate, the possibility of more permanent global climate change is altering the environments within which trees are growing. Such changes are also resulting in the rapid change of the political, economic and social environments within which tree managers operate, and the decision making processes that ensue (Moore 2006). There will be more severe weather events more often in south-eastern Australia, which will be associated with stronger winds and more intense rainfall (Table 2).

Such changes will have profound impacts on urban tree managers. Increased storm events,could see higher rates of windthrow and major branch failure. In recent storm events there have been lengthy and widespread power outages, often caused by falling trees and branches. These events should have been used to inform management practices that might be appropriate under a changed climate scenario, where the undergrounding of utility services, particularly in areas of high population density, should be adopted immediately (Moore 2009).

It has long been argued that undergrounding utility services is cost effective if installation and long-term maintenance costs are considered. However, installation and maintenance are often done by different sectors. In some States, installation is by private energy providers and tree maintenance by private land owners and local government, but in other States installation is by State Governments and maintenance by local governments and there are even greater numbers of entities involved. Australian society cannot afford such an economically and environmentally unsustainable regime.

Recent and tragic bushfires in New South Wales, Canberra and Victoria have raised many concerns about tree management and infrastructure. The findings of the Victorian Royal Commission into the 2009 bushfires recommended the undergrounding of electricity services in fire prone regions (Anon 2010). However, the above ground cabling has been replaced, just as it was, and the opportunity for a modern, safer, underground system appears to have passed.

The value of services provided by urban trees
Urban trees and landscapes are assets that require the expenditure of resources on their proper management. Questions that might be asked are: 'What is the value of the benefits that are provided by trees?' Or perhaps 'What does society get in return?' This paper deals with a number of functions or services that are provided by urban trees and calculates the economic value of that function or service.

In this paper, the economic value provided by an urban forest population of 100 000 mature trees is used as the basis of calculations. The number of 100 000 was chosen because such discussions are often about the number of mature trees managed by a single municipality. In other instances, values associated with individual trees are determined. All values have been calculated in Australian dollars (AUD) and at the time of writing, an Australian dollar is worth approximately 1.02 American dollars.

The value of shade from savings in electricity and water
The shade provided by trees can lower ambient temperatures by up to 8°C, reducing air conditioner use and carbon emissions. Estimates put the electricity savings at between 12 and 15% per annum. Manchester University's Adaptation Strategies for Climate Change in the Urban Environment Project found that increasing green space in cities by 10% reduced temperatures by 4°C, due to water evaporating from vegetation into the air (Fisher 2007). One of the major economic benefits of shade in the context of the Australian climate is reduced air temperatures that then reduce the use of air conditioners. This not only saves on electricity use but, since much of the power in Australia is generated by coal, also reduces carbon emissions (Fisher 2007).

Table 1. Current data trends on global warming and predictions of the likely outcomes for climate and sea level related changes (modified from Moore 2009).

FACTOR	HOW WE ARE TRACKING	PREDICTION
Global temperature	The last 30 years have been the warmest of the past 200 years	Suggests that temperature rises will be at or above the worst case scenario of 6–8°C
Australia terrestrial temperatures	Have increased by 1°C in the past 50 years	Is in line with higher rather than lower temperature predictions and a rise of 4°C is likely
La Nina Events	The last two years 2010-11 and 2011-12 were La Nina years and wet	2011 was the warmest La Nina event of the past 150 years and rainfall is still trending down
Drought in Victoria	After 14 below average rainfall years the past two have been above average	There will be an increased drought frequency for the State — likely to be 3–4 more droughts than over the past century
Sea levels	Have risen by 3 mm per annum for the past 15 years	Consistent with higher sea level predictions of greater than 60 cm
Global ocean heat	The heat content of global oceans is rising and it embodies massive extra energy	Consistent with temperature rises at or above the worst case scenario of 6–8°C
Atmospheric CO_2 levels	CO_2 levels for 2011 are at 390 ppm, the highest level for the past 1000 years	These are above the predicted worst case scenario and could exceed 1000 ppm
Safe atmospheric CO_2 levels	The environmentally safe level seems to be about 350 ppm, and for the past 200 000 years they have been at about 280 ppm	Atmospheric CO_2 levels are likely to rise to between about 500 and 1000 ppm, which could cause a major extinction event
Arctic ice cap	Melting more rapidly than expected. It seems the northern hemisphere is warming more rapidly than the south	Could melt as early as 2015 rather than 2040-2050 as was originally predicted
Melting polar ice caps	Melting more rapidly	Only 3% of the extra energy absorbed in global warming has gone into heating the atmosphere. Most has gone in melting the ice caps
Reflection of radiation by ice caps	As they diminish in size, less radiation is reflected from earth	Heating of the planet will accelerate to, or above, the worst case scenario

In the State of Victoria, where most of the State's electricity is from brown coal generation, this reduction in emissions is significant. Furthermore, in the generation of electricity from brown coal approximately 100L of water is used in the production of 1.0 kWh of electricity (Fisher 2007). So the shade provided by trees can also generate a saving of water that can be valued (Table 3). The shade from each tree saves 30 kWh of electricity per annum so an urban forest of 100 000 trees saves some 3 million kWh per annum. The combined savings from reduced electricity and water use are close to $1 million per annum.

The value of carbon sequestered in an urban forest

Mature trees are significant sinks of carbon, sequestering atmospheric carbon dioxide for long periods. The amount of carbon sequestered in a mature urban tree is not easy to determine accurately, but estimates can be made (McPherson 2007). Moore (2006) estimated the amount of carbon in a mature tree of 100 t total fresh weight for foliage, trunk and root system at approximately 10 t. However, these estimates can be revised as it is more likely that in older woody trees there is about 13 t (assuming 20% dry weight, with carbon constituting some 65% of the dry matter).

Table 2. Likely outcomes from climate related changes in south eastern Australia.

- Generally warmer winters and hotter summers
- A more tropical climate extending southward
- More easterly winds leading to summer storms
- More frequent major storm events
- More days of extreme fire risk weather
- More bushfire prone regions, extending to peri-urban parts of major cities
- Changed weather and fire patterns
- Fewer frosts, and in some places elimination of frosts completely
- Many more days above 30°C and double the number of days above 35°C
- Higher summer rainfall with more intense rainfall events
- Flooding of lowland coastal areas – probably minor
- For every one degree that temperatures rise, the snowline rises 100 m
- Agricultural productivity will change, in some cases improving
- Some crops will not be grown but others will become viable
- Housing and building construction processes will change
- Energy demands and patterns of use will alter

The value of the carbon sequestered can then be calculated using the current value of carbon per tonne established by the Australian carbon tax — $23 per tonne. There is debate about the validity of this value but it will be maintained until 2015, and it has been predicted that the price should be closer to $30 per tonne and could double over the next few years (Garnaut 2011). Using estimates for 100 000 mature trees, there are about $30 million worth of carbon sequestered (Table 4). To calculate the amount of carbon dioxide sequestered, multiply the weight of carbon by 3.67.

The cost of pruning for overhead utility cables
The calculations used to determine the value of carbon sequestered can be applied to the effects that pruning mature trees for construction and the installation of utility services, such as powerlines or communication cables, might have on carbon sequestered (Table 5). Different pruning regimes remove different proportions of the canopy, and so data for 30, 20 and 10% canopy reductions are shown. Given that pruning contracts and operations managed by local governments usually involve hundreds of trees, it is worth estimating overall carbon losses for pruning 100 trees (Table 5). These values could affect the economic value of pruning as a management tool, and could see the undergrounding of services, especially when the costs for three and five year pruning cycles are calculated.

Similar calculations can be applied to root damage and loss when roots are severed for construction and utility installation. There is growing evidence that there has been a general and significant undervaluation of carbon fixed below ground by mycorrhizae and microbes associated with plant root systems. Values for tree related carbon are likely to be considerably higher than any of the algorithms currently in use have so far revealed.

The value of shade in prolonging the useful life of bitumen in a tree lined street
Bitumen is a super-cooled liquid mixed with solvents, which can evaporate under the hot conditions typical of south-eastern Australia. This renders the surface of the tarmac crumbly as the asphalt degrades and reduces the useful life of the pavement. The presence of shade from trees can increase the useful life of asphalt pavement by at least 30%, but there are estimates that prolonged shade from trees can double or triple the useful life of bitumen pavements (McPherson and Muchnick 2005).

In this paper, it is estimated that a mature tree canopy with a spread of about 6 m radius provides some 113 m^2 of shade. If the shade from 33% of the canopy affects bitumen below the tree, then this represents an area of 37.3 m^2. The estimate of value is based on the premise that the life of shaded bitumen is extended by 50% from 20 years to 30 years (Table 6). It is conceded that small patches of shade do not represent real savings and it is only when extensive contiguous shade occurs that the savings are realised in the prolongation of the useful life of the bitumen. This is more likely to occur for pavements along narrow tree-lined streets and so the value of shade for a tree lined street 500 m in length, lined on each side by 50 mature trees has been calculated (Table 6).

The role value of trees in roadside reserves
Governments, through their agencies, are still major clearers of trees, forests and ecosystems.

Table 3. Economic value of shade from an urban forest of 100 000 trees.

Approximations used	Value
Number of trees in the urban forest population	100 000
Electricity saving due to shade per tree per annum (kWh per annum)	30
Total electricity saving per annum (kWh)	3 million
$ value of electricity per kWh	0.17
Total $ value of electricity saving per annum	510,000
$ value of savings in electricity use per annum for one tree	5.10
Water saved by reduced electricity use at 100 L per kWh (L)	300 million
Total $ value of water saved at $1.50 per kilolitre per annum	450,000
$ value of savings in water use per annum for one tree	4.50
Total $ value of savings in electricity and water use per annum	960 000

Table 4. Carbon fixed in urban forest of 100 000 trees.

Approximations used	Value
Number of trees in an urban forest population	100 000
Average weight of whole tree - above and below ground (tonnes, t)	100
Water content (%) of tree (approximation)	80
Dry matter mass of trees (%) (varies, so conservative estimate)	20
Carbon content of dry matter (%) (varies, so conservative estimate)	50
Amount of carbon sequestered in each tree (t)	13
Total carbon sequestered in an urban forest of 100,000 trees (t)	1 300 000
Total carbon dioxide sequestered in 100 000 trees (t)	4 771 000
$ value of carbon sequestered by 100 000 trees at $23/t	29.9 million

In most States, approaches to roadside vegetation at a time of climate change are inappropriate. Trees and roadside ecosystems are assets that fix carbon, provide shade, filter air, protect from wind, and provide wildlife corridors and habitat just to mention a few of their benefits. It is to be hoped that these benefits are properly costed for road-related projects where a balance of safety, cost and the environment has to be achieved.

However, roadside vegetation is still being cleared right across the country, despite the fact that it sequesters massive amounts of carbon that could be used to partially offset the carbon produced by the vehicles that use the roads. An old-fashioned and inflexible engineering philosophy about trees and the environment is no longer an appropriate paradigm at a time of climate change. It is clear that often the real and full economics of the situation are not properly considered.

Furthermore, in Britain, an $122 000 scheme to plant trees increasingly closer to the roadside verge is part of a $2.5 million scheme to reduce speed and improve safety (Lister 2010). Trees are also planted at so-called 'lazy diagonals' making the road appear to narrow as you approach small towns and villages. Motorists naturally tend to slow up in response.

The value of trees in land stabilisation

After the recent fires in the State of Victoria, a large number of trees were cleared from building sites. When it came to rebuilding after the fire, on at least one site, insurance companies would not insure the site because it was classed as unstable due to the risk of landslip. At least five large trees had been removed from the site along with other smaller trees and large shrubs.

There were remedies available which would satisfy criteria for insurance. One was to leave the site and allow for regeneration which would take a minimum of 10 years, reducing the use and value of the site over this period. The alternative was to use engineering techniques, such as piling to secure the site's stability, which would cost between $40 000 to $60 000 depending on the technique used and the contractors' bids, at a likely cost of about $50 000.

Given this scenario, each of the five large trees was providing a total value of $10 000 to the site (Table 7). Using the natural regeneration pe-

Table 5. Carbon lost and its value for pruning 100 mature urban tree canopies.

Approximations used	Single Tree	100 Trees
Average weight of whole tree, including above and below ground components (t)	100	
Amount of carbon sequestered in each tree (t)	13	
Amount of carbon sequestered in the canopy of each tree (t)	6.5	
Amount of carbon lost if 30% of canopy pruned from each tree (t)	1.95	195
Amount of carbon lost if 20% of canopy pruned from each tree (t)	1.30	130
Amount of carbon lost if 10% of canopy pruned from each tree (t)	0.65	65
$ value of 1 tonne of carbon	23	23
$ value of carbon pruned from 100 trees when 30% pruned	44.85	4485.00
$ value of carbon pruned from 100 trees when 20% pruned	29.90	2990.00
$ value of carbon pruned from 100 trees when 10% pruned	14.95	1495.00

Table 6. Economic value of shade for an urban street lined by 100 trees prolonging the life of bitumen.

Approximations used	Value
Estimated length of street (m)	500
Width of road surface (m)	7
Area of Bitumen road surface (m^2)	3500
50 trees on each side of the street so total number of trees	100
Shade from an individual tree canopy (m^2)	75
Area of bitumen shaded by tree canopy, estimated at 33% of total (m^2)	37.3
Total area of bitumen shaded by tree population of 100 trees (m^2)	3730
Cost ($) of resurfacing bitumen per m^2	450.00
Total $ value of extending the life of the shaded bitumen from 20 to 30 years due to the 33% shade from 100 trees	1678500

riod of 10 years, it can be estimated that each tree was contributing about $1000 per annum of function or service in securing the stability of the house site. The service could be valued over the projected life spans of the trees, which can be estimated at 50 years, which would see a $50000 benefit from five trees amortised over 50 years at $1000 per annum for $200 per annum per tree.

Value of shade in schools and other public buildings

After the 2009 wild fires in Victoria, the government moved to take action in schools located in designated bush fire regions of the State to make them more fire safe. The guidelines required the removal of trees that were closer than 30 m to school buildings.

Consequently, during the September-October holiday period of 2009, large trees were removed from several schools. One tree was removed from the middle of a large area of tarmac and several were removed from around sporting ovals and play areas where the fire risks posed by the trees were minimal. On the first hot and sunny days of late October and November, it became obvious that there was a problem. Without the trees there was no shade and during the Australian summer this posed serious health risks such as sunburn, heat stroke and skin cancer.

The remedy was simple and expensive — the installation of shade sails. There were no budgetary provisions for such costly items late in the school year. In some cases the shade provided by a single tree meant that more than one shade sail was required to compensate for the loss. However, this action has allowed the value of shade from trees in these schools to be calculated assuming the trees are at such a distance from buildings and other surfaces that there are no other compounding values (Table 8). Clearly, shade from the tree growing in the bitumen play ground may have had the added benefit of prolonging the life of the tarmac. The formula for the calculation for an individual tree is the cost of the shade sail multiplied by the number of sails required (usually one but up to four) to compensate for the shade lost.

Table 7. Economic value of trees in stabilising a suburban house site from landslip.

	Piling Replacement	Amortisation of Value from 5 trees over 50 years
Number of trees	5	5
Cost ($) of Piling	50 000.00	50 000.00
Total value ($) of 5 trees	50 000.00	1000.00 per annum
Value ($) per tree per annum	1000.00	200.00

Table 8. Economic value of urban trees in providing outdoor shade for schools and other public buildings.

	Shade sail Replacement Option
Cost ($) of shade sail (50 m^2 and support poles)	5000.00
Number of shade sails required	1
Useful life of shade Sail (Years)	10
$ value of shade provided by tree over 10 years	5000.00
$ value of shade provided by tree per annum	500.00

The value of trees in flood mitigation

Trees and public open space have a role under a changed climate in holding and absorbing water during intense rainfall events. Such a role has profound implications for the behaviour of storm water systems in cities and the role of trees in reducing localised flooding. It is not economically feasible to retrofit larger stormwater drains and alter the levels at which they enter waterways. However, trees hold rainwater on their canopies, and through transpiration significantly reduce the amount of water entering drains. Estimates suggest that trees may hold up to 40% of the rain water that impacts on them and that as little as 40% of water striking trees may enter drains (Moore 2009). This can reduce the immediate storm water load and spread the load over a longer period of time, which can reduce the need for larger stormwater pipes.

Because retrofitting larger pipes is so costly, there are trials in most major Australian cites which divert stormwater into small local retention basins or into specially designed planting pits that contain trees or other plants (Daniels 2010). Stormwater contains pollutants, particularly phosphorus and nitrogen, but when the stormwater passes into planting pits containing trees, the trees remove most of the pollutant load before it enters streams or aquifers (Denman *et al.* 2006). The extra nutrients have a fertilising effect on the trees, which grow better (Denman 2006). The removal of pollutants by trees in this way is a service that has real and calculable value.

Furthermore, along Taylor's Creek, Keilor, trees planted in a revegetation scheme in the 1980s have slowed flood water, reducing erosion and stream-side scouring. The waters are spread over a greater area, but this was available and so did not result in further or extra damage from flooding. An unexpected consequence was that litter was spread away from the creek and was left behind when the water receded. The litter can be easily and cheaply collected from the edges of the flood plain much closer to its source and with less environmental impact than it would once it entered the Maribyrnong River or Port Phillip Bay. The economic benefits of both reduced erosion and easier local litter collection could be established.

Conclusion

The economic benefits of trees are often subtle, provided over long periods of time so tend to be under-appreciated. Urban trees provide infrastructure functions and ecological services to society and have real and calculable economic value. When these values are considered, the economic algorithms and paradigms that have applied to the management of trees in urban environments will change rapidly and as a consequence the economic imperatives that apply to managing trees will change under a thorough cost/benefit analysis.

Mature trees continue to have a significant place in urban landscapes and they must be managed to ensure that they remain healthy and fulfil the full potential of their lifespans. They are assets that warrant the expenditure of resources such as labour, energy and water. Such expenditure is not wasted, as trees and urban landscapes provide far more value economically and ecologically than they use. In any comprehensive and fair calculation, urban trees and landscapes are worth more than they cost. As a truly Australian urban landscape, which values trees and recognises aridity and changed climate, emerges, it will be understood that urban trees are worth much more than they cost and that they are the keys to urban sustainability.

Acknowledgement
The author thanks Ms E Moore, linguist, for her suggestions for improving the manuscript.

References

Anon (2010) Final report, 2009 Victorian Bushfires Royal Commission. Final Report. (Victorian Government: Melbourne)

Daniels CB and Tait CJ (eds) (2005) *Adelaide - Nature of a city: the ecology of a dynamic city from 1836 to 2036*. (BioCity: Centre for Urban Habitats: Adelaide)

Daniels CB (ed) (2010) *Adelaide: Water of a City*. (Wakefield Press: Adelaide)

Dedman R (2010) Alternative water supplies for health and wellbeing. (Victorian Department of Health: Melbourne)

Denman L, Breen PF and May PB (2006) An investigation of the potential to use street trees and their root zone soils to remove nitrogen from urban stormwater. *Australian Journal of Water Resources* **10**, 303–311.

Denman L (2006) Are street trees and their soils an effective stormwater treatment measure? In *Proceedings of the Seventh National Street Tree Symposium*, pp.1–10. Eds D Lawry, DC Christophel and S Smith (TREENET/University of Adelaide: Adelaide)

Fisher P (2007) Why we need the urban forest. *Urban Magazine* July 2007.

Garnaut R (2011) *The Garnaut Review 2011: Australia in the Global Response to Climate Change*. (Cambridge University Press: Port Melbourne)

Lister T (2010) Can't see the speedo for the trees. *The Times*, 16 August 2010.

McPherson EG (2007) Benefit based tree evaluation. *Journal of Arboriculture & Urban Forestry* 33, 1–11.

McPherson EG and Muchnick J (2005) Effects of street tree shade on asphalt concrete pavement performance. *Journal of Arboriculture* **31**, 303–310.

Moore GM (1997) Benefits of street trees, *Arbor Age* 3–8

Moore GM (2006) Urban trees and the global greenhouse. In *Proceedings of the Seventh National Street Tree Symposium*, pp 23-28. Eds D Lawry, DC Christophel and S Smith (TREENET/University of Adelaide: Adelaide)

Moore GM (2009) People, Trees, Landscapes and Climate Change. In *Climate Change On for Young and Old*, pp 132–149. Ed H Sykes. (Future Leaders: Melbourne)

Mullaly J (2000) Aerial Photographic Analysis of the Urban Forest. (Unpublished Honours Thesis, Burnley College, University of Melbourne)

Tapper N (2010) How Trees save lives: the role of a well watered landscape in liveable cities. In *Proceedings of the Eleventh National Street Tree Symposium*, pp 25–33. Eds D Lawry and B Merrett. University of Adelaide/Waite Arboretum, Adelaide.

Tarran J (2006) Trees, urban ecology and community health. In *Proceedings of the Seventh National Street Tree Symposium*, pp. 58–71. Eds D Lawry, DC Christophel and S Smith. (TREENET/University of Adelaide)

Received 7 June 2012; accepted 2 August 2012

One Hundred Years Ago

VICTORIAN STATE FORESTS.—The recently issued report of the Department of State Forests, Victoria, for the year ending 30th June last, contains some interesting information. The Conservator of Forests says the output of sawn hardwood for the year was about 53,000,000 feet, of which the Warburton, Toolangi, and Yea division contributed nearly 30,000,000, while the Otway and Heytesbury mills cut 9,300,000 feet. The production of red gum by the mills along the Murray amounted to 3,930,000 feet. A gratifying record is given of various works carried out for the improvement of the forests, and of the work done in the nurseries and plantations, some 2,750,000 seedlings having been put out. In a report on the giant trees of Victoria, Mr. A. D. Hardy, F.L.S., summarizes such information as has been published from time to time regarding the tall trees of the State, from which it appears that Baron von Mueller's statement that he had measured trees of 420 feet and 480 feet on the Blacks' Spur is questioned. A definite record exists of a prostrate tree in the Otway Forest measuring 329 feet to where the top was broken off, at which point the stem diameter was still 10 inches, the general conclusion being that there are many trees still existing of 300 feet and slightly over. As regards girth, 64 feet at 8 feet from the ground, also an Otway Forest specimen, seems to be the record. These figures closely approximate those of the Redwoods of California, definite measurements of which also seem difficult to obtain.

From *The Victorian Naturalist* **XXVIII**, p. 195, February 8, 1912

The application of Zoos Victoria's 'Fighting Extinction' commitment to the conservation of Leadbeater's Possum *Gymnobelideus leadbeateri*

Dan Harley

Wildlife Conservation and Science Department, Zoos Victoria
Email: dharley@zoo.org.au

Abstract
As part of its 'Fighting Extinction' program, Zoos Victoria has developed criteria to guide when it will initiate captive-breeding programs for native threatened species. Application of these criteria, which are based on extinction risk, has resulted in the identification of twenty priority threatened species for ex situ conservation. This list includes the genetically-distinct lowland population of Leadbeater's Possum. As a result, a captive-breeding program has been initiated to prevent the extinction of this population. The 'Fighting Extinction' strategy represents a more structured, systematic and integrated approach to how Zoos Victoria is attempting to deliver tangible conservation outcomes. Notably, measures of success are tied to the condition of wild populations. Aspects of the 'Fighting Extinction' strategy and the Leadbeater's Possum captive-breeding program are described. (*The Victorian Naturalist* **129** (5) 2012, 175-180)

Keywords: Leadbeater's Possum; captive-breeding; zoo; threatened species; extinction

In its 20-year strategic plan, Zoos Victoria has committed to transforming itself into a 'zoo-based conservation organisation' that delivers tangible conservation outcomes for wildlife populations. Considerable effort has gone into defining precisely what this means, and the strategy highlights that the organisation is not just concerned with the captive collection, but is very much focused on the condition of wild populations. In terms of delivering tangible outcomes, the conservation of native threatened species has been identified as a clear priority, and forms one of the central elements to a more holistic conservation approach that has been developed under the banner 'Fighting Extinction'. Part of this approach is outlined below.

'Fighting Extinction'

To create greater transparency around when we will initiate captive-breeding programs for native threatened species, the following commitment has been made:

> 'Zoos Victoria will ensure that no Victorian species of terrestrial vertebrate become extinct.'

The focus on terrestrial vertebrates reflects the expertise at Zoos Victoria's three properties, Melbourne Zoo, Werribee Open Range Zoo and Healesville Sanctuary.

In applying this criterion, Victorian species have been assessed and prioritized based on their likelihood of extinction in the wild over the next 10 years. These qualitative determinations focused on population size and trend, extent of distribution and key threatening processes. In addition to the eleven captive-breeding programs that Zoos Victoria already had in place for species occurring in south-eastern Australia (seven of which targeted Victorian species; see Table 1), this review identified nine additional Victorian species warranting *ex situ* recovery measures (Table 2), including Leadbeater's Possum *Gymnobelideus leadbeateri*. Hence, Zoos Victoria has arrived at a priority list of 20 native threatened species. This list will be reviewed periodically, and species added or removed as new data become available and/or circumstances in the wild change. Note that under these criteria, *ex situ* intervention is not triggered for species that are in decline within Victoria but have strongholds in other States or Territories.

Having a clear understanding of why we are focused on certain species and not others has created greater clarity in where Zoos Victoria invests resources. New captive programs have already been initiated for four of the nine species listed in Table 2. For these additional species, our approach first involves the establishment of captive populations, followed by subsequent releases to the wild to recover populations.

Three of Victoria's highest profile threatened species highlight the important role that zoos can play in conservation. The mainland Eastern Barred Bandicoot *Perameles gunnii* unnamed

Table 1. The 11 native threatened species included in Zoos Victoria's captive-breeding programs prior to 2011.

Common Name	Scientific Name	Conservation Status (EPBC Act)	Year commenced	Captive breeding	Reintroduction
Tasmanian Devil	*Sarcophilus harrisii*	Endangered	2006	✓	
Mountain Pygmy Possum	*Burramys parvus*	Endangered	2007	✓	
Eastern Barred Bandicoot (mainland)	*Perameles gunnii* unnamed subspp.	Endangered	1990	✓	✓
Orange-bellied Parrot	*Neophema chrysogaster*	Critically Endangered	1991	✓	✓
Helmeted Honeyeater	*Lichenostomus melanops cassidix*	Endangered	1989	✓	✓
Regent Honeyeater	*Anthochaera phrygia*	Endangered	2002	✓	
Spotted Tree Frog	*Litoria spenceri*	Endangered	2006	✓	✓
Southern Barred Frog	*Mixophyes balbus*	Vulnerable	2001	✓	
Southern Corroboree Frog	*Pseudophryne corroboree*	Endangered	2008	✓	✓
Northern Corroboree Frog	*Pseudophryne pengilleyi*	Vulnerable	2010	✓	✓
Lord Howe Island Stick Insect	*Dryococelus australis*	Critically Endangered	2003	✓	

Table 2. The nine additional Victorian threatened species identified as warranting *ex situ* intervention under Zoos Victoria's 'Fighting Extinction' commitment.

Common Name	Scientific Name	Conservation Status (EPBC Act)
Leadbeater's Possum (Yellingbo ESU)	*Gymnobelideus leadbeateri*	Endangered
Brush-tailed Rock-wallaby (Southern ESU)	*Petrogale penicillata*	Vulnerable
Smoky Mouse	*Pseudomys fumeus*	Endangered
New Holland Mouse	*Pseudomys novaehollandiae*	Vulnerable
Southern Bent-wing Bat	*Miniopterus schreibersii bassanii*	Critically Endangered
Grassland Earless Dragon	*Tympanocryptis pinguicolla*	Endangered
Alpine She-oak Skink	*Cyclodomorphus praealtus*	Endangered
Guthega Skink	*Liopholis guthega*	Endangered
Baw Baw Frog	*Philoria frosti*	Endangered

subspp. would be extinct if it were not for the breeding and release program undertaken by Melbourne Zoo. Similarly the Helmeted Honeyeater *Lichenostomus melanops cassidix* may be extinct if it were not for the breeding and release program undertaken by Healesville Sanctuary. And the Orange-bellied Parrot *Neophema chrysogaster* is predicted to go extinct in the wild during the next five years; however a large insurance population has been established in captivity. All the recovery potential for these Victorian species rests on successful captive-breeding and release programs. Conversely, each of these breeding programs has been in place for about 20 years and yet wild populations for each species remain at risk. Thus, some adjustments are required to the recovery models being applied.

In recognition of the need to increase the effectiveness of captive-breeding and release programs, Zoos Victoria has made several changes in how it is approaching threatened species recovery. We are working with recovery teams to achieve greater clarity and integration of the recovery targets for the wild and captive components to these programs. Too often in the past, the parties driving *in situ* and *ex situ* recovery measures have operated independently of one another. If the captive-breeding programs exist fundamentally to serve the wild, then ultimately they should be responsive to the recovery needs of the wild populations.

In order to minimise the loss of genetic diversity in captive populations, we are looking to manage our threatened species as part of captive–wild metapopulations. This involves periodic transfer of individuals between all populations, regardless of whether they are captive or wild, to maintain gene flow. This is already being done effectively for the Helmeted Honeyeater. We also recognise that the 'quality' of the individuals being bred in captivity has important implications for success when we come to release to the wild. This has become a major research focus for Zoos Victoria, and includes the application of techniques to promote mate choice and the retention of appropriate wild behaviours in captive populations.

Finally, the ultimate measure of success for our 'Fighting Extinction' programs is the condition of wild populations. Specific five-year and 20-year recovery objectives have been developed for each species in the wild and captivity, resulting in greater integration of *in situ* and *ex situ* approaches.

Leadbeater's Possum

Leadbeater's Possum is a small (110–160 g), arboreal marsupial that was thought to be extinct prior to its rediscovery near Marysville in 1961 (Wilkinson,1961). The possum is the only species of native mammal restricted in distribution entirely to Victoria, and its current range is confined to a 70 × 80 km area centred on montane habitats in the Victorian Central Highlands (see Harley 2004). A single, remnant, outlying population occurs in lowland habitats at Yellingbo Nature Conservation Reserve (Harley *et al.* 2005). Molecular data have revealed that the lowland population at Yellingbo is genetically distinct from populations occupying montane habitats (Hansen 2008; Hansen and Taylor 2008; Hansen *et al.* 2009). Owing to its restricted distribution, small population size (< 2000 individuals) and the loss of mature, hollow-bearing trees that provide dens, the species is currently listed as 'endangered' under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* and 'threatened' under the *Victorian Flora and Fauna Guarantee Act 1988*. Notably, the Black Saturday wildfires in 2009 burnt approximately 45% of the high quality habitat for the species (S. Smith, unpubl. data), greatly elevating the extinction risk for this species.

Zoos Victoria has assessed the extinction likelihood for Leadbeater's Possum populations in montane habitats and at Yellingbo against its 'Fighting Extinction' criteria (i.e. our trigger for captive intervention). The montane populations are in serious decline, particularly following the Black Saturday fires, and the extinction risk is very real over coming decades. However, the species is not likely to become extinct across the entire Central Highlands during the next 10 years, and hence they do not yet trigger *ex situ* intervention. Moreover, the key challenges in the Central Highlands are related to habitat conditions, and captive-breeding is not an appropriate tool to address this problem.

In contrast, the small, genetically-distinct lowland population at Yellingbo does meet Zoos Victoria's criteria for *ex situ* intervention, as a single fire could eliminate the entire population given its localized occurrence. Hence, this population is the focus of Zoos Victoria's captive-breeding and release program.

Population monitoring for the lowland Leadbeater's Possums at Yellingbo has been underway for 17 years (Harley 2005; Harley and Antrobus unpubl. data). Data describing the species' population dynamics at this site is the best available for any Victorian mammal (given it is a closed population and more than 90% of the total population is sampled every year). The annual monitoring program results in several measures of population condition, including total population size, distribution, territory stability, mean colony size, reproductive rate, annual recruitment and dispersal. The current size of the population is approximately 60 individuals, and it has declined by 46% during the past nine years (Harley and Antrobus, unpubl. data). Changes in the genetic characteristics of the population over the past 10 years are currently being assessed. The key threat to this population is the serious decline in habitat conditions in the reserve, and as a consequence the availability of suitable foraging habitat has become the key limiting factor (Harley *et al.* 2005; Harley, unpubl. data).

Zoos Victoria has developed five-year and 20-year objectives for the recovery of Leadbeater's Possum in lowland habitats (covering both wild and captive populations). The five-year objectives developed for the wild emphasise the need to address habitat decline at Yellingbo, the key threatening process at this site. To achieve this, Zoos Victoria needs to work with partners such as Parks Victoria, highlighting the importance of integrating *in situ* and *ex situ* recovery measures.

In captivity, the five-year objectives are as follows:

1. Healesville Sanctuary and Melbourne Zoo house a viable captive insurance population comprising at least 20 individuals for the genetically-distinct lowland population of Leadbeater's Possum at Yellingbo.
2. Captive possums are managed to promote successful breeding and maintain wild behaviours.
3. Release techniques are developed to successfully establish captive-bred individuals in the wild.
4. Zoos Victoria provides unique opportunities for the public to engage with Leadbeater's Possum and its conservation.

The first four founders for the captive population were collected during May 2012 and are now housed at Healesville Sanctuary. The collection schedule for founders is four possums per year for three years. Collection has been staggered over time to minimise any negative impact on the wild population. Individuals are being selected based on their genetic attributes and to avoid disrupting colony structure (e.g. collection of dispersal-age subadults). The target size of the insurance population is 20–30 individuals, and this will be spread across two properties, Healesville Sanctuary and Melbourne Zoo. We intend to manage the insurance population as part of a captive–wild metapopulation, albeit this requires us to be able to successfully establish captive-bred young in the wild.

We are placing considerable emphasis on trying to maintain key wild behaviours in the captive possums, and this is being reflected in the types of animal monitoring we are undertaking (e.g. filming visitation to food stations and activity periods). We are using the behaviour exhibited by the wild-caught founders as a benchmark against which we can assess captive-bred young in future years.

Our ultimate goal is recovery of wild populations of Leadbeater's Possum in lowland habitats. The 20-year objectives for the wild define our vision of success, and are as follows:

1. Wild population size at Yellingbo exceeds 150 individuals.
2. Greater than 25% of the Cockatoo and Macclesfield Creek floodplains provide high quality habitat for Leadbeater's Possums.
3. Population and habitat monitoring programs maintained for Leadbeater's Possum at Yellingbo.
4. Establishment of at least one additional lowland population containing a minimum of 50 individuals.

Note that these objectives list a minimum population size for Yellingbo (≥150 individuals) that should be self-sustaining in terms of population processes. They also specify the area of habitat required to achieve this population target, and identify the need to establish additional lowland populations away from Yellingbo. The latter point highlights that success with this species ultimately means that we would no longer require an insurance population in captivity.

There are two key reasons why Zoos Victoria has directed its conservation efforts at the Yellingbo population of Leadbeater's Possum: (i) this population is at the greatest risk of extinction in the short-term (i.e. within 10 years), and (ii) the population is genetically distinct. In 2011, the Leadbeater's Possum Recovery Team debated whether conservation of the unique lowland genes at Yellingbo is of high importance. The consensus was it is important to protect them. Moreover, conservation of genetic diversity across a species' range is an important principle, and this has been reflected in the approach of the Victorian Government where several high-profile threatened species recovery programs target subspecies or genetically-distinct populations ('Evolutionarily Significant Units'), e.g. Red-tailed Black-Cockatoo, Helmeted Honeyeater, Eastern Barred Bandicoot, Brush-tailed Rock-wallaby, Mountain Pygmy Possum.

Action for the Yellingbo population of Leadbeater's Possum alone is clearly insufficient to adequately conserve this species. The species' stronghold is in the montane forests of the Victorian Central Highlands, and consequently the main conservation focus from government should be directed there. Greater recovery focus on the montane populations following the Black Saturday fires is clearly warranted. In applying a holistic conservation strategy for this species (that incorporates risk-spreading), recovery models (and actions) should be articulated for all three forest types that Leadbeater's Possum inhabits (i.e. montane ash forest, subalpine woodland and lowland swamp forest) that take account of the different threats and management issues.

Community Engagement

Melbourne Zoo, Werribee Open Range Zoo and Healesville Sanctuary attracted approximately 1.9 million visitors in 2011. A high proportion of this audience lives in urban environments, yet the majority of threatened species issues occur in regional areas. Zoos have a unique opportunity to bridge this gap, connect people with the issues and provide them with simple things they can do to assist. In recognition of this, Zoos Victoria has developed specific 'visitor objectives' to sit alongside our breeding and release targets. The 'Wipe for Wildlife' campaign at Healesville Sanctuary urging visitors to use recycled toilet paper to reduce the number of trees harvested is an example of this approach. Importantly, subsequent uptake among visitors is being measured. In association with the Leadbeater's Possum program we are promoting the use of Forest Stewardship Council (FSC) certified timber and paper products. These programs apply the Connect–Understand–Act model developed by Rachel Lowry, Zoos Victoria's Director of Wildlife Conservation & Science, to promote behaviour change amongst our visitors in ways that will benefit wildlife populations.

Zoos Victoria's 20 priority species are being promoted to the Victorian community under the banner 'Love you Locals'. And we are in the process of testing some different techniques to raise the profile of these species. Part of this involves a major campaign at Healesville Sanctuary that aims to get children to connect with Leadbeater's Possum through the creation of a cartoon character (Lunar) and an animated interactive display (Lunar's Secret Forest).

Conclusion

Several distinct changes are evident in how Zoos Victoria is currently tackling threatened species recovery through its 'Fighting Extinction' program. These include the following:

- criteria to guide when we will initiate captive-breeding programs for native species;
- closer integration between management of the wild and captive populations;
- measures of success that are tied to the condition of wild populations;
- establishment of captive–wild metapopulations to minimise the loss of genetic diversity and maintain appropriate behaviours;
- research programs directed at improving the quality of individuals bred in captivity;
- major focus on increasing community understanding and engagement with our threatened species programs. This includes use of the Connect–Understand–Act model to promote behaviour change in our visitors.

This strategy represents a more structured, systematic and integrated approach to how Zoos Victoria is attempting to deliver 'tangible' conservation outcomes.

Acknowledgements

Many people have contributed to the development of Zoos Victoria's 'Fighting Extinction' program. In particular, I would like to acknowledge the contributions made by the following Zoos Victoria staff: Rachel Lowry, Michael Magrath, Chris Banks, Marissa Parrott, Emily Dunstan, Russel Traher, Melanie Lancaster and Paul Watson. Valuable ideas have also been contributed by Graeme Gillespie, Andrew Weeks, Richard Hill, Graeme Coulson, Joanne Antrobus and several recovery teams. The success of these projects would not be possible without the support provided by the Victorian Department of Sustainability and Environment and Parks Victoria. The manuscript was improved by comments from Michael Magrath and Marianne Worley.

References

Hansen BD (2008). Population genetic structure of Leadbeater's possum Gymnobelideus leadbeateri, and its implications for species conservation. PhD Thesis, Monash University, Clayton, Australia.

Hansen BD and Taylor AC (2008). Isolated remnant or recent introduction? Estimating the provenance of Yellingbo Leadbeater's possums by genetic analysis and bottleneck simulation. Molecular Ecology, 17, 4039–4052.

Hansen, BD, Harley, DKP, Lindenmayer, DB and Taylor, AC (2009). Population genetic analysis reveals a long-term decline of a threatened endemic Australian marsupial. Molecular Ecology 18, 3346–3362.

Harley, DKP (2004). A review of recent records of Leadbeater's Possum (Gymnobelideus leadbeateri). In The Biology of Australian Possums and Gliding Possums, pp. 330–338. Eds R Goldingay and S Jackson. (Surrey Beatty and Sons: Sydney)

Harley, DKP (2005). The life history and conservation of Leadbeater's Possum (Gymnobelideus leadbeateri) in lowland swamp forest. Ph.D. Thesis, Monash University, Clayton, Australia.

Harley, DKP, Worley, MA and Harley, TK (2005). The distribution and abundance of Leadbeater's Possum Gymnobelideus leadbeateri in lowland swamp forest at Yellingbo Nature Conservation Reserve. Australian Mammalogy 27, 7–15.

Wilkinson, HE (1961). The rediscovery of Leadbeater's Possum, Gymnobelideus leadbeateri McCoy. Victorian Naturalist 78, 97-102.

Received 13 September 2012; accepted 13 September 2012

Forest Ecology – A Victorian Perspective

Abstract from a paper presented to the FNCV Biodiversity Symposium 2011

Stephen Mueck

Senior Consultant Botanist, Biosis Pty Ltd, 38 Bertie Street, Port Melbourne, Victoria 3207

Forest communities typically are defined by their floristic composition and structure. This data is collected using quadrat based surveys and analysed statistically using a nearest neighbour algorithm. Tens of thousands of such quadrats have been collected across Victoria and this data has been used to identify numerous vegetation communities known as ecological vegetation classes (EVCs). While EVCs are locally based on floristics they are more broadly defined by a consistent set of physical and climatic parameters such as rainfall, aspect and soil conditions. Wet Forest in East Gippsland therefore may have quite different floristics from those in the Otway Ranges, but as they occur under similar environmental conditions, support similar life-forms and have similar structural characteristics they are identified as the same EVC.

The composition and structure of a forest community is also governed by the type, intensity and frequency of disturbance (i.e. fire, frost, disease, wind throw, landslide, timber harvest). Plants recover from disturbance using one or a combination of two strategies including resprouting from an organ (i.e. lignotuber, epicormic shoots, rhizomes etc.), which survives the disturbance, or establishing a new individual from seed or spore. The individual life history strategies of species therefore govern their ability to persist in different ecosystems under different disturbance regimes.

Forests are often described in terms of their age, with conservation efforts often focused on the concept of 'old growth'. This tends to concentrate on the age and structure of the overstorey and time since disturbance. However, studies on the age of different understorey species indicates that some have individuals, if not populations, which are older, sometimes significantly so, than the overstorey. Carbon dating results from common, often dominant, understorey species collected from Victoria's Central Highlands Wet Forest include Soft Tree-fern *Dicksonia antartica* (5.3 m tall 350 ±50 years), Rough Tree-fern *Cyathea australis* (12.5 m tall 370 ±70 years), Musk Daisy-bush *Olearia argophylla* (~100 years from within 1939 regrowth Mountain Ash *Eucalyptus regnans*) and Tree Geebung *Persoonia arborea* (12 m tall 320–510 years).

These 'old growth' understorey components are often resprouters and can be very influential in both the ongoing structure and composition of the forest and the post-disturbance recovery process. However, where the disturbance is more physical, such as that associated with timber harvesting, these resprouters often fare very poorly in the post disturbance recovery process in comparison to their survivorship after fire. Such changes undoubtedly have ecological consequences for forest regeneration.

Dinoflagellate blooms on the surface ice of Blue Lake, Snowy Mountains, Australia

Mainland Australia's five natural snow-fed alpine lakes that regularly freeze over the winter are located in the Snowy Mountains (36° 25'S). Ice formation on these lakes usually occurs in June, close to the winter solstice, and the date of ice break-up is usually in October (Green 2011). Over the past decade the extent and thickness of ice on Blue Lake has been measured in early to mid-September. Layering in the ice was documented as overlaying snow, hard ice layers and slush layers, and monitoring of the ice cover was continued until ice break-up. Highly conspicuous red colouration on the ice cover was observed in October 2002, 2003 and 2004 but (for various reasons such as ice breakout in September 2006, heavy October snowfalls obscuring the lake ice surface in 2009) no colouration was seen between 2005 and 2010 (Table 1). Red colouration was seen in November 2003, when the ice lasted until then, but was never seen in September. Samples were collected in October and November 2003 and were preserved in gluteraldehyde for examination with a scanning electron microscope at the Australian Antarctic Division.

The organism causing the red staining on the lake ice surface (Fig. 1) was identified as a dinoflagellate, probably *Glenodinium* sp., although a definitive identification would require the appliction of molecular biology (Harvey Marchant, pers. comm. 2012). Dinoflagellates constitute a large proportion of marine phytoplankton communities and are responsible for red tides or algal blooms in coastal areas. However, freshwater red tides caused by dinoflagellates do occur, generally in waters that are moderately rich in nutrients, particularly in reservoirs (Fukuju *et al.* 1998). The most famous regular summer blooms occurred in Lake Tovel (Italian Alps) and were thought to be due to *Tovellia sanguineum* (previously *Glenodinium sanguineum*) (Cantonati *et al.* 2003). However, the processes within the lake attributed to *T. sanguineum* were actually caused by three different species of dinoflagellates (Calliari *et al.* 2004).

Table 1. The occurrence of red staining on the surface ice of Blue Lake, together with September ice thickness and ice break-up date from 2002 to 2011.

Year	September ice thickness (cm)	Ice break -up (Julian day of year)	October Staining?
2002	92	294	Yes
2003	89	316	Yes
2004	194	296	Yes
2005	73	294	No
2006	45	264	No
2007	39	294	No
2008	136	285	No
2009	91	307	No
2010	202	303	No
2011	112	296	Yes

Of the dinoflagellates in freshwater, many are cryophilic (cold loving). In Lake Tovel the presence of *T. sanguineum* is limited generally to periods of ice cover, but can occur until late spring or early summer with highest abundance during winter or spring (Calliari *et al.* 2004). *Peridinium euryceps* from Lake Erken (Sweden) also appears during winter underneath the ice (Rengefors and Meyer 1998). Dinoflagellates also occasionally stain snow on land and two records from the European Alps pre-date the first record from Canada in 1971 (Gerrath and Nicholls 1974). Microbial communities including dinoflagellates in sea ice are well studied (Thompson *et al.* 2006) whereas accounts of similar communities within the ice of freshwater lakes are rare (Felip *et al.* 1995). Reports of dinoflagellates include colouring the surface of the ice on Lake Davos in 1916 (Gerrath and Nicholls 1974), and their occurrence in the slush ice of various Pyrenean and European Alps lakes (Felip *et al.* 1995), but this is the first such collection from the ice surface of an Australian lake.

Ice cores from Blue Lake show layering of the ice. This is caused by the mass of falling snow forcing the initial hard water-ice layer beneath the hydrostatic layer, allowing lake water to mix with the surface snow to form slush, before the surface of this also freezes, forming a further hard ice layer (Green 2011). The layers of slush ice, possibly enriched with nutrients from snowfall and windblown debris, provide the basis for the inoculum of microbial species from the lake water to grow once light becomes available, as it does when the surface snow thaws in spring. The top-down melting of the ice cover helps to concentrate the dinoflagellates in slush on the lake ice surface. In the years 2002-2004, staining was widespread across the surface of the lake ice but concentrated around cracks in the ice. In 2011, after a heavy snowfall at the end of September, there was no widespread staining because the snow lasted well into October; instead, the dinoflagellates appeared to be concentrated along cracks in the ice.

Dinoflagellates in freshwater environments, whether open water or ice, are uncommon. Their appearance on lake ice for such a short period in October, and not in all years, added to the possibility that they are cryophilic and present in the water column at other times of the year in only very low numbers, means that research on them must, of necessity, be opportunistic.

Acknowledgements

Thanks to Harvey Marchant who identified the dinoflagellate and commented on the manuscript.

References

Calliari D, Corradini F and Flaim G (2004) Dinoflagellate diversity in Lake Tovel. *Studi Trentini di Scienze Naturali Acta Biologica* **81** (Suppl. 2), 351–357.

Cantonati M, Tardio M, Tolotti M and Corradini F (2003) Blooms of the dinoflagellate *Glenodinium sanguineum* obtained during enclosure experiments in Lake Tovel (N. Italy). *Journal of Limnology* **62**, 79–87.

Felip M, Sattler B, Psenner R and Catalan J (1995) Highly active microbial communities in the ice and snow cover of high mountain lakes. *Applied and Environmental Microbiology* **61**, 2394–2401.

Fukuju S, Takahashi T and Kawayoke T (1998) Statistical analysis of freshwater red tide in Japanese reservoirs. *Water Science and Technology* **37**, 203–210.

Gerrath JF and Nicholls KH (1974) A red snow in Ontario caused hy the dinoflagellate, *Gymnodinium pascheri*. *Canadian Journal of Botany* **52**, 683–685.

Green K (2011) Interannual and seasonal changes in the ice cover of glacial lakes in the Snowy Mountains of Australia. *Journal of Mountain Science* **8**, 655–663.

Rengefors K and Meyer B (1998) *Peridinium euryceps* sp. nov. (Peridiniales, Dinophyceae), a cryophilic dinoflagellate from Lake Erken, Sweden. *Phycologia* **37**, 284–291.

Thompson PG, McMinn A, Kiesling I, Watson M and Goldsworthy PM (2006) Composition and succession of dinoflagellates and chrysophytes in the upper fast ice of Davis Station, East Antarctica. *Polar Biology* **29**, 337–345.

Ken Green
National Parks and Wildlife Service,
Snowy Mountains Region, PO Box 2228,
Jindabyne, NSW 2627, Australia
kenneth.green@environment.nsw.gov,au

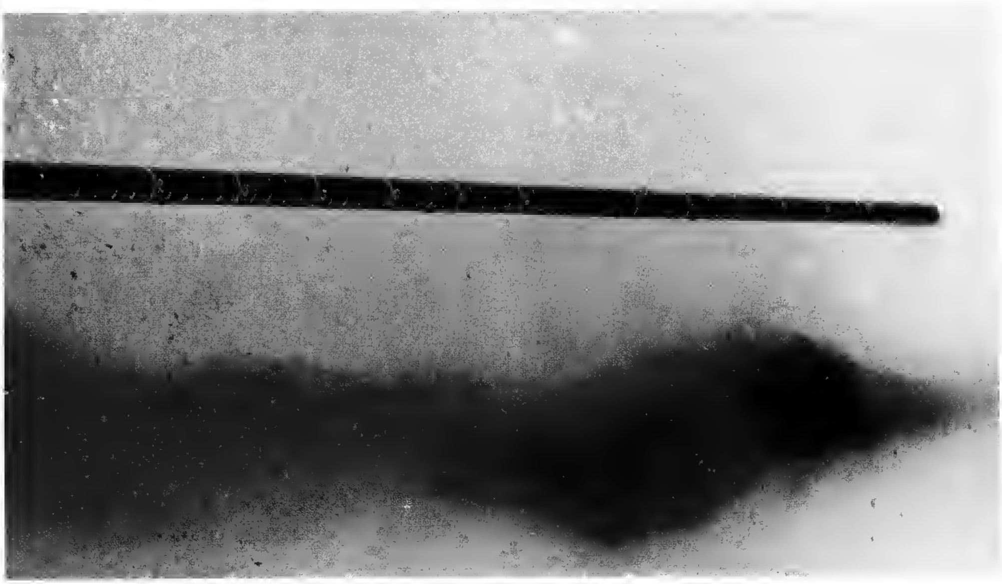

Fig. 1. Red staining on surface ice of Blue Lake by dinoflagellates in October 2011. The avalanche probe reading nearest the camera shows 70 cm.

Noon Flower: An iconic plant species and a link across time to the life of early Melbourne

Introduction

Many cities don't have anything special to offer insofar as geophysical features are concerned, because either they never had them in the first place, or they have long since been lost to urban development. Melbourne is a case in point of the latter, as James Boyce (2011: 211) records:

> By the time Anthony Trollope visited Melbourne, then a city of 206,000 'souls' in the early 1870s, the city had already largely turned its back on the Yarra (River), drained the swamps, filled in the lakes and flattened the hills, so that Trollope knew 'of no great town in the neighborhood of which there is less to see in the way of landscape beauty.'

Boyce further details the stunning ecological features of that lost landscape (2011: 4):

> This natural bridge where salt water and fresh water met was also where geology and botany divided in an apex of ecological encounter. Within an easy walk could be found grasslands, various woodlands, as well as, in almost every direction, mud. On the northern side of the river stretching three kilometres to the north-west, 'was a wide expanse of boggy land greater than 1000 acres ... in extent'. In the middle of this was a permanent lagoon which one early settler recalled as a 'beautiful blue lake ... intensely blue, nearly oval and full of the clearest saltwater' but this by no means deep'. On the southern side of the Yarra between the river and the edge of the bay, swampy land stretched for about six and a half kilometres and included a number of permanent lagoons including what was to become (with more than a little taming) Albert Park Lake. There were also extensive lagoons in the region of what is now Port Melbourne. By contrast much of today's central business district was well-drained grasslands framed by gentle and lightly wooded hills, such as Batmans Hill, where Southern Cross Station now stands, and the pastoral plains stretched far to the north and west.

Today you're really hard pressed to find any remnants of this truly magical place. Boyce points to a couple of river red gums in the lower reaches of the Botanic Gardens. But a further unexpected relic is *Disphyma crassifolius* ssp. *clavellatum*, commonly called Rounded Leaf Noon Flower (original botanic name *Mesembryanthemum* sp.) which grows as a prostrate, succulent or perennial herb, from 2 to 30 centimetres high. Unlike the other Aizoaceae its leaves are round in cross-section and it does not hybridise with them. Flowers are pink, purple or violet (Fig. 1).

Local Aborigines used its succulent leaves as the source of a refreshing but astringent drink and the juice was also applied as an antiseptic on scratches and insect bites (Watson, APS Website). Rounded Leaf Noon Flower was a signature plant for much of early central Melbourne, as shown by the following extracts:

Pigface

'The encroaching pigface pours its molten magenta down the sides of cuttings.' (Furnley Maurice 1934)

> Where has all the pigface gone? The vivid-flowered succulent is everywhere in accounts of Melbourne from its earliest days up to the mid-20th century. The Blue Lake at the west end of town was wreathed around with it. In Dr Godfrey Howitt's Collins Street garden of 1853 were 'beds of mesembryanthemum ... brilliant with florescence'. Perhaps the pigeons ate it all.
> (Annear 2009: 81)

Blue Lake

> During Melbourne's first five or ten years (and for untold years before that) a shallow sheet of water known as the Blue Lake stretched north-west from Batman's Hill, encompassing the site of today's Docklands. Before long, though, grazing cattle trampled it into a morass, so that it merged with the West Melbourne swamp before disappearing altogether in the 1860s when it was filled up and buried under rail yards and waste ground. George Gordon McCrae, a boy in the early 1840s, would recall – 'a real lake, blue, nearly oval, and full of the clearest salt water, though by no means deep. Fringed gaily all round with the purple mesembryanthemum [pigface] in full bloom, it seemed in the broad sunshine to be girdled by a belt of magenta fire'. (Annear 2009: 12). (Fig. 2)

Fig. 1. A *Disphyma crassifoliuis* ssp. *clavellatum* floral carpet, photographed in Tasmania. (Sourced from Australian Plant Society – Tasmania website.)

Fig. 2. Robert Hoddle's watercolor 'Near Melbourne 1847' has captured the top corner of the Blue lake with Mount Macedon in the left background. (Sourced from State Library of Victoria.)

Coode Island

> The sky was ablaze with skylarks ... every few yards there were nests on the ground. Springtime was full of their music. Sometimes there were dolphins in the river. The most beautiful thing I have ever seen was the pigface growing on the island in spring. It was a swamp in the middle before they drained it. I will never forget that pigface. (Lahey 1994:7).

Relic Population

A relic population, scale-free and thick on the ground, was uncovered by Ian Taylor of Western Plains Flora Nursery at the southern-most end of Dudley Street on both banks of the Moonee Ponds Creek (nee Railway Canal) in the early 1990s. The area in question is rather neglected but clothed in some native plantings under the Bolte Bridge and presently teeming with rabbits.

Reference to Russell's 1837 map of Melbourne (Fig. 3) and a later map depicting an enlarged street grid shows that this point corresponds to the south-eastern boundary of the lake which Russell had labelled 'Salt Lake'. The plant in question was discovered at a point in time when there had been no introduced native plants, the site otherwise being a wasteland.

The Moonee Ponds Creek here is represented by the vestiges of the Railway Canal excavated along the channel of the creek in the late 1880s to provide access for coal barges to a landing stage near the North Melbourne Locomotive Depot. The various works along this stretch of waterway - it was narrowed at one stage - would have left at least some overburden in the vicinity from which the plant has regenerated (Arnott pers. comm. 2010).

There is also a local population of angle leaf pigface, Karkolla *Carpobrotus rossii* (Fig. 5).

The way forward

It is recommended that, in view of Rounded Leaf Noon Flower's link across time to pre- and early settlement of Melbourne, the area where the relic population is found, be:

- Cleaned out of weeds and any other inappropriate species amidst the population and integrated into the Port of Melbourne Corpo-

Fig. 3. Russell's 1837 map of Melbourne shows the area of the Blue Lake, depicted as Salt Lake. (Sourced from State Library of Victoria.)

ration's Shared Spaces landscape plan for the area;

- Boardwalks be established;
- Interpretative signage erected of the plant and its historic association with the Lake and early Melbourne;
- The reserve be called Blue Lake Noon Flower Park or something similar;
- Docklands Way be renamed Noon Flower Way or Blue Lake Way.

References

Annear R (2009) Mrs Bradley's Melbourne. http://robynannear.com/docs/mrs-bradleys-melbourne.pdf.

Australian Plant Society – Tasmania *Warming to the Ice Plants* http://www.apstas.com/iceplants.html

Boyce James (2011) *1835: The founding of Melbourne and the conquest of Australia.* (Melbourne: Black Inc. Publishing)

Fearnley Maurice (1934) *Melbourne Odes* (Melbourne: The author)

Lahey John (1994) When Coode Island was a paradise for birds. *The Age*, 15 March, 7.

Peter M J Fisher
Adjunct Professor, Environment & Planning
School of Global Studies, Social Science and Planning
RMIT University
Email:pmjfisher@bigpond.com

Fig. 5. Pigface *Carpobrotus rossii* pictured at Altona. (Photo reproduced from *The Yarra: a natural treasure* by David and Cam Beardsell.)

A Flutter of Butterflies

by Michael Braby and Penny Olsen

Publisher: *National Library of Australia, Canberra, 2011. 106 pages. ISBN 9780642277251. RRP $34.95*

Butterflies are highly regarded. We see them as beautiful, fragile and ephemeral creatures. Their lives seem carefree, filled with sunshine and light breezes as they flit from flower to flower. They are portrayed favourably in children's literature, poems and artwork. In the classroom we marvel at metamorphosis, where the caterpillar is transformed into an elegant adult. With few exceptions, we ignore the caterpillars of troublesome species or treat them as aberrations.

By contrast, many moths and other insects seem to have been skulking behind the door when beauty and charisma were handed out. Quite unfairly, we blend fact, supposition and legend and tend to show favouritism, glorifying some insects and demonising others. Consequently, a book that charms us with beautiful paintings of both butterflies and moths is welcome and may encourage us to value all lepidopterans. Furthermore, the book draws together a wide range of illustrations and connects them with a well-written narrative that places them in a historical context and illuminates the many and varied pathways taken by artists over the past two hundred or more years.

During the Age of Exploration, butterflies and some moths featured prominently in collections destined for museums and private collections in Europe. Some artists depicted these specimens, while others living in Australia or visiting it painted them in their homeland. The best of these paintings have artistic merit while being scientifically accurate. Our appreciation of these works is enlivened by an understanding of the times in which the paintings were executed and the personal story of the artists. This book touches on many artists and describes their exploits and motivations. These are understandably diverse, given that an interest in butterflies and moths has never been solely the province of scientists. The artists that came to paint them are quite varied: naturalists and explorers, naval draughtsmen, 'gentlewomen', wealthy private collectors, scientists and many others. As well as providing an overview of the development of lepidopteran art in Australia, the book examines in greater depth the lives and exploits of eleven of the most well-known and influential artists. We discover how they became interested In painting these subjects. The personal journey of each is deftly described, revealing their inspirations, triumphs and tribulations.

The authors of *A Flutter of Butterflies* are hoth prolific and respected authors of numerous books and journal articles. In the past decade or so Michael Braby has opened up the world of Australian butterflies to amateur naturalists and scientists alike, producing an identification guide and comprehensively referenced works on the taxonomy and biology of Australian butterflies, as well as a carefully crafted list of common names for butterflies. He is currently the Curator of Entomology at the Museum and Art Gallery of the Northern Territory. Penny Olsen, based at the Australian National University in Canberra, is a natural history writer and research scientist with particular interests in birds of prey and natural history illustrations. In 2001 she wrote the award-winning *Feather and Brush* (CSIRO Publishing), which described and extensively illustrated the history of Australian bird art.

Graeme Ambrose
School of Science, IT and Engineering
University of Ballarat
PO Box 663
Mt Helen, Victoria 3353