Short Communication

Exotic pest insects: another perspective on coffee and conservation

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Abstract Research on crop systems and biodiversity conservation in the tropics has mainly been concerned with how low to mid intensity agricultural systems can benefit from adjacent natural habitats by receiving ecosystem services from natural biodiversity. One intensively studied crop in this framework is coffee. Positive effects are relatively easy to quantify by comparing coffee yield and by recording native species diversity. However, a largely overlooked issue is how agricultural areas affect native organisms in adjacent natural habitats, for example through movement of pest species that could impose a risk of degrading these habitats. We give an example from Mauritius, where an introduced coffee pest severely reduces the reproductive success of a threatened endemic plant species. We argue that such effects may be more common than suggested by the literature, especially when crop and native plants are congeneric. In the long term, such negative effects may degrade natural habitats, thereby causing ecosystem services derived from these habitats to decline.

Keywords Agroecosystem, biodiversity, coffee, ecosystem services, insect pest, Mauritius.

Studies in biodiversity research and conservation biology have emphasised the loss not only of species but also of ecosystem functions and resulting ecosystem services (e.g. Daily, 1997). Pollination and pest control are two examples of crucial ecosystem functions and their loss may have profound ecological, economical and social consequences (Chapin *et al.*, 2000). Animal pollination represents a critically important group of ecosystem functions and is of particular value in agricultural landscapes (Nabhan & Buchmann, 1997; Roubik, 2002). For example, it is estimated that crop pollination by animals is worth USD 112 billion per year on average (Costanza *et al.*, 1997), and the decline of managed and wild pollinators is therefore of great concern (Allen-Wardell *et al.*, 1998; Kosior *et al.*, 2007; but see Ghazoul, 2005). Recent research has highlighted the role of natural habitats in maintaining a high pollinator diversity that provides stable, high levels of pollination services to nearby crop plants (Roubik, 2002; Klein *et al.*, 2003; de Marco & Coelho, 2004; Ricketts, 2004). Similarly, the natural service provided by predatory and parasitic organisms in controlling pest species on crop plants may depend on the diversity of natural habitats in which these organisms can persist throughout their life cycles when pest insects are not available (Naylor & Ehrlich, 1997). Thus, current consensus is that the management of agricultural landscapes in the tropics should aim to maximise the benefits derived from ecosystem services rendered by animals by maintaining structurally diverse habitats that harbour stable populations of beneficent animal species.

One well studied crop plant in the tropics is coffee. In many tropical montane regions forest fragments are embedded in a matrix of traditional coffee plantations (Perfecto *et al.*, 1996; Perfecto & Vandermeer, 2002). Planting coffee bushes in proximity to forest fragments or even directly in the forest increases coffee yield because the structurally more complex habitat of the forest supports a higher diversity and abundance of pollinators and natural pest control agents for the coffee plants than impoverished agricultural land (Moguel & Toledo, 1999; Klein *et al.*, 2003; Ricketts, 2004; Steffan-Dewenter *et al.*, 2006).

While the benefits of native animals to crop plants in the tropics are increasingly being assessed and used to inform agricultural and related conservation policies, there has been little concern with the potential impacts of agricultural practices and introduced animals on

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native plants in their natural habitats. The most obvious explanation for this disparity is that quantifying positive effects of, for example, pollinator diversity or negative effects of pest species on crop yield is more straightforward and economically rewarding than measuring gains or losses in biodiversity in surrounding natural habitats (Edwards & Abivardi, 1998). While effects on crop yield can be expressed directly in economic terms it is more difficult to assign a universally understandable economic value to a change in natural ecosystem functioning, which can only be assessed indirectly following a decrease of biodiversity in natural habitats (Pearce, 2001).

One potential negative consequence of mixing crop plants with natural habitats could be the invasion of pest species from agricultural landscapes to the surrounding natural habitats. The global distribution of many crop species provides a large base for invasion of pest species from agricultural landscapes to surrounding natural habitats (Mack *et al.*, 2000). Wild hosts can provide an opportunity for pest species to build up or maintain reservoir populations before dispersing to cultivated hosts (Panizzi, 1997; Sudbrink *et al.*, 1998; Fox & Dosdall, 2003) but the role of wild hosts in pest population dynamics is usually only considered when there is an economic impact on crop yield (van Emden, 1981). Although such research bias is inevitable, it is vital to also consider the possibility that crop plants can serve as hosts from which pests may spread into natural habitats.

Here, we add another perspective to the present debate (Rappole *et al.*, 2003; Steffan-Dewenter *et al.*, 2007; Vandermeer & Perfecto, 2007) on coffee and conservation in the tropics by presenting an example from the island of Mauritius, where an introduced pest species of coffee seriously affects the reproductive success of an endangered endemic plant. In Mauritius commercial coffee *Coffea arabica* L. (Rubiaceae) plantations were established in 1721 (Rouillard & Guého, 1999). The coffee berry moth *Prophantis smaragdina* (Lepidoptera; Crambidae) was accidentally introduced to Mauritius and was first documented in coffee plantations in 1938 (Vinson, 1938). It has long been recorded on *C. arabica* in other countries, for example on the island of Sao Tomé in the Gulf of Guinea, where it destroyed up to 80% of the coffee yield (Derron, 1977). The last reported infestation of *P. smaragdina* on coffee in Mauritius was in 1995 on plantations close to the Black River Gorges National Park, which contains the largest remaining area of native forest on the island. Preliminary observations in the National Park during another experimental study (Kaiser, 2006) suggested a strong negative effect of herbivory by *P. smaragdina* on fruit production of the endemic dioecious shrub *Bertiera zaluzania* (Rubiaceae), which is closely related to *Coffea* (Davis *et al.*, 2006). To substantiate these observations we monitored the fruit development of 20 female *B. zaluzania* plants, which constitutes *c*. 10% of the largest extant population on Plaine Champagne, an upland heath area within the National Park. This population is located parallel to the closest commercial coffee plantation, resulting in similar distances between each *B. zaluzania* individual and the coffee plantation. Experimental plants were assigned randomly by dividing the area into 100 quadrats and selecting the most central *B. zaluzania* plant in 20 randomly chosen quadrats. We surveyed 10 randomly

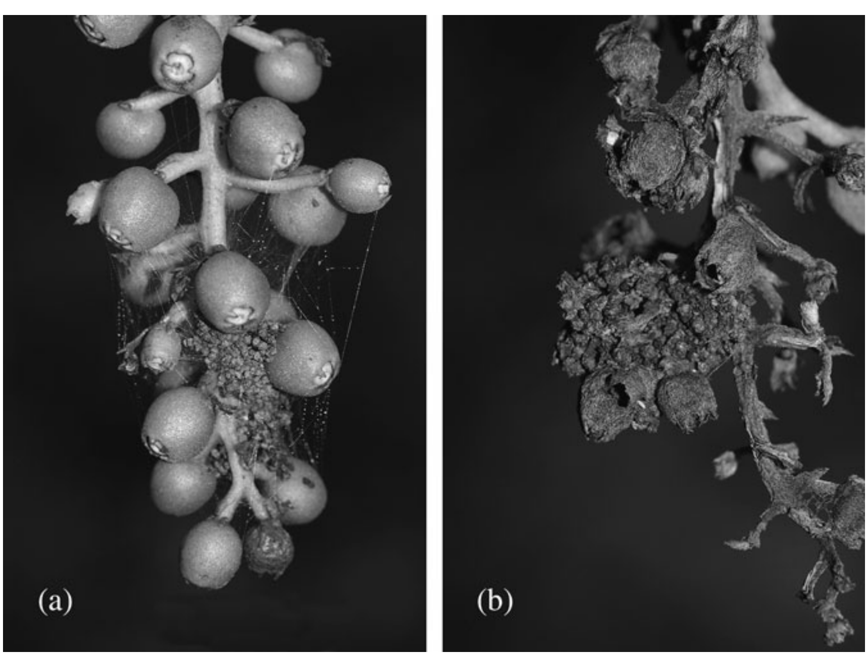

Plate 1 Fruit of *Bertiera zaluzania* (Rubiaceae) (a) freshly attacked and (b) fully destroyed by *Prophantis smaragdina* (Lepidoptera: Crambidae). All fruits had been destroyed within 2 weeks of exhibiting signs of attack.

selected infructescences per plant (mean number of infructescences per plant was 21.5 ± 2.3 SE) in the first week of February 2004 and 2005, once fruits had started to develop and had reached a diameter of *c*. 4 mm. In 2004, 14 out of 19 plants (flowers of one of the 20 study plants were attacked by fungi and did not set any fruit) were attacked by *P. smaragdina* caterpillars (Plate 1a), affecting an average of 23.0 ± SD 19.6% of infructescences in attacked plants. Within two weeks, all fruits on attacked infructescences had been destroyed (Plate 1b). In 2005 all 20 experimental plants were attacked, at a mean rate 81.3 ± SD 21.2% infructescences per plant. This represented an increase in attack rate on individual plants from 73.7 to 100%, and a three-fold increase in attack rate of infructescences per affected plant compared to 2004. To assess whether the spread of *P. smaragdina* through the population was density-dependent, we measured the nearest neighbour distance from the 20 experimental plants to the three closest *B. zaluzania* plants. Attack rate was independent of the mean distance between experimental plants and the closest neighbouring *B. zaluzania* plants ($r = 0.24$, $n = 19$, $P = 0.33$), suggesting that density dependence in the attack rate of the larvae did not occur. It is unlikely that *B. zaluzania* is the only endemic Mauritian Rubiaceae affected by this pest species, but no surveys have been carried out of any other species in the family. As in many tropical countries, the Rubiaceae is species-rich in Mauritius, with 15 genera and 59 native species, 88% of which are endemic to the island. Twenty-nine of these endemic species are categorized as Critically Endangered or Endangered according to IUCN criteria (IUCN, 2001; Mauritian Wildlife Foundation, unpubl. Database). In Mauritius *P. smaragdina* could threaten the reproduction of many endemic relatives of *C. arabica*, in particular the endangered congeneric *C. macrocarpa, C. mauritiana* and *C. myrtifolia*, as well as species from more distantly related genera, such as *Chassalia* and *Gaertnera*. Given that the National Park is surrounded by crops and exotic forest plantations it is likely that associated pest species will utilize new host species among native plants in the vicinity. This may pose an additional significant threat to the threatened Mauritian flora and further research on this issue is needed.

Our observations from Mauritius are applicable elsewhere. In North Queensland, Australia, Blanche *et al.* (2002) compiled information on 49 economically important arthropod pest species of which 31 (63%) were introduced. Nine of these species used native rainforest host plant species for at least part of their life cycle, and the author emphasized that it may be unwise to plant crops close to the forest.

It is ironic that, although agricultural schemes encompassing natural habitat are intended to both benefit from and protect this habitat, they may in fact accelerate the impoverishment of such areas, and thereby ultimately compromise their own existence. Studies into such contrary effects are urgently required to counteract the largely one-sided economical approach that has dominated this emerging and active field of research to date.

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Biogeographical sketches

Christopher Kaiser and Dennis Hansen have studied plant-animal interactions, plant reproduction and effects of restoration management in collaboration with the Mauritius Wildlife Foundation and the National Parks and Conservation Service in Mauritius for the past 4 and 8 years, respectively. Christopher Kaiser is currently identifying barriers to plant reproduction and population viability of Seychelles threatened endemics. Dennis Hansen is developing a project to assess the impact of the loss of large seed-dispersing vertebrates in Mauritius and how to use ecological analogue species to resurrect some of the lost interactions. Christine Müller leads a research group on food web ecology and plant-animal interactions. Her research focus is on effects of microbes on insect food web interactions, plant-bee-parasite communities in agricultural landscapes, and effects of invasive species on plant–insect interactions.