RISKS OF NON-TARGET IMPACT VERSUS STAKEHOLDER BENEFITS IN CLASSICAL BIOLOGICAL CONTROL OF ARTHROPODS: SELECTED CASE STUDIES FROM DEVELOPING COUNTRIES

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INTRODUCTION

Classical biological control of insect pests has long been upheld as environmentally safe, yet in recent years, new concerns about safety have been raised, and in particular, the scope for impact on non-target organisms has been discussed and demonstrated (e.g., Thomas and Willis, 1998; Follet and Duan, 2000; Howarth, 2000; Lynch and Thomas, 2000; Henneman and Memmott, 2001; Wajnberg *et al.*, 2001). Non-target effects can be direct (an introduced biological control agent attacks a non-target host) or indirect (through the effects of the target being successfully controlled; the introduced biological control agent competes with or displaces indigenous species; ecosystem and food web changes, etc.). Biological control workers must accept that there are hazards and risks involved in the introduction of any biological control agent. In order to justify an introduction, a risk-benefit analysis is needed to identify and if possible quantify the risks posed, including the potential effect of not implementing biological control, and the benefits to be gained, including those to non-target species already being affected by the target pest.

In discussing this topic, it may be worthwhile to separate non-target *impact* and the *risk* of non-target impact. "Impact" is what actually happens when a biological control agent is introduced, whereas "risk" is the *a priori* assessment of the chances of that impact happening. One can have a high risk of minimal impact, or a low risk of a huge impact, or any combination of the two. In many cases, it will be difficult to evaluate the potential non-target impact or the risk of such non-target impact happening. The combination of the total risks of different potential impacts needs to be balanced against a similar exercise in terms of benefits and probability of securing those benefits.

Some risks relate to biological control not being done properly, e.g., parasitoids contaminated by diseases or hyperparasitoids, shipments contaminated by plant diseases. These issues are not addressed here, and they should be avoidable by following internationally accepted procedures and best practices, e.g., as set out by IPPC (1996).

In this analysis, a stakeholder analysis is considered the first step, in order to identify national (and international) concerns and issues, i.e., all those groups of society nationally (and ideally internationally) who may be affected directly or indirectly by making, or not making, a biological control introduction, its potential intended impact, and its potential non-target impact.

Applying procedures developed to assess the possibilities of non-target effects, such as may address the concerns of developed countries, is not always straightforward in developing countries with different national perceptions and priorities (Neuenschwander and Markham, 2001). Here I describe three recent cases in which CABI Bioscience has been involved in assessing the potential impact on non-target species in biological control programs with developing countries: *Orthezia* scale in St. Helena, *Hibiscus* mealybug in Grendad, and coffee berry borer in Colombia. The cases studies show increasing complexity both in terms of the impact and risks and the risk-benefit analysis.

ORTHEZIA SCALE IN ST. HELENA

The following account is summarized from the author's personal knowledge and the following references: Booth *et al*. (1995), Fowler (1996), and Wittenberg and Cock (2001).

The Biological Control Program

In the 1990s, gumwood (*Commidendrum robustum* DC. Asteraceae), the endemic national tree of St. Helena, was in danger of extinction because of an alien insect. Orthezia scale, *Orthezia insignis* Browne, is native to South and Central America, but is now widespread through the tropics. It was accidentally introduced into St. Helena in the 1970s or 1980s and became a conspicuous problem when it started feeding on gumwood in 1991. Gumwood once formed much of the extensive woodland that used to cover the higher regions of the island but at the time of this program was restricted to two stands of around 2000 trees. It is a typical example of the remarkable and globally important endemic flora on St. Helena.

Once the gumwoods became infested in 1991, an increasing number of trees were being killed each year and at least 400 had been lost by 1993. Orthezia damages its host primarily through phloem feeding but the colonization of the honeydew that orthezia excretes by sooty moulds has a secondary effect through the reduction of photosynthesis. Because orthezia is polyphagous, and large populations could be maintained on other hosts such as lantana (*Lantana camara* L., Verbenaceae), it spread easily onto the relatively rare gumwood trees. Gumwoods are susceptible to orthezia and if nothing had been done, it is most probable that gumwood would have become extinct in its natural habitat.

CABI Bioscience assisted the Government of St. Helena in carrying out a biological control program against this pest. Between 1908 and 1959, the predatory coccinellid beetle *Hyperaspis pantherina* Fürsch had been released for the biological control of *O. insignis* in Hawaii, four African countries, and Peru. Substantial control was reported after all releases. Accordingly, *H. pantherina* was obtained from Kenya, and it was cultured and studied in CABI Bioscience's U.K. quarantine.

In 1993, *H. pantherina* was imported, cultured, and released in St. Helena. It rapidly established and did indeed control orthezia on gumwoods. It was concluded that gumwood had been saved from extinction in its natural habitat. This is probably the first case of biological control being implemented against an insect in order to save a plant species from extinction.

The Stakeholders

Stakeholder analysis suggested that the following key groups were concerned with biological control of orthezia scale:

- Conservationists, particularly those concerned with the preservation of St. Helena's globally important flora and fauna;
- The agricultural industry in St. Helena, particularly those concerned with crops likely to be affected by orthezia;
- Garden owners, as some ornamental plants are adversely affected by orthezia scale;
- Landowners whose land is infested by *L. camara*, since this alien invasive plant is also attacked by orthezia scale, which can be quite damaging to lantana, possibly offering some control; and
- The British Government, which is responsible for the colony of St. Helena, as the control of orthezia scale would help them meet their obligations under the Convention on Biological Diversity.

The Risks and Benefits

The risk of non-target impact associated with the introduction of *H. pantherina* were seen as minimal for these reasons:

- No adverse effects had been reported following its introduction elsewhere (not that these would have been specifically looked for);
- Studies showed that reproduction of the beetle is dependent on the presence of orthezia, that *H. pantherina* normally lays eggs directly onto adult females of *O. insignis* and that the first two instars of the larvae are frequently passed inside the ovisac of the female host, after which the host itself is consumed; and
- An assessment of the St. Helena fauna showed that there did not seem to be any related indigenous species (although there were quite a few exotic pest scales present).

So it was concluded that introduction of this predator would not only be safe in terms of impacts on non-target organisms, but also would be likely to control the orthezia scale, and save the gumwoods.

The benefits of the program are clear; the orthezia scale was brought under control and the gumwoods were no longer in immediate danger of extinction. Hence, efforts to re-establish natural vegetation can still use this important tree. Whether orthezia was providing any control of lantana, and whether this was disrupted, has not been documented, but would have been an interesting study.

HIBISCUS MEALYBUG IN GRENADA

The following account is summarized from the author's personal knowledge plus Kairo *et al*. (2000) and references therein.

The Biological Control Program

Hibiscus mealybug (*Maconellicoccus hirsutus* Green) is native to parts of Asia, but has been introduced to other parts of the tropics. It was first reported from Grenada in 1994, and has subsequently spread to at least 25 territories in the Caribbean region. Hibiscus mealybug attacks the new flush growth, young shoots, flowers, and fruits of a wide range of plants, particularly those in the family Malvaceae. Important hosts include ornamental hibiscus (*Hibiscus rosa-sinensis* L.), blue mahoe (*Hibiscus elatus* Sw., an important indigenous watershed tree in Grenada), samaan (*Samanea saman* [Jacq.] Merril), teak (*Tectona grandis* L. f.), soursop (*Annona muricata* L.), ochro (*Abelmoschus esculentus* Moench), sorrel (*Hibiscus sabdariffa* L.), cotton (*Gossypium hirsutum* L.), cocoa (*Theobroma cacao* L.), and citrus (*Citrus* spp.). Damage on these crops was often substantial, including loss of fruit, defoliation, and death of plants.

Hibiscus mealybug was the subject of a successful biological control program in Egypt, is the target of ongoing augmentative efforts in India, and was fortuitously controlled in Hawaii when it was introduced with its natural enemies. Initially, two natural enemies were introduced into Grenada: a narrowly specific encyrtid wasp (*Anagyrus kamali* Moursi) and a polyphagous coccinellid mealybug predator (*Cryptolaemus montrouzieri* Mulsant), although others were introduced later. Both became established and good control in most situations was rapidly achieved. The program was considered an outstanding success.

The Stakeholders

Stakeholder analysis suggests the following key groups concerned with biological control of hibiscus mealybug:

- The Grenada tourist industry, the country's largest industry, specifically those responsible for the tourism image, hotel grounds, catering (supply of local fruit and vegetables);
- The Grenada agriculture industry, a mainstay of the economy, since several of the island's major crops were affected;
- Traders, especially those involved in inter-island trade by sea of agricultural produce;
- The public, particularly garden owners because of the impact on many ornamentals;
- The government, because of the impact on the economy and criticism of their handling of the crisis in the lead up to an election;
- Crop protection scientists, under pressure to solve the problem;
- Regional and international organizations, who saw an opportunity to solve a major, high-profile problem; and
- Agro-chemical suppliers who hoped to sell a lot of products.

In short, more or less the entire population was a stakeholder in the control of hibiscus mealybug, in one way or another.

The Risks and Benefits

The risk of non-target impacts associated with the introduction of *A. kamali* were seen as minimal for these reasons:

- It belongs to a group of parasitoids known to show a high degree of host specificity;
- All host records referred to the genus *Maconellicoccus*;
- Laboratory tests which CABI Bioscience carried out on a small selection of mealybugs confirmed its specificity; and
- It was credited with playing the major role in the successful biological control program in Egypt, and implicated in the fortuitous control in Hawai'i.

The risk of non-target impacts associated with *C. montrouzieri* were seen as significantly greater, although difficult to assess for these reasons:

- It was known to have a wide field host range, especially on a broad diversity of mealybugs, and other soft-bodied sedentary Homoptera;
- In the laboratory its host range was much wider, including several orders of arthropods; and
- It was considered a high prey density predator, i.e., it would reduce populations, but then would be more likely to disperse than to wipe out the local prey population.

Based on this assessment, the program planned by CABI Bioscience and FAO (a branch of the United Nations) with the Ministry of Agriculture, Grenada, focused on *A. kamali*, as likely to solve the problem with minimum risk of non-target impact, and retrospectively this probably would have been the case. However, it soon became apparent that the political and social pressures to solve the hibiscus mealybug problem were so great that other biological control agents, including *C. montrouzieri*, were being demanded irrespective of the greater associated risks. Other agencies moved to introduce *C. montrouzieri*, and Grenada immediately agreed to this.

The benefits of the program are very clear, and in most aspects the situation returned to what it was before the arrival of hibiscus mealybug, although some quarantine barriers remained in place until hibiscus mealybug colonized Grenada's trading partners. The pattern of pesticide sales before, during, and after the hibiscus mealybug invasion and its control is not available. The only other possible loser was the incumbent government. The success of the biological control program was not yet apparent when the election took place, and the government lost. The extent to which this was a reflection of their handling of the hibiscus mealybug crisis is open to speculation, although this does appear to have been a factor. The experience in Grenada enabled other Caribbean and mainland countries to rapidly implement biological control when the pest reached them, thereby minimizing the impact on their economies. Biological control, in the context of Integrated Pest Management tools, is now an accepted strategy for pest management in the region.

COFFEE BERRY BORER IN COLOMBIA

The following is based on the author's personal knowledge and the following references: Lopez-Vaamonde *et al*. (1997), Lopez-Vaamonde and Moore (1998), and Baker (1999).

The Biological Control Program

Coffee berry borer (*Hypothenemus hampei* [Ferrari]) is an important worldwide scolytid pest of coffee (*Coffea* spp.) originally from Africa, which spread through Colombia in the 1980s. Rigorous harvesting to remove all ripe berries provides some control. Coffee berry borer is difficult to control using pesticides because most or all of its life cycle takes place within the coffee berry, and the use of chemical pesticides runs contrary to the environmentally friendly "Café de Colombia" image. Biological control is an obvious alternative. However, even though two bethylid wasps have been successfully introduced into Latin America, they do not provide adequate control. As part of a project funded by Department for International Development, U.K. (DFID) in the 1990s to develop IPM of coffee berry borer, CABI Bioscience and Cenicafé, the Colombian coffee research institute of the Federation of Colombian Coffee Growers, investigated a new potential biological control agent, the tetrastichine wasp *Phymastichus coffea* LaSalle, which was described from coffee berry borer. The wasp was imported from Africa into CABI Bioscience's U.K. quarantine, where it was reared and host specificity tests carried out on a selection of non-target scolytid species. Several small scolytids could be parasitized under no-choice conditions, although this does not mean they would be attacked under field conditions. The risk of impact on indigenous scolytids was included in the dossier prepared for the Colombian authorities, and permission was given for the release of the wasp. It was imported, mass reared, released, and is reported to be established and causing high (>50%) levels of parasitism. It is not yet known whether the wasp by itself will control the pest, and the most likely scenario is that it will become an important component in an IPM approach (Baker *et al.*, 2002). At the very least, such an approach is now much more feasible than it was without potentially effective natural enemies.

The Stakeholders

From several perspectives, coffee is a very important crop in Colombia, and even at the current low world coffee prices, coffee is a major contributor to the economy. Hence, there are many important stakeholders in this project to develop effective control for its key insect pest in Colombia:

- Coffee growers, both large scale and small scale, who between them farm most of the agricultural land in the coffee belt of Colombia;
- The Federation of Colombian Coffee Growers, who justifiably market and sell Café de Colombia as an environmentally friendly product;
- The Government of Colombia, as coffee is a major contributor to the economy;
- The country as a whole, since the profitable production of coffee is a major force for stability in the country, helping to balance the narcotics industry and the paramilitary organizations;
- Environmental interests, since coffee is a major landscape element where it is grown, and depending upon the degree of intensification, and especially the use of shade trees, can substantially affect the landscape and its biodiversity; and
- Those countries to which the Colombian narcotics industry exports, inasmuch as the coffee industry is a stabilizing force in Colombia, and provides some balance to the influence of the narcotics industry.

The Risks and Benefits

The risks of non-target effects due to the introduction of *P. coffea* relate principally to the possible impact on other small scolytids in Colombia. Little is known about which scolytids occur in Colombia, what their population dynamics are, or what their ecological role might be. Hence, it had to be concluded that impact on small non-target scolytids was possible, but that it was impossible to predict which species were at risk, how they would be affected, or what impact on ecosystem function their control might have. Faced with such unspecific risks, against the potential effects if coffee berry borer were not controlled, there was little hesitation in giving permission to release the wasp.

In contrast, the possibility of coffee berry borer proving uncontrollable had very significant implications, especially when combined with low coffee prices on the world markets. Coffee berry borer is a relatively intractable pest problem, and the establishment of biological control agents capable of significant impact on the pest is seen as a potential key to developing effective IPM strategies. Thus if *P. coffea* were not introduced, the industry might end up with no effective natural enemies and no effective IPM strategy. This would directly affect the economics of coffee, through reduced quality and quantity of the crop or increased production costs due to increased use of chemical insecticides and complete harvesting, or both. Environmentally friendly coffee production is part of the Café de Colombia image, and increased pesticide use, adverse environmental effects, and reduced crop quality could all lead to a loss of credibility of the brand. This would in turn lead to reduced sales (quantity and value) and reduced on-farm income.

These aspects in themselves are bad, but in the Colombian socio-economic context, one can extrapolate further, albeit fully recognizing that the effects of a failed biological control program are only one of many factors involved and that these effects could easily be over-ridden by other factors such as changes in world coffee prices. The Federation of Coffee Growers is an active civil organization that provides considerable infrastructure support to the coffee growing areas, not just in terms of support for the coffee growing system (research, extension, buying, selling, marketing), but also in terms of financial credit systems, roads, bridges, schools and hospitals. If the Colombian coffee industry is in trouble, the Federation will be in trouble, and the standard of living and quality of life of coffee growers will deteriorate. The Colombian coffee belt is one of the more stable and wealthy sectors in Colombia, but if standards begin to slip, it is likely that the influence and activity of paramilitaries, guerillas, and narcotics groups will increase, leading to destabilization of the coffee growing areas, and ultimately to breakdown of civil order and local government. This is a long chain of cause and effect, and untangling all the factors is not possible, but an unsuccessful biological control program against coffee berry borer versus a successful program could tip a balance from which it would be difficult to recover.

DISCUSSION AND CONCLUSIONS

In these case studies, the problems being addressed were major ones in their context, with substantial actual and potential effects on a wide range of stakeholders. The potential non-target impacts associated with the biological control introductions varied from minimal to potentially quite substantial, and the associated risks from very small to unquantifiable. Other risks associated with biological control introductions, e.g., contamination, were managed by following accepted international procedures (IPPC, 1996).

In any biological control introduction, it must be accepted that there is a risk of impact on non-target organisms. At present, these can only be assessed to a limited extent for oligophagous species, and most easily in those developed countries where the local ecology is relatively well known. Comprehensive post release monitoring of non-target impact is desirable and should be encouraged. However, due to funding and capacity constraints, it is unlikely to take place in many cases in developing countries, not least because detailed knowledge of the local ecology may be too rudimentary for this to be practical.

The imperative of substantial immediate impact of an alien species may not allow decision-making bodies in developing countries to be greatly concerned about the risk of potential impact to non-target organisms that are not of clear economic value. Government authorities need to be fully informed of the potential impacts, even if some of the risks cannot be objectively assessed, and this is the requirement that CABI Bioscience addressed in these case studies. National decisions will be made in light of the information provided, but not necessarily follow the advice provided. Decisions will be based on the nation's values at the time of that decision, even though these values will change over time. We have to recognize that it is the responsibility of governments to make such potentially irreversible decisions in light of the available information, even if from a distance, or with hindsight, we may disagree with them.

In spite of these concerns, the case studies here show that the impact of not implementing biological control, and the benefits to be achieved by doing so successfully, are likely to be orders of magnitude greater than the non-target impact associated with introducing biological control agents. Biological control still provides a relatively safe, and potentially very effective, tactic for control of alien pests.

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