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Exotic Terrestrial Arthropods in the Hawaiian Islands: Origins and Impacts

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Abstract—More than 98% of arthropod pests now present in the Hawaiian Islands were accidentally introduced by man, the majority since Hawaii was colonized by Europeans about 200 years ago. During the past 50 years, new exotic arthropods have become established at the rate of nearly 20 per year, including, on average, 3 new pests of economic significance. Major increases in the speed and volume of overseas air traffic have materially increased the rate of new pest introduction during the past 25 years. Many new potential pests arrive in Hawaii with no effective natural enemies. In such cases, initial population growth is often exponential, leading to major pest outbreaks (e.g. *Bactrocera dorsalis* 1946–48, *Nezara viridula* 1962–64, *Aleurodicus dispersus* 1978–80, *Heteropsylla cubana* 1984–86). Most new pests in Hawaii have originated from North America, Asia and the south Pacific, but during the past 15 years new Neotropical pests have become noticeably more frequent (e.g. *Aleurodicus dispersus*, *Heteropsylla cubana*, *Hypothenemus obscurus*). Biological control usually is the tactic of first choice to combat new pests in Hawaii. Success has ranged from complete (*A. dispersus*) or substantial (*N. viridula*) to partial (*B. dorsalis*). For some introduced pests (e.g. *Adoretus sinicus*) attempts at biological control have been largely ineffective. Unless more effective quarantine measures can be implemented, a continuation of the present high rate of new pests establishment in Hawaii is likely.

Origins and Impacts

The Hawaiian Islands constitute one of the most geographically isolated archipelagos in the world. They are nearly 2,500 miles from the nearest continental land mass (North America), and the nearest extra-Hawaiian island (Johnson) is 900 miles to the southeast.

There are approximately 10,000 species of insects and other terrestrial arthropods present in Hawaii today. Of these, more than 2,000 species are recent immigrants which have become established during the approximately 1,000 years that humans have inhabited the islands. The endemic insect fauna (i.e. that which evolved in Hawaii) is highly specialized and disharmonic (i.e. many groups com-

mon in continental faunas are unrepresented). Although a few endemic species have adapted successfully to lowland urban and agricultural environments, most today are confined to upland areas in association with the endemic flora.

More than 98% of the arthropod pests now present in Hawaii are non-endemic species which have become established since humans arrived in the islands; most since Hawaii was first colonized by Europeans about 200 years ago. Hawaiian entomologists have annually recorded the discovery of new immigrant terrestrial arthropods since the inception of the "Proceedings of the Hawaiian Entomological Society" in 1905. This yearly record of new arrivals (or new discoveries), plus data from specimen labels in local collections, enabled me to analyze rates of arrival and areas of origin for newly discovered terrestrial arthropods in the Hawaiian Islands (Beardsley 1962, 1979, 1991a). These analyses showed that during the past fifty years (1941-1991) exotic terrestrial arthropods have become established at the rate of nearly 20 per year. Most of these immigrants have been of little or no economic significance, and some may even be beneficial (e.g. accidentally introduced natural enemies of pest species). However, hardly a year went by during the past half century without at least one new serious arthropod pest making its debut in Hawaii. Overall, new pest introductions during this period averaged more than three per year. I have pointed out earlier (Beardsley 1991a) that the rate of introduction of new pests into Hawaii and elsewhere in the Pacific Basin appears to have increased during the past 25 years, with a concomitant increase in pests originating in tropical America. Several of the latter have spread from Hawaii southwestward to other Pacific islands and Asia (e.g. spiraling whitefly, *Aleurodicus dispersus* Russell; leucaena psyllid, *Heteropsylla cubana* (Crawford), and others will likely follow (e.g. tropical nut borer, *Hypothenemus obscurus* (Fabricius) (Beardsley 1991b); sugarcane tingid, *Leptodictya tabida* (Herrick-Schaeffer)).

There are about 500 species of terrestrial arthropods in Hawaii which are, or have been, pests of some economic significance. Perhaps 100 of these have caused serious problems that required major control efforts. Virtually all such pests are introduced species, and most of them developed large, damaging populations at the time they were first discovered in the islands or shortly after. This rapid, exponential buildup, often referred to as a "population explosion", is characteristic of newly established arthropod species which invade environments where effective natural enemies are absent.

Hawaiian entomologists have utilized classical biological control to combat exotic arthropod and weed pests, often successfully, over the past 100 years. The first recorded biological control introduction into Hawaii was the Indian mynah bird, introduced in 1865 to combat armyworms. This introduction was made by a horticulturist. The first introduction by entomologists was the vedalia beetle, *Rodolia cardinalis* Mulsant, from California in 1890 to combat the cottony-cushion scale, then a serious new immigrant pest. Since that time, nearly 700 species of biological control organisms have been purposely introduced into Hawaii, of which 250 species are known to have become established; a success rate of over 35% (Funasaki et al. 1988).

I will now briefly consider a few of the more important exotic insect pests with which I have been involved during 40 years of entomological work in Hawaii and other Pacific islands. These examples illustrate several aspects of biological control work in Hawaii, as well as different pests and natural enemies.

(i) Banana skipper, *Erionota thrax* L.

This species provides an example of classical biological control using readily available natural enemies, and resulting in complete control. The pest was first found in Hawaii in 1975, having arrived from Southeast Asia or Guam. The damage caused was complete defoliation and crop failure in all infested banana plantations. Two natural enemies were imported and established, an egg parasitoid, *Ooencyrtus erionotae* Ferriere (Encyrtidae), and a gregarious larval parasitoid, *Cotesia erionotae* (Wilkinson) (Braconidae). Complete control was achieved within less than one year after establishment (Mau et al. 1980) and no serious resurgences have occurred.

(ii) Southern green stink bug, *Nezara viridula* (L.)

This is an example of classical biological control with readily available natural enemies, resulting in partial to substantial control. The pest was first found in Hawaii in 1962. Its origin is unknown, as the species is widespread in tropical and subtropical regions. It damaged fruits, nuts, vegetables and flowers, particularly mango, macadamia, beans, tomato and orchids. Natural enemies imported were an egg parasitoid, *Trissolcus basalis* (Wollaston) (Scelionidae), and an adult parasitoid, *Trichopoda pilipes* (Fabricius) (Tachinidae). Substantial but incomplete control was achieved within one year (Davis 1964). Sporadic damage, particularly on macadamia and beans, still occurs. Augmentative releases of insectary reared *T. basalis* were attempted, but results are unavailable.

(iii) New Guinea sugarcane weevil, *Rhabdoscelus obscurus* (Boisduval)

This is an example of classical biological control resulting from foreign exploration and natural enemy introduction, and later natural enemy conservation. This pest was first found in Hawaii around 1870, its origin having been south Pacific islands. Damage is caused by larvae boring within mature sugarcane stalks, coconut trunks, etc. It has been a major pest of sugarcane in Hawaii. The natural enemy successfully introduced is a gregarious larval parasitoid, *Lixophaga sphenophori* (Villeneuve) (Tachinidae), discovered in New Guinea in 1910. Control was considered to be very substantial by 1920, but pest resurgence occurred in the 1960's. Field research demonstrated that adult parasitoids require food in the form of nectar which they obtain largely from the flowers of weedy *Euphorbia* species (Topham & Beardsley 1975). Conservation of nectar source plants, which previously were eliminated by routine herbicide applications to roadsides and ditch banks, restored the previous level of substantial control.

(iv) Gray pineapple mealybug, *Dysmicoccus neobrevipes* Beardsley

Work on this major pest of pineapple provides an example of classical biological control with imported natural enemies, together with natural enemy

conservation through ant control. The pest was first found in Hawaii about 1905; its origin was tropical America. Feeding by this mealybug on pineapple is associated with mealybug wilt disease, a highly contagious condition which, if not controlled, causes complete crop failure. Natural enemies successfully imported from tropical America include the parasitoid wasps, *Anagyrus ananatis* Gahan and *Euryrhopalus propinquus* Kerrich (Encyrtidae), and the predators, *Lobodiplosis pseudococci* Felt (Cecidomyiidae) and Coccinellidae (several species). Control is complete in the absence of mealybug-tending ants. Where aggressive polydomous ant species such as *Pheidole megacephala* (Fabricius) are present, natural enemies are ineffective. Ant control by means of low dosage formicidal baits such as Amdro (hydramethylnon), which do not eliminate beneficial mealybug natural enemies, allows the natural enemies to effect complete control (Beardsley et al. 1982).

(v) Angraecum scale, *Conchaspis angraeci* Cockerell

The history of this pest in Hawaii is an interesting example of fortuitous biological control. This scale was first found in Hawaii in 1980, its origin being tropical America. Heavy infestations developed on several kinds of ornamental trees and shrubs, resulting in stunting, die-back, and sometimes death of entire plants. *Pittosporum tobira*, a widely planted ornamental, was particularly seriously affected. In 1989, a parasitoid wasp, *Marietta pulchella* (Howard) (Aphelinidae), was found heavily parasitizing *C. angraeci* in and around Honolulu. The parasitoid, apparently an accidental introduction from America, was previously unknown in Hawaii. Since its discovery, *M. pulchella* has exerted complete control over the angraecum scale which is now uncommon in Hawaii. The parasitoid develops as a solitary primary, externally on the host body beneath the scale cover (Beardsley & Tsuda 1991).

Discussion

Classical biological control utilizing exotic natural enemies has been a highly successful endeavour in Hawaii, as many of the most serious exotic arthropod pests have been brought under complete or substantial control. Lai (1988) listed 43 cases of complete, and 16 cases of substantial biological control as having been achieved in Hawaii. These include some weeds (eight species) as well as arthropod pests. The total of 59 successes does not include cases of fortuitous control; only those where natural enemies were purposely introduced.

However, there have been some failures (e.g. with oriental rose beetle, *Adoretus sinicus* Burmeister). In the case of the fruit-infesting tephritid pests, *Bactrocera cucurbitae* (Coquillett), *B. dorsalis* (Hendel), *B. latifrons* (Hendel) and *Ceratitis capitata* (Wiedemann), introduced parasitoids have produced pronounced reductions in population levels but, largely because of quarantine restrictions on exported fruit, fruit flies remain a major economic problem.

Hawaii probably has achieved as many, or more, successes in classical biological control as have been achieved in any comparable area of the world.

Without doubt this is due, at least in part, to the many opportunities for biological control that are created by the continuous influx of new exotic pests. These opportunities will continue to arise in the future, unless the entry of new pests can be stemmed through implementation of more effective plant quarantine and disinsectization procedures.

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