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Biological Control: Mutual Advantages of Interaction Between Australia and the Oceanic Pacific

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Abstract—Australia and Oceanic Pacific countries share a number of major introduced insect and weed pests and both must endure continuing intrusion of new pests. Some important Pacific pests have already been brought under biological control in Australia and the natural enemies employed will almost certainly be of value also in the Pacific. Conversely, some pests already in the Pacific, but which have not reached Australia (e.g. banana skipper, spiraling whitefly), are targets for biological control programs. If these programs are successful (as they probably will be), the reduction in pest densities should help to delay the further spread of these pests. An additional important benefit is that, if other countries are invaded, tested natural enemies will be readily available. There are clearly mutual advantages in close regional collaboration in biological control activities. Reasons for emphasizing the biological control approach and criteria for selection of target pests are discussed.

Introduction

From a biological point of view, for several million years, the Pacific oceanic islands and Australia were substantially—although not completely—isolated from each other and from the rest of the world by the large expanses of water that surround them. Of course, over the millenia the insect faunas that had managed to establish themselves had been changing steadily due to evolutionary forces. Rarely, additional species would be transported in upper air currents, by birds or on flotsam from one country and established in another, sometimes far away. The undoubted trend, however, was for the insect faunas of isolated Pacific islands or island groups to diverge from each other rather than to become progressively more similar. In the Pacific all this was changed, first by the arrival of Polynesian, Melanesian and Micronesian peoples and then dramatically so by the abrupt intrusion of European man in ever increasing numbers into the region in his sailing ships, together with an ever increasing range of plants and animals, many of them with insects as fellow travelers. I shall first touch briefly on the origin and nature of the Australian insect fauna and follow, equally briefly, with that of the Pacific.

Human occupation of Australia began when the first Aborigines arrived from the north at least 40,000 years ago. At that time the accumulation of ice at the poles resulting from the most recent ice age had lowered the ocean by as much as 100 m below its present level. This resulted in the emergence of extensive land bridges, not only between Papua New Guinea, mainland Australia and Tasmania, but also connecting many islands now lying between Papua New Guinea and Asia. Nevertheless, even at the time of lowest sea level, the shortest distance across the ocean deeps between Malaysia and Australia still involved 8 sea voyages, the longest of these being nearly 70 km. These first people had, of course, been preceded by many northern organisms that had evolved earlier and had been steadily extending their ranges southwards over roughly the same route for the previous 3 or 4 million years.

In the new land the Aborigines would have recognized examples of the flora and fauna with which they had already become familiar during their wanderings through the island arcs to the north. However, as they progressed southwards, this familiar biota became attenuated, and increasingly they encountered an extensive group of southern organisms that had evolved on the Australian continent during the 50 or so million years of its isolation from other large land masses, especially that known as Gondwana Land. No doubt many of these organisms were then as strange to them as they were to European man when he arrived several tens of thousands of years later.

Probably the only insects to travel along with the early Aborigines were human lice. These feature in dreamtime legends and must presumably have long antedated the arrival of Europeans. Furthermore, Bayly in 1777 wrote of Tasmanian Aborigines at Adventure Bay (who at that stage had no known contact with Europeans) that they 'have many lice sticking about the neck and other parts of the body.' The Maoris carried lice before the arrival of Europeans and lousiness may indeed have been a universal human condition, since lice have been recovered from mummies of ancient Egypt, preColumbian America, fifteenth century west Greenland and the Aleutian Islands.

There is no evidence from legends that human fleas were fellow travellers. This is not surprising since, because their larval life cycle is spent off their host, fleas would have had extreme difficulty in surviving a long trek to Australia unless a fairly uninterrupted flow of people made the journey. Nakedness would not help fleas either and it is of interest that the dingo which, with its more hospitable hairy body, would be capable of transporting man-infesting fleas, did not arrive in Australia before about 4,000 years ago.

Estimates suggest that there are at least 250,000 species of native insects in Australia, possibly 1,000 or so unwelcome migrants that have gained access since European colonization and a much smaller number than this of beneficial species, mainly introduced intentionally for biological control.

Some native Australian insects have proved to be important pests of man and his crops, such as the bushfly, the Queensland fruitfly, several large brown blowflies, a number of species of mosquitoes, sand flies, termites, the Australian plague locust and the larvae of a number of moths–but, at most, no more than a few hundred species. However, a far larger number of unintentionally introduced species have become serious agricultural pests. That they are agricultural pests is not surprising, since almost all Australian agriculture is based on introduced plants. Indeed, the only native plant to have gained wide acceptance both in Australia and overseas as a source of human food, is the eastern Australian macadamia nut. Of course, the aborigines also ate various grass seeds and the fruits of a handful of shrubs and trees, but none of these is in widespread use today.

A number of plants that have been introduced—some intentionally, others unintentionally—have become our most important weeds. These introduced weeds, like the majority of our most important insect pests, have seldom, if ever, been accompanied by the full complex of natural enemies that serve to reduce their abundance in their area of origin. So much, very briefly, for Australia: what of the Pacific oceanic islands before the arrival of European man?

Many Pacific islands have never had continental connections and were elevated from the ocean bottom. Thus, animals requiring land connection for dispersal were excluded from ever reaching them. It is possible to generalize that islands not greatly isolated tend to have richer faunas than very isolated islands; and older islands generally richer faunas than younger islands or atolls. Another generalization is that the terrestrial fauna of oceanic islands is characterized by poverty and disharmony (the absence of many groups). Until 2 or 3 thousand years ago when humans first appeared in the Pacific, vertebrates were poorly represented: mammals only by bats; birds largely by wideranging sea birds with generally very few land birds; reptiles by a few skinks and geckos; and amphibia and fresh-water fish were absent.

In so far as arthropods are concerned, it appears that most immigration to oceanic islands was by aerial dispersal. In the south west Pacific area this was mostly in storm winds contrary to the direction of prevailing good-weather winds, but sometimes probably by sea birds. There is, indeed, a fairly good correlation between the types of insects trapped on ships at sea and those that have populated the more isolated islands. It seems that relatively few insects were able to colonize islands by surviving on flotsam. Crucial to the establishment of phytophagous insects on islands is the prior establishment of appropriate plants to provide breeding sites. In the case of insects dispersing in moving air masses, another major hazard is that of making a landfall, seeing that only so little of the Pacific is above water. Other serious obstacles include damage in strong winds; desiccation, particulary in clear weather; injury on landing; and adverse effects from salt spray.

Insects derived from the Oriental/Southeast Asian region (China, Japan, Malaysia, Philippines, Indonesia) dominate the fauna of the mid Pacific as well as the islands of the western Pacific. The influence of North, Central and South America is quite minor west of the Galapagos. Even in Hawaii, which is nearest to North America, American elements (except for birds) are not dominant and, in the Marquesas and Society Islands, American influence is still less. Hawaiian plants also display a predominantly Oriental influence. In stark contrast, Australian influence on the oceanic fauna of a few hundred years ago was weak beyond New Zealand, New Caledonia, New Guinea and nearby islands.

If an insect survives the journey to an island and manages to reproduce, it may become established in an empty niche, enter into competition with relatives, or compete with unrelated ecological equivalents. It is interesting that, for Hawaii, only about 250 perpetuated establishments over the last 5 million years are necessary to account for the present insect fauna which amounts to 7,000 or so species. This is only one successful establishment every 20,000 years or so. Similarly, there are about 1,800 species of seed-bearing plants in Hawaii and these appear to have been derived from an estimated 272 original introductions.

By comparison with the 40,000 years or more that aborigines have been in Australia, human colonization of the oceanic Pacific islands is recent—possibly less than 4,000 years and in many areas less than 1,500 years. The early Polynesians sailed eastwards into the Pacific in long out-rigger canoes bringing with them coconuts, bananas, taro, yams, sweet potato, breadfruit and a few other plants. The Micronesians and Melanesians apparently moved eastwards into their areas of the Pacific somewhat later and they too brought with them the same basic food plants.

Of the 30 insect pests rated to be the most important in the Pacific, 4 occur nowhere else (3 on coconut and 1 on taro). A further 15 are native to the Oriental region. Only 2 come from the Americas and several are pests of vegetables introduced with these from Europe or Africa. In contrast, only 3 of the 17 most important weeds are native to the Oriental region, whereas 13 originated in Central or South America—a situation so different from that of insect pests that it points to a quite different means of dispersal, probably man-mediated in the last couple of hundred years.

Pest Species

More than half of both the major Pacific insect pests and the major Pacific weeds also occur in Australia. For a number of these, moderately to very successful biological control campaigns have already been launched in Australia and others are in progress. Among the moderately to very successful projects I would place, for insect pests, the diamondback cabbage moth (*Plutella xylostella* (Linnaeus)), the green vegetable bug (*Nezara viridula* (Linnaeus)), and, most recently, the banana weevil borer (*Cosmopolites sordidus* (Germar)). For weeds I would list *Salvinia molesta*, water hyacinth (*Eichhornia crassipes*) and *Lantana camara*. It is highly probable that Australian experience with the biological control of these pests could be utilized to great benefit for Pacific nations and I shall illustrate this in a moment.

I shall also take one example of a recently arrived pest, the leucaena psyllid (*Heteropsylla cubana*) and two examples where new pests are spreading steadily in the Pacific, but have not yet reached Australia. These are the banana skipper and the spiraling whitefly. Both are amenable to biological control and indeed have already been controlled in Hawaii. Biological control of introduced pests is highly appropriate for oceanic island nations with small human populations and extreme shortage of foreign exchange for purchasing pesticides. The extension of effective biological control of such pests to other Pacific islands where they have become established would not only be of great value to these islands but, by reducing populations of pests that Australia does not yet have to low levels, should diminish the speed with which they reach its shores.

Aleurodicus dispersus RUSSELL

A pest that has steadily extended its distribution in the Pacific in the direction of Australia is the spiraling whitefly *Aleurodicus dispersus* which is native to Central America and the Caribbean region. It first gained a toehold in southern Florida in 1957 and then a bridge-head in Hawaii in 1978. In the last 7 years it has invaded several islands in Polynesia and Micronesia and also the Philippines and it seems inevitable that it will reach Australia before long.

All stages suck sap from the leaves of their host plants causing unthriftiness and leaf drop, but seldom death. However, copious amounts of waxy white flocculent material are secreted and this creates a very unsightly appearance when dispersed by the wind. Even more importantly much sticky honeydew is produced which serves as a substrate for dense growth of sooty moulds, which interferes seriously with photosynthesis.

The spiraling whitefly adult superficially resembles a tiny white moth and the pest drives its common name from the irregularly spiraling deposits of waxy white flocculence which the female deposits when laying eggs.

The spiraling whitefly is an important pest of vegetables, fruit trees, ornamentals and shade trees. Its host range includes well over 100 plant species in more than 26 plant families. Among important hosts in the Pacific are coconut, banana, pawpaw, mango, guava, citrus and capsicum.

A. dispersus was discovered in Honolulu in September 1978, and spread rapidly throughout the island of Oahu. By 1981 it was established on the other islands. A search was made for natural enemies in the Caribbean in 1979 and 1980. Three species of predatory coccinellid and two species of aphelinid parasitoid were introduced, studied for host-specificity and liberated. Of these the coccinellid *Nephasis oculatus* (Blatchley) and the parasitoid *Encarsia haitiensis* Dozier were the most effective. As is typical of coccinellids, *Nephasis* was effective in reducing high populations of whitefly, but relatively less effective against low populations. On the other hand, *Encarsia* was effective in low whitefly populations and ultimately, therefore, the more valuable biological control agent. *A. dispersus* is now regarded as being under successful biological control in most areas of Hawaii.

These parasitoids have been introduced in the last 2 or 3 years to Cook Is, Fiji, Kiribati, American and Western Samoa and Tonga and indications are that they will reduce the spiraling whitefly to the category of a minor pest. When it comes to Australia's turn I would strongly recommend that the parasitoid *Encarsia haitiensis* be introduced first, leaving the less specific coccinellids to a later stage, if indeed they are required. Indeed I hope that the efficacy will be established in the Pacific of this tactic, of introducing the parasitoid alone, long before we have to face a decision in Australia.

Erionota thrax (LINNAEUS)

A pest butterfly that is an increasing threat to Australia is the banana skipper (*Erionota thrax*), a hesperiid that is native to Southeast Asia. It has spread in the last 20 years to Hawaii, Guam and Mauritius and quite recently to northern Papua New Guinea, and more recently, throughout the country. There would appear to be no effective barrier to a southwards extension to Australia, and possibly as far as the banana-growing regions of northern New South Wales.

The brownish adults, with a wingspan of about 75 mm fly rapidly and apparently erratically among banana plants in the evening and early morning and are occasionally attracted to lights. The yellow eggs are laid at night mainly on the undersurface of the leaves. The newly hatched larva proceeds to the edge of the leaf where it starts feeding and begins to roll and tie the leaf. As the larva grows, the roll is enlarged and moved towards the midrib. All except the first instar larvae are covered with a whitish waxy powder. Rain causes high mortality of young larvae, due to their lack of waxy powder and the poor construction of their leaf rolls. Older larvae close their rolls more securely and produce enough wax to be water repellent. Depending upon temperature there are two to five or more generations a year. Foodplants include banana, in particular, but the skipper is also reported to attack coconut, bamboo, Manila hemp and several palms.

Heavy infestations of bananas leave only the midrib with numerous leaf rolls attached to it. At the height of the attack in Hawaii more than 80% of all banana plants were damaged and *E. thrax* was regarded as a serious threat to the banana industry.

Although there are occasional damaging outbreaks in its area of origin, it is attacked there by a large number of parasitic wasps and flies, many of which are themselves heavily parasitised.

After the skipper became established in Hawaii, Guam and Mauritius it was brought under biological control in each country by the introduction of an encyrtid egg parasitoid (*Ooencyrtus erionotae* Ferriere) and particularly, by a braconid larval parasitoid (*Apanteles erionotae* Wilkinson). The former is already present in Papua New Guinea. In Hawaii and Guam, there are no native Hesperiidae, so there were no problems relating to possible lack of host specificity when introducing the parasitoids. Mauritius lists the occurrence of four hesperiids, some of which may be native, but the question of host specificity of the introduced parasitoids was apparently not considered. On the other hand, both Papua New Guinea and Australia have many scientifically important native hesperiids. The host specificity of the two parasitoids has been examined to ensure that only adequately specific species will be introduced.

Tests on selected Papua New Guinea skippers and birdwings using *Apanteles erionotae* have proved negative and this parasitoid has recently been liberated in several sites in Papua New Guinea. Specificity tests are in progress against additional Australian butterflies, so that the way will be cleared for rapid action should the banana skipper be discovered in Australia.

Heteropsylla cubana CRAWFORD

The most spectacular recent invasion of the Pacific and Australia by a new insect pest has been that of the leucaena psyllid (*Heteropsylla cubana*). It spread very rapidly and extensively from its area of origin, namely Central America. It was first reported in the Pacific in April 1984 in Hawaii. Before the end of 1985 it had reached most of the central Pacific islands, Taiwan and the Philippines; by 1986 the Solomon Islands, Papua New Guinea, Australia, Indonesia and Christmas Island (in the Indian Ocean); by 1987 Sri Lanka; and by 1988 India.

Leucaena species are leguminous shrubs or trees which are being used increasingly in the Asian-Pacific region as shade trees (for cocoa and other crops) for animal forage, firewood, erosion control and a number of other purposes. The damage caused by *H. cubana* is primarily to new growth, where eggs are deposited. Large numbers of psyllids removing sap rapidly cause new growth to become stunted. In addition, the deposition of honeydew permits the growth of sooty molds which inhibit photosynthesis. When new growth is repeatedly attacked there is severe defoliation and ultimately death of the plant.

The most commonly grown species, *L. leucocephala*, is particularly susceptible to attack, although some other *Leucaena* species are less so, as are several of the hundreds of crosses and cultivars that have been produced. It is hoped that suitable resistant or partially-resistant cultivars will become available in due course.

In Hawaii the psyllid is attacked by a number of predators, particularly nonspecific coccinellids, that had been introduced previously against other pests. Several of these, including *Curinus coeruleus* (Mulsant), consume large numbers of psyllids when they are abundant, but turn their attention to other prey when psyllid numbers drop and hence are not very efficient in maintaining psyllid numbers at adequately low levels.

A search for more specific natural enemies in the Caribbean resulted in the introduction to Hawaii of a eulophid wasp (*Tamarixia leucaenae* Boucek) and an encyrtid (*Psyllaephagus yaseeni*). *Tamarixia* was not established and died out, but *P. yaseeni* has been mass reared and established, but with some difficulty, in the field.

A problem arises for Australia and a number of Pacific countries in deciding whether or not to consider introducing parasitoids of *H. cubana*. This is because another species of *Heteropsylla* from Brazil appears to be specific and highly damaging to a serious introduced weed, the giant sensitive plant (*Mimosa invisa*). This weed is responsible for losses of several millions of dollars a year in the moister, warmer areas of Queensland and is a major problem in many Pacific countries. The Brazilian *Heteropsylla* has been established in recent years in Queensland and Western Samoa on *M. invisa*, and appears to be causing serious damage to the weed. Several Pacific countries are waiting to follow suit if successful control is achieved.

Unfortunately tests by CIBC in Trinidad have shown that the two parasitoids of *Heteropsylla cubana* will also attack the Brazilian *Heteropsylla* and thus they are likely to interfere with the biological control of *Mimosa invisa*, should they be introduced. It is hoped that additional, more specific, parasitoids may be found in Central or South America where *Heteropsylla cubana* occurs naturally and is not regarded as a pest.

Australia and the Pacific islands in this instance share a common interest, namely to ensure that only the most highly specific natural enemies of *Heteropsylla cubana* are introduced to our region or indeed to countries bordering it.

Cooperative Pest Control

In these few examples of many that could have been chosen, it is abundantly clear that there are great advantages of mutual interaction in biological control activities between Australia and the oceanic Pacific. Never in the past has biological control of arthropod and weed pests in the Pacific been more needed, and never has it been more attainable for a significant proportion of the important pests of the region.

These assertions can be justified on many grounds.

In relation to the need:

1. The steady increase in Pacific populations in modern times has progressively eroded traditional forms of agriculture, particularly those based on the use, in rotation, of part only of available land at any one time. A far higher proportion or agricultural land than ever before is now being used to produce the larger quantity of food needed and there is a correspondingly far greater dependence now on a reliable, sustained yield. It is thus even more important than before for crop losses to be kept to a minimum.

2. Traditional crops, such as coconut, taro and yams, have been supplemented by many new vegetables and fruits and these are becoming progressively more important in the economy (including cabbage, capsicum, cocoa, corn, cucumber, egg plant, tomato, mango, pawpaw, watermelon, etc.). These crops are attacked by a range of pests introduced with them.

3. At least three quarters of the major insect pests and all of the major weeds have been introduced to the region—the majority of them during this century. New pests are arriving steadily and the rate of arrival will increase with increasing tourism.

4. All pesticides have to be imported to the Pacific region, requiring foreign exchange.

5. There is a rapidly growing world recognition of the need to limit, as far as practicable, the use of pesticides because of a variety of undesirable side effects.

6. When carried out properly, biological control offers for many pests (particularly introduced pests in relatively simple island ecosystems) an opportunity for sustained and selective suppression of pest populations to densities below economic injury levels. Where effective biological control is possible, it is clearly the method of choice.

Table 1. Criteria relevant to an assessment of the importance of a pest to a country or region.

1. Importance of crop(s) affected:
   • area of crop
   • export value
   • subsistence value
   • size of population affected
   • social importance
2. Importance of the pest:
   • estimate of losses—actual
     potential
   • acceptable threshold of damage
   • cost of existing control
   • environmental/social cost
   • quarantine considerations
3. Biological control:
   • previous successes
   • size and cost of a program
   • perceived chances of success
   • conflict of interest (if any)
4. Are appropriate alternative methods of control effective and economic?
   • chemical control
   • cultural control
   • use of resistant varieties

In relation to being attainable:

1. Where important Pacific pests have already been brought under effective biological control elsewhere, the chances are high of repeating this success. In such instances the time scale is likely to be short (1 to 3 years) and the costs low.

2. With rapid air transport, care in eliminating unwanted fellow travellers, and better knowledge of culturing techniques, it is far simpler than ever before to import and establish natural enemies in a new country.

It is not necessary to describe again here the assembling of information from the south western Pacific in which 47 major pests of the region were selected as possible biological control targets—30 insects, a mite, a snail and 17 weeds. There are, of course, many additional pests of generally lesser importance, or of importance to a limited region and, regrettably, serious new pests continue to appear from time to time. The information presented in 'Biological Control: Pacific Prospects' indicates that promising natural enemies are already known for between 15 and 20 of the 47 pests. Categorized as promising, are agents that have already been used in another country with some success and those for which there is already information suggesting that they may be valuable. A start has already been made on several of these target pests and it is perhaps worth noting that, of the 6 additional pests in Supplement 1 (1987) to Biological Control: Pacific Prospects, 3 are already targets for biological control investigations.

What then are the main constraints to a substantial increase of biological control activities in the region? The principal constraint identified by all countries in the region is the shortage of funds. Other constraints included the shortage of trained staff in many countries and the need to upgrade quarantine and rearing facilities.

Crucial to a sustained increase in biological control activity in the Pacific is the selection of appropriate targets. In addition to an early success in as many countries as possible, if biological control is to contribute most effectively to Pacific problems, possible targets must be placed in some priority order relating to the importance of a particular pest to a country or region. In this regard, the set of criteria drawn up by a biological control workshop in Tonga in 1985 provides a useful guide (Table 1). There will inevitably be gaps in supplying the documentation sought, but even a first attempt will help to provide each country with a logical basis for selecting projects for early action. Highly important also, the documentation will provide the very sort of information that will help to persuade donors to lend their support.

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