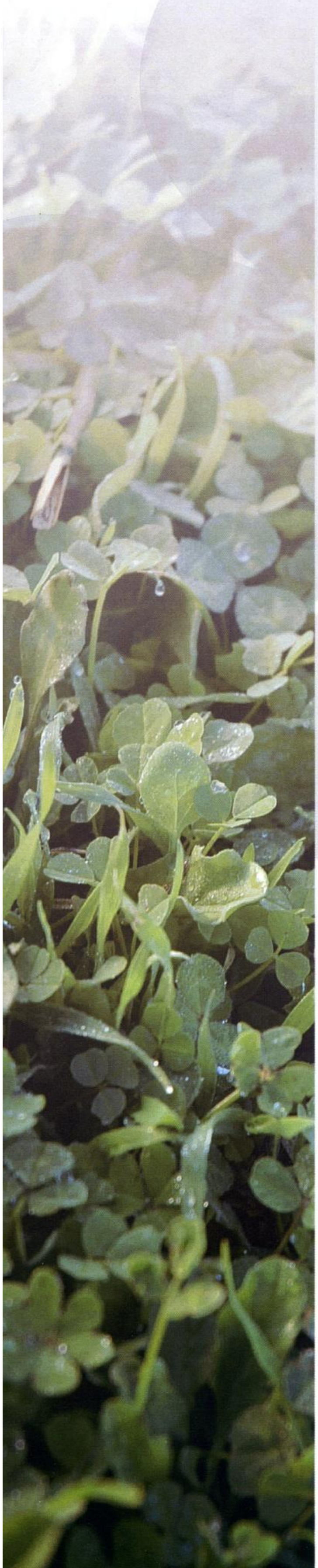

The AW Howard Memorial Trust Inc.

The Amos W Howard Medal and Oration

The inaugural AW Howard Medal is awarded to

Dr James Ridsdill-Smith

Dr Ridsdill-Smith is recognised for his 40-year career in research on the behaviour, ecology and management of insect and arthropod pests of pasture plants, leading to better control of redlegged earth mites, of aphid pests of annual pastures and lupins, of ground-dwelling scarab beetles and grass grubs, and of pod-borers of legumes, especially chickpeas.

Dr Ridsdill-Smith is widely-recognised for the quality of his research and professional leadership.

Professor Rob Lewis

Chair AW Howard Memorial Trust Inc.

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Insects in pastures: a hidden force

TJ Ridsdill-Smith, CSIRO Ecosystem Sciences, Floreat, WA
James.Ridsdill-Smith@csiro.au

AW Howard's work in introducing the use of sub clovers has revolutionised pastures in Australia. This was a development from natural curiosity and careful observation rather than from a focused program of scientific research. In my career as a biologist and ecologist I have tried to balance the modern theoretical and technological aspects of science with the now sometimes overlooked observational and natural history approach.

Pasture research and people

As a boy in England I was interested in all aspects of natural history and spent the summer holidays of my teenage years at a bird observatory at Monks House in Northumberland helping to put marker rings on the legs of birds. At university I was impressed by the synergies that came from combining different disciplines such as biology and chemistry into biochemistry. The combination I took was natural sciences and economics. After graduating I was offered a job by CSIRO Entomology and following a four week journey from England to Australia by ship with my wife Nicola, baby daughter, I arrived in Armidale NSW to start work as an entomologist. My research has mostly been on pasture insects and mites.

James Ridsdill-Smith receiving the Howard medal from Professor Rob Lewis, Chairman of the Howard Trust

Farms usually contain a mixture of pastures and crops, so the farmer needs to manage crops, as well as pastures and stock, and the weeds, pests and diseases in both these systems. Australia has some 28 million ha of subterranean clover based pastures, and the value of these pastures comes predominantly from grazing by sheep, beef and dairy cattle worth $13 billion a year. The optimum management changes with rainfall and soil type. Pastures support many insect species. For example, between 1995 and 1997 our team was studying the invertebrates in improved pastures at Jennacubbine in Western Australia, and 69 species were caught in vacuum samples (the majority on vegetation) and 119 species in pitfall traps (on the soil surface), all in winter. In the vacuum samples 67% of individuals were herbivores, while in pitfall traps 85% of individuals were litter feeders. Differences in pasture management will result in different pest problems. The complexity of interactions in pastures was described by Charles Darwin in his book *On the Origin of Species*. Bumble bees pollinate red clover in England. The numbers of bumble bees in a district are controlled by the numbers of field mice which destroy their combs and nests in the soil. The number of mice depends on the number of cats. Near villages and small towns there are more cats. So cat numbers influence red clover production. One of my first introductions to insects was keeping bumble bees in glass topped hives for a school project in the 1950s, and I have always liked this story.

Pastures have a carrying capacity for pest populations, just as they do for sheep or cattle. Pest damage to pastures is a concept based on the farm system. The impact of pests on pasture production is influenced by how well the pasture is growing. When the pasture is growing well larger losses have been measured, where the insects reduce the ability of the plants to grow, but overall damage may not be visible. There are however also critical times when pests cause damage for instance when they destroy seedlings in the autumn. This shows the need to understand the system for effective pest control. Insects in pastures may be small but they represent a hidden force whose impact can be large.

Strategies for controlling pests should be based on a thorough ecological understanding of the species. Before arriving we read books about Australia, such as *Flying Fox and Drifting Sand* by Francis Ratcliffe which covered problems of overgrazing in pastoral areas, and *Kangaroo* by D.H. Lawrence which was the personal view of a European on Australians. They represented views from the 1920s and 1930s but gave interesting observations. Francis Ratcliffe used an ecological framework to describe how overgrazing in arid pastoral areas of South Australia during droughts in the 1930s was destroying the vegetation which resulted in loss of soil structure. When I arrived in Canberra in 1964 the argument about population regulation was in full swing. AJ Nicholson, ex Chief of the Division of Entomology, proposed population regulation was by density dependent factors, while HG Andrewartha at the University of Adelaide was proposing that the environment and abiotic factors were more important. Members of CSIRO Entomology were expected to be champions for the importance of density dependent factors, limited by the food resource and I have written papers on density dependence in insects, and co-edited a book on reproductive competition in dung beetles.

Pasture scarabs

The job to which I went was on pasture scarabs in a team led by Reg Roberts. In the late 1960s we wore white shirts and ties for office work and changed into more casual clothes for field work. Armidale was still a bit isolated and since I was clearly a newly-arrived pommie with an Eton collar and a posh accent, I was fair game practical jokes with rubber snakes and for getting into very large shouts at the pub. In Armidale I learnt a lot about the functioning of pastures from the strong group of pasture scientists in CSIRO under Bill Willoughby, and at the Department of Agronomy at the University of New England under Alec Lazenby. In 1967 the Howard memorial research fellowship was set up by AIAS. Looking back perhaps the 60s represented the end of one era of research in Australia and the start of a new period of growth. My career was greatly influenced by contact with able and experienced scientists, and I am pleased that I have also had the opportunity to give something back to the discipline of entomology both nationally, as Vice President and later President of the Australian Entomological Society, and internationally as Honorary Secretary of the Council for the International Congresses of Entomology.

My first individual research project was looking at the impact of a group of parasitoid wasps (Thynninae) as biological control agents of root feeding scarab larvae. Female thynnine wasps call for males from grass stems. The male wasps pick up the wingless females from pastures and carry them to trees where they mate and the male feeds the female by regurgitation. After mating the male drops the female back to the spot where she was picked up, and she burrows into the soil searching for a scarabaeid larva to paralyse and on which to lay a single egg. There is an interesting post-script to this. *Drakaea* hammer orchids are endemic to Western Australia and the flowers mimic female thynnine wasps both in appearance thynnine wasps both in appearance and by producing chemical attractants. The male thynnines try to mate with them resulting in pollination. So although my studies on the biology and behaviour of thynnines showed they did not have a significant effect on the control of pasture scarabs, these studies are now helping orchid conservation work.

Female thynnine wasp calling with pheromones on grass

About 20 species of scarabs are occasional pests of improved pastures and crops on the New England Tablelands. Wool growers through Australian Wool International supported this project because they were concerned that increasing outbreaks of scarabs were threatening the pastures improved by the 'super and sub' revolution. We surveyed SE Australia to assess the occurrence and abundance of the different species, and at selected sites carried out more detailed studies on scarab ecology. My research project was a laboratory study of the feeding behaviour by scarab larvae; some species select living roots of grasses for food, while others feed readily on dead organic matter in the soil and only cut off roots incidentally. Plant growth and feeding by root feeding scarabs are greatest under conditions of favourable soil moisture, while in dry soil root larval feeding and plant growth are both reduced. However, damage to the pasture is most visible after the soil dries out, because it is then the plants which have had their roots previously removed by larvae are unable to obtain sufficient moisture, and die. It is evident that the time of year that severe damage is observed is not the time when scarab larvae are most actively feeding, and therefore is not the best time to control scarabs with insecticides.

Economics of agricultural research

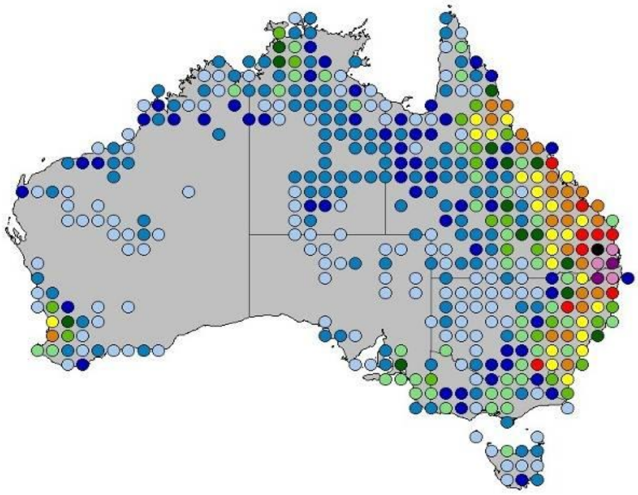
In 1975-1976 the Industries Assistance Commission carried out a report on 'Financing Rural Research'. I was asked to join the group to represent CSIRO in a supplementary study of the benefits from all the research in the Division of Entomology for 15 years. The Commission reported that there was good evidence for the profitability of rural research, and its contribution to efficient resource use, and concluded that rural research has a high social return particularly when account is taken of external benefits to the community, which were not assessed here. There was considerable publicity at the time about government expenditure on research being seen as an investment that paid off well, and Bob Hawke, the Prime Minister, was a strong supporter of Australia being seen as the clever country. I would like to think that our work helped to contribute to the positive image of investments in agricultural research in those years.

In 1993 I was a member of another economic study for CSIRO looking at 'Research for southern Australian dryland farming: a business system approach'. Here we defined seven rural business systems from resource base, to farm production and discussed the role of market signals.

Dung beetles and biological control

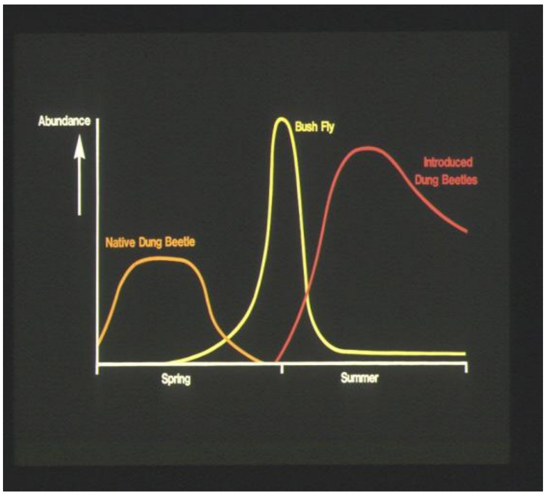
In 1977 I moved to Perth WA where I worked firstly on dung beetles and then on redlegged earth mite. This was a highly productive period of research for me with successful outcomes. There were advantages in being so remote from my headquarters because we could focus on the work, but we were vulnerable because we were a small group. We argued strongly and successfully that the Division should keep a national focus including the Perth laboratory, with support from our State colleagues.

The dung beetle program was supported by beef growers through Australian Meat and Livestock. Prior to this program cattle dung just used to accumulate on pastures, particularly in summer. In Africa there is a very rich fauna of dung beetles feeding on dung of the wild animals in summer, and species selected by George Bornemissza and his team were sent to Australia, where scientists in Canberra mass reared them in quarantine. Regional groups were set up at Rockhampton for northern Australia and at Perth for southern Australia to release the introduced beetles and evaluate their impact. The first species introduced quickly became abundant. Of the 43 species released 23 species are known to be established with some in all areas cattle are present in Australia. In south Western Australia there are now 10 introduced species recycling cattle dung in pastures. The ecosystem services expected from increased dung beetle activity on pastures include a reduction in populations of dung breeding nuisance and biting flies, reduction of pasture fouling, increased nutrient cycling and water percolation. Since my group were insect ecologists we decided to evaluate the impact of introduced dung beetles on the dung breeding bush fly, *Musca vetustissima*, a human nuisance pest.



Distribution of introduced dung beetles in Australia (Edwards 2007). Number of species (1-13) for each degree square

John Matthiessen researched the bush fly ecology, I researched the dung beetles, and we worked together on the fly control. At Busselton in January when the dry weight of introduced beetles was 60 fold greater than its previous level, fly abundance fell to 12% of its previous value essentially halving the duration of major fly problems in the area. This coincides with the Christmas holiday period and provides a great benefit to holiday makers and residents. The changes in lifestyle to be able to sit outside at cafes and barbecues with reduced fly nuisance during summer in Australia are a long term public benefit from the dung beetle program. Benefits to nutrient recycling and improved water percolation which follow from increased burial of animal dung have not been quantified.



Bush fly populations in SW Australia increase during a short period in spring

In the winter rainfall regions the bush fly study showed that when the flies first arrive in spring dung quality and fly fecundity are high and there is a short period of a few weeks when numbers increase rapidly. By the summer poor dung quality and predators result in low fly survival in the dung. The greatest abundance of the introduced dung beetle species is in summer after this peak rate of increase in flies, when fly survival is already low. Dung beetles do not control flies as well in high quality spring dung than low quality summer dung. To try and fill this spring gap we are investigating the possibility of introducing further species with activity more seasonally restricted to spring. Beetles vary in their dung burial behaviour and this seems to be important for fly control. Large dung beetle species (more than 15 mm length) bury more dung within a day of arriving at fresh dung than small species (less than 13 mm length) (pre-emptive dung burial), and they control bush fly better. In Africa the large and small species coexist in dung. However in pastures in Australia the small species dominate, even though equal numbers of large and small species are established. This is a puzzle. In a pasture in Spain which has a better climate match to SW Australia than southern Africa, 81% of the dung beetle biomass (DW) present in spring 1981 is of large species, and so large beetles can dominate in this climate. This is a continuing area of my research.

Plant resistance

The use of plant resistance is an important strategy to reduce the impact of pests. My involvement has been in pre-breeding research for several systems, where the emphasis is on developing screening methods, identifying lines with improved resistance and identifying the mechansisms of resistance. This last was helped greatly through my involvement with the Cooperative Research Centre for Legumes (CLIMA) and collaboration with Yong Jiang, Shaofang Wang and Emil Ghisalberti, who are natural plant chemists. Transferring the resistance to well adapted lines through plant breeding is a lengthy process taking many years. The release of new varieties with pest resistance is the eventual aim but has not been in the scope of my work.

A new program to see how plant resistance could be used to manage redlegged earth mites with a focus on ecology was started in CSIRO supported by wool growers through Australian Wool International from 1990-1995 to add value to an existing pasture legume breeding program. The ability of mites to distinguish between cotyledons of resistant and susceptible subterranean clover varieties within an hour was an important finding. The chemists developed methods to extract chemicals from plants for both constitutive compounds and induced volatile compounds, which were then tested for repellency to the mites. Using bioassay guided fractionation the active compounds from the plants were identified and the concentrations at which they were active determined. In Gland clover, *Trifolium glanduliferum* the resistance in leaves was due to an induced volatile, coumarin. Mite feeding on cotyledons of resistant subterranean clover varieties induces the production of a volatile compound 1-octen-3-one which repels the mites. Resistant varieties also have higher

Ted Knights NSWDPI and Hari Sharma ICRISAT inspecting chickpea crossbreds at Hyderabad, India

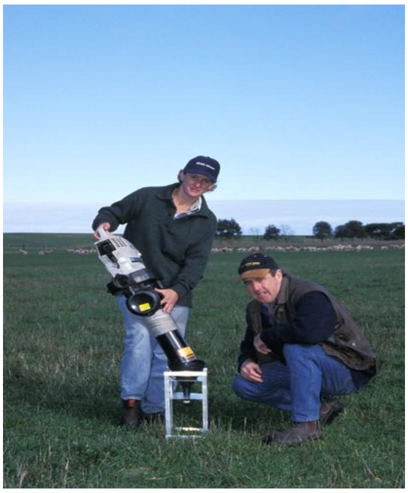
mechanical strength of the upper surface of their cotyledons, a constitutive factor, which reduces mite feeding. Resistance to redlegged earth mite in trifoliate leaves of subterranean clover is associated with the constitutive presence of free isoflavones, and especially genistein. Resistance in cotyledons and leaves of yellow lupin, *Lupinus luteus*, to mites is associated with quinolizidine alkaloids which are constitutive, of which sparteine is the most potent. A Gland clover variety with mite resistance, Prima, was released in 2002 and sub clovers Bindoon, a mid rainfall variety, in 2010, Narrikup, a high rainfall variety, in 2011 and Rosabrook, a high rainfall variety, in 2011. Breeding was outside the scope of my work.

We also looked at resistance in lupins to aphids. In these phloem feeding insects the resistance is associated with lupanine in narrow leafed lupins and with gramine and a gramine analogue in yellow lupins. The lupin breeders in DAFWA have included resistance to aphids in their breeding program. Resistance has been investigated in another grain legume, chickpea, where the pest is a budworm, *Helicoverpa armigera.* We developed new improved screening methods, and workings with Hari Sharma and colleagues at ICRISAT in Hyderabad, India, have found novel sources of resistance in the ‘wild’ relatives of chickpeas. The domesticated chickpea has little variability in resistance, but some of the other *Cicer* species do contain considerable resistance which can be used as a novel source of resistance. Closely related species have been crossed with *Cicer arietinum* at ICRISAT and by Ted Knights, the NSW chickpea breeder. It is hoped that new chickpea varieties will be released with better budworm resistance as one of the traits.

Summer diapause in redlegged earth mite and TIMERITE®

We undertook ecological and biological studies to understand factors influencing redlegged earth mite (RLEM) abundance in pastures. Spraying is the most effective way to control pests in pastures, but does not kill eggs. From 1990-1993 at Keysbrook, WA, between May and October the average population of mites plus eggs was just under 24,000/m^2 of which 40-50% were eggs. The number of eggs laid is associated with the number of RLEM present in pasture. The high proportion of eggs means that insecticide sprays during the winter have only limited impact on the ongoing populations. The mites avoid the hot dry summer by producing diapause eggs which are retained in the cadavers of their mothers. From 50,000-100,000 diapause eggs/m^2 were counted during summer on the surface soils of pastures. Local weather conditions in autumn can be used to predict when emergence occurs at a site, but because the time of emergence varies between years it is not possible to predict timing for control in autumn before the event. In contrast, the onset of the summer diapause in spring at any one site is constant from year to year, with some variation between sites. Celia Pavri collected 50 adult female mites for five weeks before and five after the expected onset of diapause from 55 sites and dissected them to count the number of diapause and non-diapause eggs/female. From this dataset we found that the onset of diapause varied by up to six weeks between sites, and was best predicted by daylength (80% of variability) and mean length of growing season (9% of variability). By extrapolation a database was developed for every 10 km square of southern Australia where the mites occur predicting the day of the year that redlegged earth mites produce diapause eggs. Repeat measures at sites in different years provided a check for the model.

Redlegged earth mite feeding on subterranean clover



Celia Pavri sampling mites at a demonstration site on farm

A meeting was held to discuss how best to use this information for mite control with Phil Michael and Mike Grimm (entomologists from the WA Department of Agriculture), Allen Clarke (a Brookton farmer), and Alan Davey (Australian Wool International). If we could spray the mites at the critical time when there were no winter or oversummering eggs present we could kill the oversummering population. AWI did not see the benefit of continuing the project but Allen Clarke, a farmer with whom we had been working at Brookton, became the champion of the project to fellow farmers and the Wool Industry. The project was then funded and the chemical company Bayer Ltd joined the team.

Two hectare demonstration sites were selected across the country with enthusiastic support from 55 farmers. Half of each site was sprayed on the predicted day, and the other half left as a control. Mites and plants were measured by Celia Pavri. The benefits were spectacular, with 95% control of mites in the following autumn, eight months after the spray, and massive increases in subclover seedling densities. The average increase in the subclover seed bank in summer is 38%, and an average increase in seedling density in the autumn is 68%. The lack of mites emerging in the autumn meant seedlings that did emerge survived better. At demonstration sites where there was summer rainfall in the high rainfall regions of eastern Australia there were no seed yield pasture benefits. In small scale field trials the seedling density in the three varieties with seedling resistance averaged 36% higher and in the following summer the seed bank averaged 33% higher, than the susceptible commercial varieties. However resistance does not stand up with high mite populations. Mite populations recovered quickly each winter at all sites.

The name TIMERITE® was registered, and a package put together for the spring spraying in collaboration with CSIRO, AWI, Bayer Ltd. and the Kondinin group. It was critical that farmers stuck closely to the spray date in spring, and the package explained the ecological reasons for this. Subsequently when work at the demonstration sites was completed the package was further updated with help from Australian Wool International Ltd. and is now maintained on their website (www.timerite.com.au). A farmer can obtain the spray date for any paddock by entering the latitude and longitude. Uptake was rapid and an independent economic assessment from this project indicated benefits of $700 million up to 2020 for a total cost to all parties of $2.5m (www.ruralrdc.com.au). It is estimated 20% of sheep farms will continue to use it. No estimates were made of additional benefits for beef or dairy farmers or to improved survival of seedlings for the grains industry following pasture. The uptake of the technology has been rapid. It should be remembered that the study of onset of diapause for redlegged earth mite on which this project was built is the result of curiosity driven research that was not aimed at a known practical outcome.

Lessons learnt

Over some 40 years it is easy to give the impression that research always produces positive outcomes. However this is not the case, and some areas just did not lead to outputs that could be used. I worked with collaborators on models to predict the interactions between scarabs and pasture growth and between dung beetle and bush fly numbers. They failed to predict correctly observed responses to changes in insect density, and clearly some key interactions are missing. To make correct decisions about sprays farmers and consultants require quick methods or rules to estimate pest abundance. For dung beetle numbers we did find a good quick method, but for pasture scarabs and mites we did not. Mir Mulla from California and I developed chemical attractants for bush fly that could be used in control strategies, but our best bait was no more attractive than fresh dung. Redlegged earth mite resistance is partly due to leaf toughness and we spent time developing a hand held small punch to use as a quick test for resistance in single plants. The results were not sufficiently clear to be adopted by others.

The success or failure of projects in agriculture depends on technological, human and environmental factors. Collaboration between scientists can help provide understanding of areas of different skills. For example the chemists have provided very important knowledge of plant resistance mechanisms. In my experience some collaborations were highly successful and very positive, while others could only be described as a disaster, and it is not easy to predict how they will turn out. Drought can completely destroy field work, and I now try and combine field and laboratory work in projects as some protection against adverse weather conditions.

Future directions

For myself I plan to continue some research to develop more stable dung beetle communities, and also to look at travelling waves of high density patches of redlegged earth mite around paddocks between generations. Perhaps this will provide a precision agriculture approach to redlegged earth mite control. Based on my experience I believe that a good understanding of the biology and ecology of the insect or mite and the ecosystem in which they function is the most important basis for developing new pest control. For example many biological events have a very critical timing for pest control. Some research can be delivered direct to farmers like biological control agents or resistant varieties of plants, but for much research there is a need to incorporate the findings into farming systems. In terms of understanding the interactions in pastures I am not convinced that research into Integrated Pest Management (IPM) is sufficiently problem embedded to be likely to provide results that can be used. Farmers are managing complex farming systems and they require special tools to deal with the environment/soil/farming system interactions that influence pest control. The drivers for farmers are productivity and systems economics rather than market development. This requires creative scientists to work directly with the farmers, and I believe that currently this type of work is not sufficiently well funded.

We only seem to appreciate the robustness of our ecosystems when they collapse. We go on doing things to them until there is a breakdown. We really don't know how much built in redundancy they have, and what measures we can use to measure this. In ecological theory diversity is predicted to result in stability, but we need to know how to use biodiversity as an index of stability. For this we need to look at the relations between biodiversity and stability in longer term ecological pest research. This is becoming difficult with cuts in government funding for agricultural research, but large impact projects are likely to come from the long term studies that can look at trends.

Professor Pauline Mooney, Executive Director SARDI, James Ridsdill-Smith and his wife Nicola Ridsdill-Smith

E-C Oerke and colleagues have shown that on average 16% of attainable yield is lost due to insects, and post harvest losses are a further 10%, in spite of the fact that large sums of money are spent on pesticides and management to reduce these losses. I believe that for pastures there is still potential for considerable future improvements in productivity from better pest control, but advances are more likely to come from solving a particular problem than a broadacre reduction of average pest abundance.

Acknowledgements

The interactions and discussions with other scientists are an extremely important part of a successful research project. I am very grateful to many people for their help and advice over the years. Thank you both to those who are listed and to many others with whom I have worked. Thanks also to my family for their support.