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Carabids as potential indicators of sustainable farming systems

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Abstract. Carabid beetles are important biological control agents in a range of agricultural crops throughout the world. This paper outlines the history of carabid research in Australia to provide a point of reference with European and USA studies. The ecological and applied agricultural knowledge of the Australian fauna lags far behind that of Europe and the USA but we are now at the point of using the available knowledge to assess agricultural ecosystems. This paper describes how aspects of the biology and ecology of the Australian carabid fauna differ from that described in published work on other carabid populations. In particular, this paper describes how it may be possible to identify dominant (key) species in particular ecosystems (such as pasture or cropping) and use these species as indicators of ecosystem health.

Carabids are a family of beetles (Coleoptera : Carabidae) that includes many predatory species. The body shape of carabids with typical prognathous mouthparts is that of a predator. The jaws project forward so that prey can be captured easily. The 'ground beetle' body shape is recognisable throughout the world and the simple silhouette alone is enough for recognition (New 1996). Immature stages of carabids are also predatory and are likely to be important predators below the soil surface.

Despite their relatively easy recognition and popularity among amateur collectors, there has been very little attention paid to this group by Australian entomologists and ecologists. Although it is widely accepted that carabids are mostly beneficial in terms of biocontrol of pests in agriculture (Thiele 1977; Kromp 1999), the detailed knowledge of key species in any agricultural ecosystem in Australia can only be described as poor. Only basic ecological information has been published by Moore *et al*. (1987) on named species.

The early studies were conducted by European carabid specialists and their aim was to describe new species (Dejean 1828; Chaudoir 1865). Pioneering works by de Castelnau (1868) and Sloane (1902, 1913, 1915) remain the major scientific studies of Carabidae in Australia in the last 200 years. Castelnau proposed over 330 new species, and Sloane published over 50 papers on Carabidae. However, since Sloane's time 'there has been little activity in this area' (Moore 1960). Papers by Barry Moore (a series beginning with Moore 1960) are the major contribution to carabid research in Australia in the last century, including biochemical aspects and taxonomy (Moore 1979). Some recent applied aspects of carabid research, including the use of carabids as indicators of ecosystem health, have been published by Horne and collaborating workers between 1992 and 2004 (Horne 1992*a*, 1992*b*, 1995, 1999; Horne and Edward 1997, 1998; Horne *et al*. 1995; Yen *et al*. 1993, 1994).

In Europe and the USA there has been far more work undertaken on carabid beetles. For example, Baars (1979) after years of continual observation, was able to propose the 'year catch' as an indicator of carabid abundance. In Australia, we do not have that level of knowledge but I believe that there is sufficient information to *begin* to use carabids as indicators of sustainable farming in Australia.

There has been work in the UK to suggest that refuges that foster carabids can be used by farmers to help with pest control. These were given the name of 'beetle banks' (Wratten 1992). However, the same author has indicated that he believes that the same approach will not succeed for control of slugs in New Zealand (P. A. Horne, pers. comm.) despite the fact that carabid beetles are present. Research is currently underway in Australia and New Zealand to establish the impact of native carabid beetles on introduced slugs (Foundation for Arable Research 2006). In this case the native fauna is being assessed as to how it can deal with exotic pests. The main complicating factor is that insecticides used for other pests (such as redlegged earth mite, *Halotydeus destructor* or redheaded pasture cockchafer grubs, *Adoryphorus coulonii*) are highly likely to kill the species of beneficials that would otherwise control slugs. This mortality of carabids occurs in several ways, including direct contact with spray droplets, contact with treated surfaces and ingestion of affected prey.

Moore *et al*. (1987) list 1800 species of carabids in 266 genera known from Australia. There are some introduced species of carabids in Australia, and the most frequently encountered is *Laemostenus complanatus*. It is a cosmopolitan species usually encountered in association with human habitation. The Pterostichinae are well represented and the largest genus is *Notonomus* Chaudoir. Other Pterostichinae, such as species of *Rhytisternus* and *Sarticus,* have been recorded from native grasslands and some grazing and cropping systems (Horne and Page, in press).

The bulk of Australian research on carabids has been focused on taxonomy. It is not surprising that when Australia was discovered by Europeans that the new fauna would be of interest. European and Australian taxonomists collected and named the new genera and species that they found. However, the initial taxonomic work has not been followed by many ecological studies.

The importance of carabids as biocontrol agents of pests in Australian agriculture has been recognised (Horne 1992*c*;

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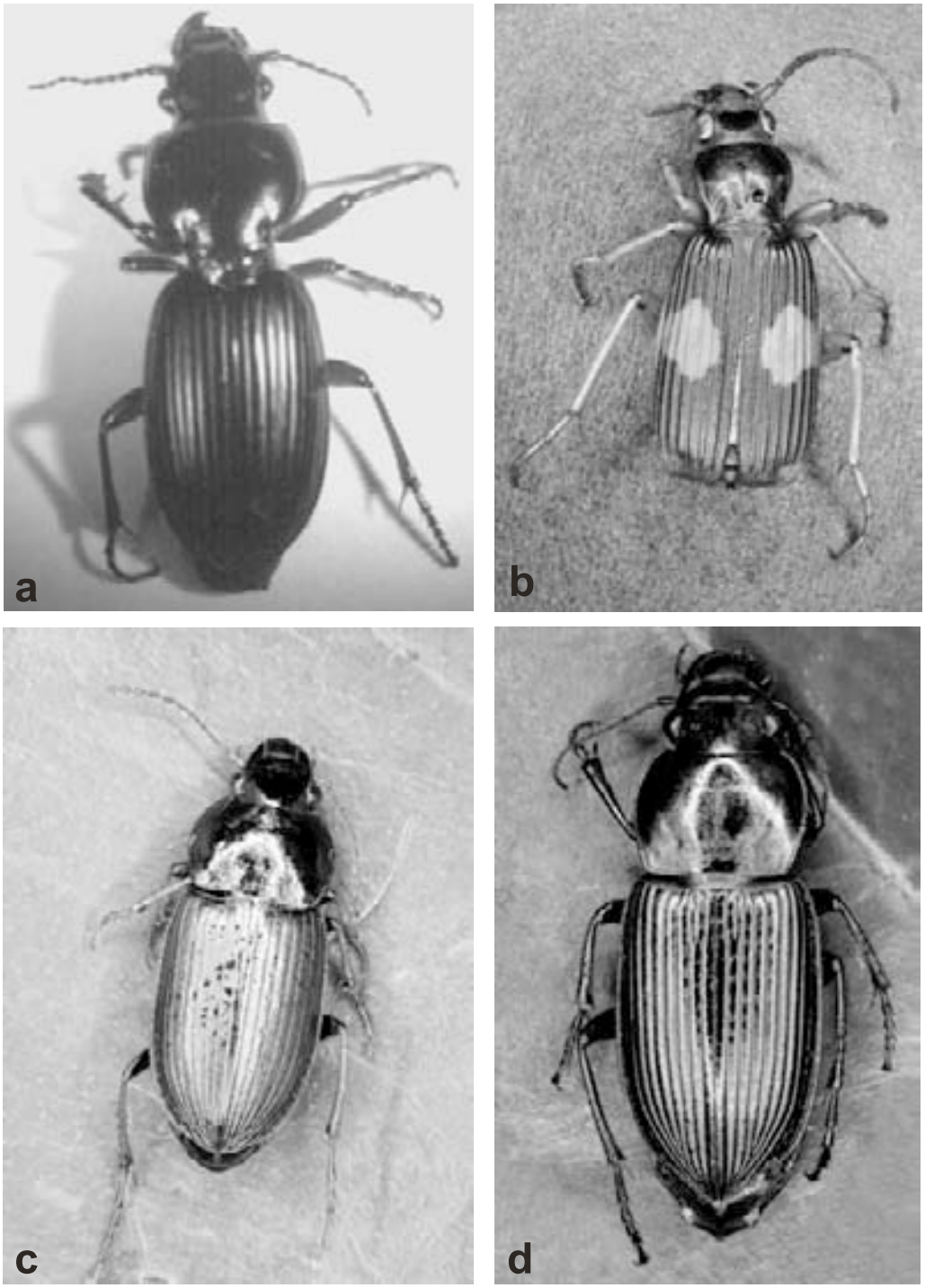

Fig. 1. Australian native ground beetles (carabid beetles) common in Victorian forests and cultivated fields (photographs supplied by M. G. Paoletti and D. Sharley): (*a*) *Eurylychnus* cfr. *blagra*. det. Martin Baehr: 16 mm; collected near Gerangamete remnant primary forest in Victoria; (*b*) *Pheropsophus verticalis* Dejean, det Eric Mattews:14 mm; Mildura mallee in Victoria; (*c*) *Gnathaphanus* cfr. *multipunctatus* Macl.det. Martin Baehr: 12 mm; Murray river banks, Mildura in Victoria; (*d*) *Gnathaphanus pulcher* Dej.det. Martin Baehr: 15 mm; vineyards Mildura in Victoria.

Horne and Edward 1998). They are the focus of a current project to investigate improved control of slugs in broadacre cropping (Horne and Page 2004). The significance of this work is that native species of carabids are seen as potential biocontrol agents of several species of exotic pests. Carabids are being investigated as a key component of the native biodiversity of agricultural ecosystems in south-eastern Australia but there are few previous studies documenting the species composition of different agricultural (or natural) ecosystems (Horne 1992*c*; Yen *et al*. 1993, 1994). In this current research, the species of carabids in the cropping systems could be (are likely to be) different to those in pasture ecosystems in the same area. The difference would be the species composition rather than the number of carabids of any size-class. A comparison of the carabid faunas of native and modified (exotic vegetation) sites has just commenced in Victoria.

The cultural practices of farmers, especially of those farming broadacre arable land, have changed in the last two decades. There has been a significant change to minimal tillage and stubble retention, instead of conventional ploughing and burning of stubble. This has happened worldwide and has known effects on both pest and beneficial species, including carabids (Stinner and House 1990). Given that farmers usually use broad-spectrum insecticides to control some pests, and so kill predators such as carabids, the effects of minimal tillage and stubble retention is associated with increased pest problems (slugs, snails, wireworms) and the beneficial effects of increased predator populations are not seen. A few studies in Australia have shown the increased abundance of predators such as carabids if tillage regimes are reduced (Horne and Edward 1988).

There is extremely little information on the role of carabid beetles in horticultural crops in Australia and no published information available. There has been some use of carabids in environmental impact statements before forestry activities, but these studies have not attempted to investigate ecological relationships of carabids and other species. In Victoria, carabids have been included in environmental impact assessment studies of the fauna of areas of proposed development other than forestry or mining. One study included carabids as indicator species for ecosystem assessment (Cropper 1998). The study was an ecological assessment before a proposed freeway development, and the carabid species involved were *Notonomus phillipi*, *Eurylychnus blagravei* and a species of *Loxandrus* (Fig. 1).

The one serious assessment of the potential for using carabids as ecological indicators in Australia was conducted by New (1998). The conclusion reached then was that more information was needed before reliable indicator taxa could be used in Australia. However, there are sufficient data now to suggest that we do know enough to be able to use carabids in sustainable farming in Australia. We know that resident carabids that may impact severely on major pests occur in almost all, if not all, cropping areas in Australia, and that they are affected by pesticides (Curtis and Horne 1995; Horne and Page 2004). So it follows that broad-spectrum insecticides will also have a detrimental effect on these carabids.

It is now clear from many researchers that predators can ingest a lethal dose of pesticide through eating prey that may contain a sublethal dose. Australian carabids in cropping or pasture ecosystems are likely to be very vulnerable to this type of poisoning as many appear to be predator–scavenger species (P. A. Horne and J. Page, unpubl. data). The impact of some insecticides on carabids is likely to be as great or greater than that observed on other groups such as parasitoids because of secondary poisoning. Despite the fact that extremely few carabids would be contacted directly by most foliar insecticide applications (most are nocturnal and shelter during the day), they could accumulate a lethal dose by feeding on dead or dying prey (Curtis and Horne 1995).

Australian carabids include many flightless species. This means that they can be easily identified, even in one-off sampling as resident species rather than recent immigrants. This characteristic is likely to make them slow to recover after any disturbance or destruction of a population. This characteristic means they are sensitive to such stresses and as such have potential as ecological indicators. Therefore, Australian carabids could have potentially great indicator value because of a greater response to stresses than more mobile species. At present there is insufficient data on any species to use a species as an indicator, but the species composition and the relative abundance of dominant species could make carabids very good indicators of sustainability and appropriate management.

The composition of Australian carabid communities (that is, the species of carabids in any particular habitat or environment) appears to be very different to that of Europe or North America (Thiele 1977). In particular, from the limited number of studies available, there appears to be a much smaller number of species in Australian environments and the carabid fauna is typically dominated by one or two species with very few subdominant species (Horne and Edward 1997).

Another potentially important difference is the possibly greater number of species in Australia exhibiting parental care (Horne 1990). Thiele (1977) cited a total of 15 species of carabids known worldwide to exhibit parental care (and none from Australia) but from the extremely small numbers of species studied in Australia there are four species in one genus

Fig. 2. *Geoscaptus* cfr. *laevissimus* Dej. det Martin Baehr. found abundant in humid pastures and gardens: 26 mm; collected in Mildura in vineyards.

(*Notonomus gravis, phillipi*, *kershawii* and *molestus*) recorded to have this form of behaviour and others known but not recorded in the scientific literature (Horne 1990). This behaviour may render Australian species more vulnerable to activities such as conventional tillage, depending on the timing of activities including ploughing and brood care.

The juvenile stages of carabids are also predators and they live in different niches to the adult beetles. Current studies in Victoria include investigations of the impact of juvenile carabids on pests in broadacre cropping systems (P. A. Horne and J. Page, unpubl. data).

Until very recently, the situation in most Australian (and overseas) agricultural environments, horticultural and broadacre, would have been that broad-spectrum insecticides (synthetic pyrethroids, organophosphates and carbamates) were applied as a routine to control a variety of pest species. The likely effect of this pesticide application is to have had a greater impact on carabids than on many other predatory insects because there are many species that are flightless. This aspect of their biology has made them the topics of many zoogeographic studies in the northern hemisphere (Moore *et al*. 1987).

Pesticides have been the standard method of controlling pests in Australia since 1940 and the use of broad-spectrum insecticides remains almost the only perceived option to many farmers. Under such a pesticide regime, there is little hope of finding a carabid fauna having a major influence on pest species. However, despite this history there are data that document carabids in broadacre cropping (Horne and Edward 1998; P. A. Horne and J. Page, unpubl. data). So, the use of carabids as indicators depends on: (i) the history of pesticide use, (ii) the carabid populations likely to be encountered in any ecosystem, and also (iii) the types of carabids found in any agricultural ecosystem.

We have found that there are carabid species in all agricultural systems that we have sampled (Horne and Edward 1998; Yen *et al*. 1993, 1994). The current state of knowledge about Australian carabids suggests that this group of beetles is most likely to be used as indicators in a very particular way; for example, a comparison of the composition of species present after any action has occurred with the species composition known to occur in a region or habitat type could be used to indicate disturbance or sustainability. The loss of dominant species or a change in dominance hierarchy, are factors that can be used at present to indicate the degree of change from native habitats. Current research (P. A. Horne and J. Page, unpubl. data) is aimed at determining the type of change that different agricultural practices have on carabid species in western Victoria. Together, these data will provide a means to rapidly assess farms in terms of any loss of natural biological control agents and could be used as a measure of sustainability by determining: (i) the level of change from natural state and (ii) the level of resident biological control agents for key pests. All of this information is not available now, but is the subject of my current research.

Ideal indicators need to be sensitive to the factor to be measured, reasonably abundant in samples and easily recognisable. The larger carabids such as species of *Notonomus*, *Rhytisternus* and *Geoscaptus* (Fig. 2) found in arable ecosystems studied in southern Australia fit these criteria and offer the potential to be used much more in the future. The use of pitfall traps is a simple and very well established method of sampling for adult carabid beetles and is likely to deliver good data on the species of importance in agricultural ecosystems. Shelter traps are also an option but they are more difficult to use.

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