Integrated pest management: an under-utilized tool for conservation and the management of invasive ants and their mutualistic Hemiptera in the Pacific

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INTEGRATED pest management (IPM) is a well-developed technology applied primarily in agroecosystems. In many situations, IPM, with associated biological control agents, can stop the need for pesticide applications and results in pest densities being sustained below economic or ecological thresholds. My thesis is that IPM is a highly functional tool that is largely being ignored in conservation, and specifically that it is critical for the sustained control of invasive ants in many Pacific island and atoll systems.

Five ant species are listed in "100 of the World's Worst Invasive Alien Species" (Lowe et al. 2000). These ants can kill or compete with native animals, directly or indirectly altering habitat structure and ecosystem processes (Holway et al. 2002). How can something so small be so devastating? The key to their success is their abundance. On Christmas Island in the Indian Ocean, Yellow Crazy Ants *Anoplolepis gracilipes* occur in "super-colonies" ($\sim$1000 ants m^{-2}), but are also observed in much lower densities outside of these super-colonies. Only within supercolony areas are the dramatic changes to the fauna and flora observed, including the killing of large numbers of crabs and consequent increased plant abundances (O'Dowd et al. 2003). On Palmyra Atoll, islands with high densities of Big-headed Ants *Pheidole megacephala* are experiencing the widespread die back of *Pisonia grandis* (Fig. 1; Handler *et al.* 2007). Although the end results for Palmyra Atoll and Christmas Island are different, high ant densities drive the observed floral and faunal changes.

Among the several mechanisms which contribute to the abundance of these invasive ants are the mutualistic relationships that they form with hemipteran insects, including scale insects, aphids and mealybugs. The hemipteran insects receive protection from their natural enemies, while the ants receive carbohydrates (in the form of honeydew). When ant populations are removed, hemipteran mutualist densities crash (Abbott and Green 2007).

Preventing or limiting the international movement of invasive ants, and quickly identifying and treating new incursions is vital. Chemical treatment to achieve eradication is possible for small or moderately sized infestations (e.g., Hoffman and O'Connor 2004). However, for established or widespread infestations on many islands of conservation importance chemical control techniques are considered risky, with eradication possibly unachievable over wide areas, and/or the strategy may be ultimately unsustainable. Long-term management plans for invasive ants that specifically limit their densities are desperately needed for many Pacific archipelagos including Palmyra Atoll, Papau New Guinea, and the Solomon islands where Little-fire Ants *Wasmannia auropunctata* are devastating subsistence crops and doing who-knows-what to the local biodiversity.

Integrated pest management and biological control techniques need to be given much more prominence as a long-term and sustainable option for invasive ant control. These techniques can target either the hemipteran mutualists or the ants themselves. The control of the hemipteran mutualists is perhaps the most likely avenue for success. For example, the key mutualist responsible for the die-off of *Pisonia* on Palmyra is Green Scale *Pulvinaria urbicola*. In one of few examples of the use of IPM for the control of invasive ants and conservation, dramatic reductions in *Pulvinaria* densities have been achieved on *Pisonia* on North East Herald Cay in the Coral Sea using biological control agents (Smith et al. 2004). Although examples of successful programmes for the direct biological control of ants are few, a biological control of programme of the Red Imported Fire Ant *Solenopsis invicta* involving pathogens and parasitoids is underway. A major advantage of biological control agents that directly attack ants is that many Pacific islands contain few or no native ant species, limiting the potential for non-target effects.

IPM approaches in agroecosystems offer useful models for conservation. A recent example of successful IPM is with a mealybug pest that caused up to 80% crop failure of cassava. Cassava is a drought resistance crop that is important or vital to subsistence farmers in 26 African countries. Sustained control of mealybug on cassava has been achieved by the widespread introduction of a parasitoid. Commonly, however, to achieve such sustainability, the aim is to optimize tritrophic interactions among the plant, the phytophagous pest organisms, and their natural enemies, rather than to maximize the effect of a single intervention (Neuenschwander 2001). For example, chemical control of invasive ants may be first required prior to the introduction of biological control agents, in order to reduce the amount of ant protection given to hemipteran insects (Smith et al. 2004).

It seems contrary to conservation ethics to introduce foreign species onto remote and valued ecosystems. I'm not advocating the indiscriminate

Fig. 1. Top photograph shows Pisonia forest on Palmyra atoll with low densities of ants and scale insects; the lower photograph shows high densities of each plus an inset of a Pisonia leaf with lots of scale.

use of biological control agents and I am concerned over non-target effects. However, time is ticking. For example, Palmyra Atoll supports one of the largest remaining native stands of *Pisonia grandis* forest in the tropical Pacific Ocean. In 2002, 12% of vegetated land area of Palmyra was covered by *Pisonia*, but this figure was reduced to ~ 8% in 2005 (Handler et al. 2007). Biological control approaches have suggested on Palmyra and in other invasive ant management plans (Commonwealth of Australia 2006, Handler et al. 2007). Biological control is ideal for these scenarios, as successful introductions can permanently lower densities of hemipteran insects and ants. Low ant densities have negligible effects on communities.

Biodiversity is measurably declining while managers debate the introduction of exotic species for biological control and IPM onto small and into fragile ecosystems. Conservation funding agencies, some of which specifically do not fund the introduction of non-native species, need to recognize the potential of biological control programmes as a sustainable and environmentally friendly approach for conservation on remote Pacific islands. Ethics and equivocation may have a downside: it's called the loss of biodiversity value.

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