What can insects do to help the farm? soil improvement, pollination and pest control

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Abstract: *While the negative impacts of insects are well understood and subject to management, we tend to be less well informed about beneficial impacts of insects. It is important to conserve insects for their biodiversity value, but they also provide value through direct beneficial impacts on agricultural production. To illustrate this we describe three case studies, showing three different kinds of ecosystem services from insects. 1) Our study of flower visitors in canola fields shows that there are a range of potential pollinators for this seed crop, and that abundance of these pollinators can respond to the arrangement of habitats in the area around the crop. 2) We experimentally reduced the abundance of ants and termites in a wheat field and found that crop yield was greater when these "soil engineers" are present, and that part of the benefit is likely to come from their positive effect on soil infiltration. 3) Our research on a significant crop pest in a cotton growing region found that remnant woodlands were not a source of the pest, but do act as a source of natural enemies (potential control agents). Presence of these remnants could reduce the frequency of this pest problem in the region, but the control effect was not constant over time.*

Introduction

Insects are everywhere, they are abundant, and they get involved in a lot of biological processes. For these reasons managing insects has always been important to agriculture. They also account for a significant part of biodiversity (Odegaard 2000) and for this reason too we need to think about their management. While the negative impacts of insects (such as crop damage and spreading disease) are well understood and subject to active management, we tend to be less well informed about the beneficial impacts, and management of them is correspondingly less well developed. It is important to conserve insects for their biodiversity value, but it should also be understood that insect biodiversity provides great value through its direct beneficial impact on agricultural production.

Among the most significant beneficial impacts of insects (and their relatives) are their role in regulation of pest populations (the "natural enemy" effect), the pollination of crops, and soil engineering (Losey & Vaughan 2006). Although these benefits have been familiar in principle for a long time, recent research has begun to more effectively demonstrate how we can realise these benefits in agricultural systems. Here we describe three case studies that show insect-driven agricultural benefits of three very different kinds, to stimulate thinking about how farm practices can be modified to maximise the benefits to production provided by insect biodiversity.

Crop pollination

Approximately 75% of the crop species grown worldwide benefit from insect pollination (Klein *et al.* 2007). While many of these are horticultural crops grown in orchards, there are nevertheless a number of species grown in broadacre dryland cropping (such as is common in grassland environments) including canola and a number of pasture legumes (lucerne, pigeon pea, some clovers) (Schellhorn *et al.* 2008).

Canola (*Brassica* oilseed) is among the better studied crops. *Brassica juncea* yield is diminished by 30% when pollinators are absent (Chand & Singh 1995) and pollination affects oil content as well as seed number (Mahindru *et al.* 1998). *Brassica napus* is self fertile, but nevertheless shows a seed set benefit from flower visitors. Honeybees from managed hives increased *Brassica napus* yield in Western Australia by more than 20% (Manning & Boland 2000; Manning & Wallis 2005). Field trials in Canada show seed yield of *B. napus* can be increased 46% by increasing the density of bees (Sabbahi *et al.* 2005).

In spite of this we find that the majority of Australian growers do not pay for honeybee pollination and thus rely on free unmanaged pollination. Our research around Boorowa, NSW (34.438°S, 148.716°E) (Arthur *et al.* in press) showed 3 groups of flower visitors dominate: hoverflies (a few species), feral honey bees (one introduced species) and native bees (a suite of many species). The two smallest fields (~20 ha) had a higher density of flower visitors than the larger fields (34–86 ha, Fig. 1), reflecting that the pollinator population in the landscape is diluted when visiting large areas of a synchronously flowering crop. While hoverflies as a group were the most frequent visitors to canola flowers, they were also quite variable (see error bars and differences between fields, Fig 1). The feral European honeybee was a very frequent visitor in all fields. While feral honeybees are common in the landscape at present, they are expected to all but disappear when *Varroa* mites become established in Australia (Cunningham *et al.* 2002; Cook *et al.* 2007), exposing canola growers to significant risk. The remaining flower visits are from a diverse list of solitary native bees. Honeybees and hoverflies were more common when there was more remnant woody vegetation within 300m, and when this vegetation was less fragmented.

We suggest that canola growers currently get a very significant benefit from feral honeybees in particular. When *Varroa* invasion destroys feral honeybees, hoverflies and native bees will become relatively more important. Preserving

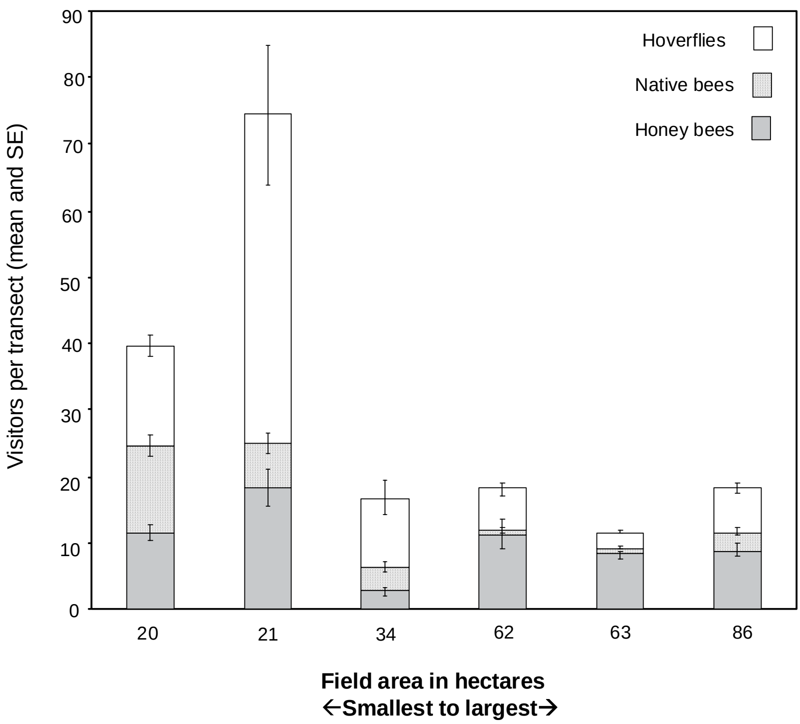

Figure 1. The mean number of canola flower visitors (±SE) counted per transect (22.5m long over 5–8 minutes) in canola fields near Boorowa, NSW, broken down into three visitor categories. Data are presented separately for 6 different fields, ordered from smallest in area to largest.

patches of non-agricultural vegetation in the landscape can help support pollinators. While honeybees require woody vegetation because they nest in trees, solitary native bees are likely to be more sensitive to soil management, because most species nest in the ground. Future research will examine the potential to maintain native bee populations by preserving patches of uncultivated ground in and around crops.

Soil Engineering

The warmer parts of Australia are notable for supporting high densities of ants and termites. These social insects live mostly underground where they tunnel and sometimes feed. Their tunnelling creates pores in the soil that can increase water infiltration to the root zone of crops. Their feeding can also re-distribute organic matter, potentially bringing more carbon and nutrients from above ground into the root zone. Many termite species also host nitrogen-fixing organisms in their gut and, so, can increase the nitrogen content of soil. We were interested in quantifying the extent to which termite and ant activity changed the structure of the soil in a wheat cropping environment and, more, importantly whether these changes to the soil provided agricultural benefits.

In a paddock near Binnu, WA (27.921°S, 115.028°E) we set up a replicated set of plots with four treatments in a two-way design: insects present vs. poisoned, and soil tilled vs. no till. To reduce ant and termite density we applied an insecticide (BiFlex) known to be effective against these insects, and which has a long lasting residual effect. For the control we applied the equivalent volume of water but with no insecticide. Tillage was applied to the top 10 cm (half the plots), which we expected to disrupt some of the existing soil structure. We surveyed to ensure that the insecticide was effective, and then measured a number of soil traits and crop yield for the next two years.

We found that the termite and ant poisoning treatment had a strong and significant effect on soil moisture at 50 cm after rainfall events, with 50% more water when insects were present (comparing tilled plots). There were also increases in soil nitrogen. In parallel, we saw

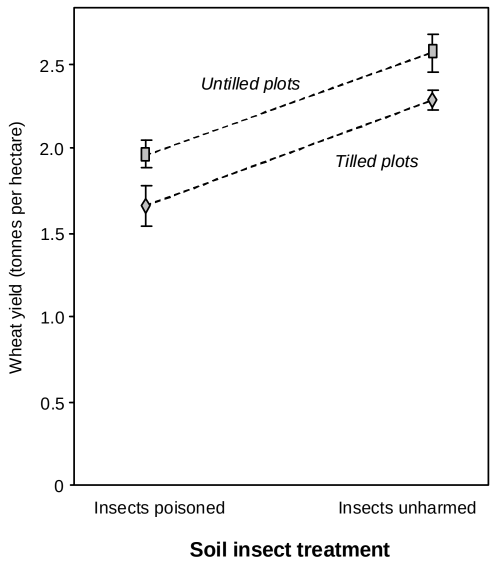

Figure 2: Wheat yield (in tonnes per hectare, mean ±SE) from plots either tilled (diamond symbol) or untilled (square symbols) and with insects poisoned or not poisoned (x axis).

that 2 years after the treatments were applied, wheat yields were >30% greater in treatments with soil insects than in those treatments where insects were poisoned (Fig. 2). Given the responsiveness of wheat to water and nutrient availability, we suggest that the yield advantage in the presence of soil insects is most likely due to the soil engineering activity of ants and termites (Lobry de Bruyn & Conacher 1990; Lavelle *et al.* 2006).

The benefits of low tillage systems have been known for decades, but our experiment shows that further benefits can be gained by optimising the activity of soil engineering insects. Further research will focus on methods of maintaining strong populations of these insects, which are likely to include judicious use of insecticides, and the maintenance of source populations in the landscape to ensure that beneficial ants and termites are not lost from the paddock.

Natural pest control

The economic significance of pests to farmers is obvious, not least in terms of the amount of money spent on insecticide to reduce their impact. Costs can also be measured in terms of yield losses when damage is uncontrolled, and negative impacts on the broader environment. Given the evidence discussed in the previous two case studies, it is also useful to think about how insecticide use can have perverse negative impacts on production in terms of reduced pollination for pollination dependent crops, or reduced soil quality through loss of beneficial soil engineers. For these reasons, pest control with no or few chemicals should be embraced. But how can it be achieved?

While some herbivorous insects are significant economic pests, there are also many insects and other invertebrates that are predators or parasitoids of pest species. Because natural enemies suppress populations of a wide range of insect herbivores, the vast majority do not become pests in crops. Our goal should be to support populations of these "natural enemies" at a level that suppresses the pest population. Pests and their enemies tend to be very mobile, and agricultural crops tend to be ephemeral in time and space. Therefore, we need to think about capturing the service of natural pest control beyond the scale of the crop alone, and determine which habitats in the landscape mosaic are sources of pests and their enemies (Schellhorn *et al.* 2008).

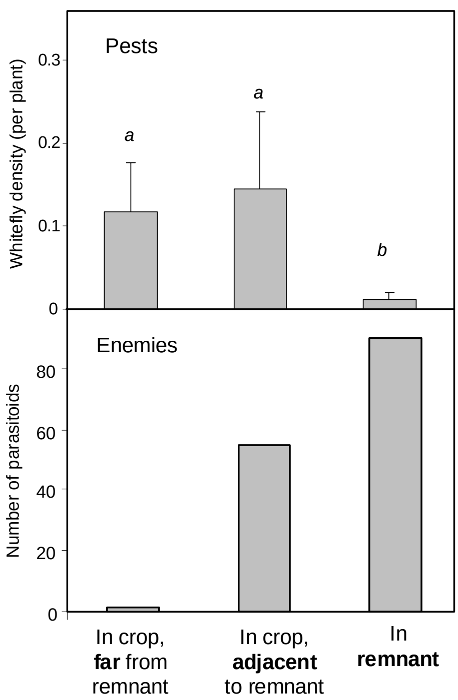

Figure 3: A comparison of plots far (>400m) from remnant, adjacent to remnant and in remnant vegetation in terms of whitefly density on cotton seedlings (mean ± SE, top graph) and the total number of whitefly parasitoids recorded (bottom graph). For the whitefly density effect, landscape position is significant at P = 0.033 (F 2,14 = 4.38, letters indicate significant differences using least significant difference in ANOVA). For the parasitoid abundance, the landscape position effect is significant at P < 0.001 (X2 = 278.1).

To understand the role of landscape heterogeneity in pest-enemy interactions, we surveyed insects in crops and in remnant vegetation and tracked changes over time, focusing on two landscapes in southern Queensland (near Dalby 27.183°S, 151.264°E). We focused only on juvenile stages (i.e. individuals likely to be born in the sampled site) and examined the ratio of pests to their enemies. We found that crops generally supported a higher ratio of pests than enemies, and conversely remnants of native vegetation appear more important as a source of natural enemies (Bianchi 2009).

To test the way pests and enemies colonised crop plants, we conducted a large replicated trial in which cotton plants were placed in different parts of the landscape, and then monitored for the presence of different insects. Further, we deliberately infected plants with some significant pest species to act as bait for enemies. While different insects showed different patterns of colonisation, there were important instances in which native vegetation appeared to serve as a source of natural enemies. For example, silverleaf whitefly (a pest) was most strongly parasitised (killed) when on plants in or near remnant native vegetation (Fig. 3). In contrast, recruitment of whitefly was higher in the agricultural land than in the remnant (Fig. 3), whereas recruitment of cotton pests such as *Helicoverpa* spp., aphids and whiteflies was not influenced by native vegetation. The pattern for whitefly was strongly significant in one year (Fig. 3), but then neutral in the following year, illustrating that these effects are dynamic in time, but in a way we cannot yet predict.

These patterns show that the presence of remnant vegetation in the landscape can contribute to pest suppression because its function as a source of natural enemies is greater than its role as a source of pests. Future research is focusing on understanding the scale at which this benefit is felt (how much remnant vegetation do you need?) and whether deliberate habitat manipulation could provide greater benefits.

Conclusions

These examples show how beneficial insects can provide real economic benefits in Australian farming systems. In each case, we have broad principles for supporting the beneficial insects and processes, but more research is required to make the management recommendations more specific, and to improve certainty around benefits. We know that risk management is an important part of farming, and that for new practices to be adopted there needs to be confidence that they are not increasing risk.

We already know some of the activities likely to harm populations of beneficial insects. The single biggest step toward maintaining invertebrate biodiversity and maximising the services it provides is eliminating the use of broad-spectrum insecticide use. When deciding whether or not to apply insecticide, one needs to balance the loss of harmful insects against the loss of beneficial insects, and the direct economic cost of application. Secondly, we know that habitat conservation is important. This might be in the form of larger patches of remnant vegetation, or sometimes even small patches of land on farm that are not under cultivation or intense use. While it is easy to say that "more is better" in terms of conservation and provision of beneficial services, there can be costs to production if one forgoes production from parts of the farm. If we can better understand these trade-offs (i.e. costs and benefits from reducing production from patches of land), then we will be in a better positions to make wise land use choices. These choices can be thought of at the level of the farm, or at the level of the broader landscape where there are interactions between neighbours and between parcels of public and private land. Better understanding of these benefits can make conservation decision-making more harmonious with productive land use, and improve the bottom line for Australian farmers.

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