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Population Increases of Native Moths Following Biological Control of an Introduced Pest Moth

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Abstract—Populations of several species of Lepidoptera consuming mango leaves and flowers increased after successful biological control of the noctuid caterpillar *Penicillaria jocosatrix* on Guam. These included the geometrids *Anisodes illepidaria, Thalassodes* sp. and *Chloroclystis* sp. and the noctuid *Nanaguna breviuscula. A. illepidaria* populations increased 10 fold, and became damaging at certain times of the year. A comparison of its larval biology with that of *P. jocosatrix* suggested that there was indirect competition, and the larger, earlier, *P. jocosatrix* was preempting resources. The other moths increased, apparently as a result of increased flowering of the mango trees as a result of suppression of *P. jocosatrix*. The introduced biological control agents acted as keystone natural enemies and increased the resources available for other Lepidoptera. Implications in relation to ecological effects of biocontrol introductions are discussed.

Introduction

Exotic species of Arthropoda are being introduced at high rates into many islands in the tropical Pacific. Rates of 24 or more new arthropods per year have been documented for the Hawaiian islands (Beardsley 1979), and 1 to 3 pest introductions per year have been observed in Micronesia (Nafus 1991a, Schreiner 1991, Schreiner & Nafus 1986). When these immigrants are pests, economic problems such as loss of crop yield or destruction of structures are apparent. Impacts on populations of indigenous species are less conspicuous and are rarely documented except for a few striking cases. Introduced phytophagous insects, often present in large numbers, may have serious effects on native plants (Amman & Speers 1965, Groves 1955, Schreiner & Nafus 1992b). Ants, other social predators (Loope et al. 1988, Medeiros et al. 1986, Zimmermann 1948) and general parasitoids (Funasaki et al. 1988, Howarth 1991) are suspected of having serious impacts on the native insects of Hawaii. Potentially, an introduced insect may compete with the native insect community, but this has rarely been documented except in the case of ants (Simberloff 1981). Among phytophagous insects, two cases are known. On the island of Barbados, milkweed butterflies eliminated milkweed bugs by almost completely removing their host plant (Blakely & Dingle 1978) and in the eastern United States, McClure (1980) observed a case where one exotic scale competitively excluded a second exotic scale.

Many of the islands in the Pacific have introduced large numbers of exotic predators and parasites to control accidentally introduced pests. This effort has been most intensive in Hawaii (Funasaki et al. 1988), but other islands including Guam (Nafus & Schreiner 1989), the Carolines, the Marshalls, (Schreiner 1989) and Fiji (Clausen 1978) have also made numerous biological control introductions. Evaluation of these introductions, if done, concentrated on how well the target pest was controlled, and assumed all effects were beneficial. Concern about possible negative effects of exotic biological control agents on native species has surfaced recently, and Howarth (1983, 1991) has gone so far as to call the agents biological pollution. He suggests that many purposefully introduced parasites have attacked native species and caused them to become rare or extinct. Biological control agents may also have other effects on the structure of island ecosystems, but these are even less well documented than the possible extinctions discussed by Howarth. Recently, we found an example of structural changes that took place in a community of Lepidoptera on mango following biological control of the exotic mango shoot caterpillar *Penicillaria jocosatrix* Guenée (Noctuidae) (Schreiner & Nafus 1992a).

Results

ECOLOGICAL EFFECTS OF BIOLOGICAL CONTROL ON MANGO COMMUNITY STRUCTURE

The mango shoot caterpillar *Penicillaria jocosatrix* was first reported from Guam by Swezey (1946) in 1936. Studies showed that the caterpillar was consuming more than 50% of the total leaf area produced by mango as well as eating flowers and young fruits (Schreiner & Nafus 1991). The importance of this herbivory was shown by a dramatic increase in flowering and fruit production after successful biological control of the caterpillar (Nafus 1991b). After caterpillar numbers declined from a mean of 0.8 larvae per shoot to 0.2 per shoot, leaf damage dropped to 20% or less, flowering increased from 0.2 to 1.1 inflorescences per branch per year, and fruit production increased 40 fold.

In addition to effects on the host plant, we noted an increase in the numbers of several previously rare moths that eat mango and are probably native to Guam. During 1983 and 1984, we studied the herbivore community on mango to determine whether a biological control program of the mango shoot caterpillar was warranted. Abundances of other Lepidoptera that were feeding on mango were monitored along with those of the mango shoot caterpillar. At that time, the only species found consuming the leaves was the geometrid *Anisodes illepidaria* Guenée, a species that was probably present at least as early as 1911 (Fullaway 1912). This species is widespread in Asia. It is unclear when or how it was introduced to Guam. It could be native or accidentally introduced by humans.

A. illepidaria was rare in the 1983 to 1984 abundance survey. In subsequent studies on the biology and control of the mango shoot caterpillar, its rarity was confirmed as we only occasionally noted its presence from 1985 through 1987. No outbreaks were observed or reported by homeowners, farmers, or the University Extension Service until biological control of *P. jocosatrix* was achieved. In 1988, high populations on mango flowers and new foliage resulted in numerous requests for information from the public. Outbreaks of *A. illepidaria* also took place in 1989 and 1990, but not in 1991 when flowering was disrupted by a typhoon. We monitored populations of *A. illepidaria* in 1989 and 1990, and found them to be significantly higher and more consistently present throughout the year than in 1983 to 1984 (Fig. 1) (Schreiner & Nafus 1992a). In 1983 to 1984, populations were only noted in the months when large numbers of new leaves were present. During times of the year when foliage was scarce, mango shoot caterpillars ate almost all of the new leaves (Fig. 2) and *A. illepidaria* was scarce.

A comparison of the biology of the two caterpillars suggests why mango shoot caterpillars had a negative impact on *A. illepidaria*. Both species only consume immature leaves, but *A. illepidaria* performs best on leaves that are older than those most suitable for the mango shoot caterpillar (Schreiner & Nafus 1992a). Survival of mango shoot caterpillars is highest if larvae are fed leaves three to nine days old. Pupal weight is highest when the larvae are fed six day-old leaves. In contrast, survival of *A. illepidaria* is poor if they are fed on three day-old leaves, and highest on nine-day old leaves. *A. illepidaria* larvae consume 13 day-old leaves, an age class that the mango shoot caterpillar cannot develop on. Pupal weight is maximal for *A. illepidaria* fed nine-day-old leaves. No study of the oviposition behavior of *A. illepidaria* in relation to leaf age was made, but *P. jocosatrix* is known to oviposit preferentially on leaves less than 6 days old

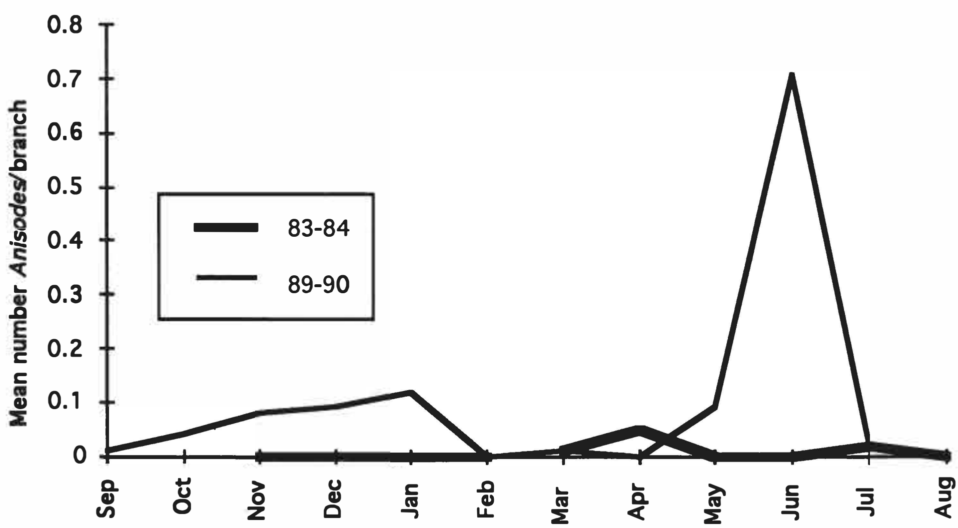

Figure 1. Number of *A. illepidaria* per branch in 1983–1984 and 1989–1990.

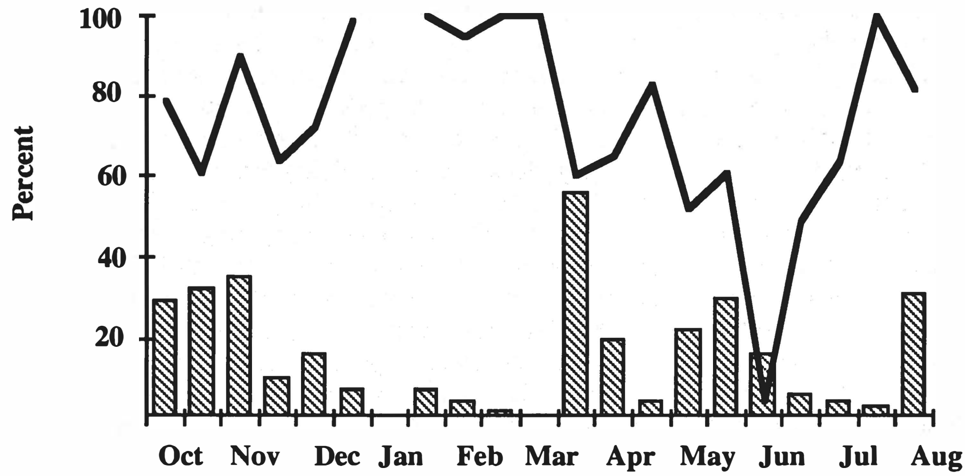

Figure 2. Percent mango branches with new leaves and percent of new foliage consumed by mango shoot caterpillars. Bars are percent of branches flushing, line is percent foliage consumed.

(Nafus et al. 1991). *P. jocosatrix* is larger than *A. illepidaria,* the pupa being about four times heavier (Schreiner & Nafus 1992a).

We believe that the mango shoot caterpillar was preempting the potential resources of *A. illepidaria* and that this was the primary factor keeping the moth rare. Prior to biological control, mango shoot caterpillars consumed a large proportion of the new leaves, including almost all the new leaves formed during periods when leaves were scarce, preempting this resource and reducing the vigor of the trees so they did not flower. This reduced the abundance of this second resource and, when flowers did form, the mango shoot caterpillars consumed most of them as well. The introduced parasitoids of the mango shoot caterpillar acted as a keystone natural enemy (Paine 1966, Risch & Carroll 1982), selectively removing the dominant competitor, freeing leaf resources and making new flower resources available. This allowed an increase in populations of *A. illepidaria,* as well as several other species of indigenous Lepidoptera.

In addition to the changes in population of *A. illepidaria,* the 1989 results showed an increase in several other species (Table 1). Two species not found in 1983 to 1984, *Thalassodes* sp. (Geometridae), and *Nanaguna breviuscula* Walker (Noctuidae) were present. Mango shoot caterpillars were dominant in both surveys, but less so in 1989 to 1990. In flowers, we found the same four species plus *Chloroclystis* sp. (Geometridae). On mango flowers the mango shoot caterpillar was less common than *A. illepidaria* (Table 1), but we could not compare this community to the 1983 to 1984 one since none of the study trees flowered. We had found *N. breviuscula* on mango flowers prior to 1987, but had never found *Thalassodes* sp. or *Chloroclystis* sp., which must have been extremely rare on the sparse mango flowers available at that time.

Table 1. Insects collected on mango in 1983–1984 and 1989–90

	Number of caterpillars collected on		
	Leaves		Flowers
Species	1983–1984	1989–1990	1989
Penicillaria jocosatrix	1309	395	44
Anisodes illepidaria	17	190	57
Thalassodes sp.	0	2	13
Nanaguna breviuscula	0	1	1
Chloroclystis sp.	0	0	1

The geometrid fauna of Micronesia has never been formally worked on by a taxonomist, so species identities and distributions are not fully known. H. Inoue examined the *Thalassodes* and *Chloroclystis* specimens and believes that they are both undescribed species (personal communication). Both genera are prone to speciation in the Pacific region (Robinson 1975) and it is possible that the Guam specimens will eventually prove to be endemic to the island. We know little about their biology except on mango, although we have also collected *Thalassodes* sp. on *Spondias dulcis*. The noctuid *N. breviuscula* is widespread in Asia and the Western Pacific, being found as far out into the Pacific as Samoa (Robinson 1975). It seems likely that it reached Guam without human assistance and might thus be considered a native insect, although it is not endemic. It feeds on the flowers of several trees including mango and *Desmodium umbellatum* (Robinson 1975).

ECOLOGICAL EFFECTS ON NONTARGETS: POTENTIAL FOR PARASITIZATION

Four parasitoids were introduced for biological control of the mango shoot caterpillar, but only two became established, *Euplectrus* sp. near *circumscriptus* (Hymenoptera: Eulophidae) and *Blepharella lateralis* Macquart (Diptera: Tachinidae). *Euplectrus* sp. is an undescribed species, so no information was available as to its host specificity. The fly *Blepharella lateralis* Macquart parasitizes at least one other species in its native range, the arctiid moth *Spilosoma obliqua* Walker (Kumar & Yadev 1987). Neither species was found to parasitize the other caterpillars found on mango trees (Nafus 1991b). We have not yet recovered either parasite from other moth species, but it is possible that they do attack other noctuid or arctiid species on Guam. The noctuid fauna of Micronesia has not been thoroughly examined, but none of the species listed in *Insects of Guam* (Swezey 1946) is endemic, and all the noctuid and arctiid specimens in the University of Guam collection are widespread species with distributions extending into South-East Asia. We plan to continue to collect noctuid caterpillars to see if we can find any that are being attacked by either parasite species.

Conclusions

There is currently concern that biological control introductions may have serious negative impacts on native insect communities. Biological control workers are concerned that the end result will be stringent regulations on importing biological control organisms and that expensive testing programs for host specificity of entomophagous parasitoids will be required. There are already many problems in host specificity testing that cause long delays in implementing programs, and require substantial inputs of skilled manpower and sophisticated facilities. In many cases it is difficult to rear species and substantial research is needed to develop methods for both parasitoids and native or other species that are to be tested. In the current example, *Blepharella lateralis* could not be successfully reared in the laboratory. This tachinid lays tiny eggs on the host plant of the caterpillar that it parasitizes. The caterpillar is infected by eating the egg as it eats the leaf. Other than field collecting parasitized larvae, the best possible rearing technique is to feed leaves with eggs on them to laboratory reared caterpillars. This rearing method can only be done in the host country, thus precluding testing for potential parasitization of endemic species. Even host range testing in the host country is difficult because the eggs are difficult to find, being extremely small and relatively uncommon. Host specificity tests on Lepidoptera that do not feed on mango would require development of special techniques for infecting the larvae, or may be impossible. In this case we presumed it not to be necessary because there were no known endemic (restricted to Guam) species that would be affected, based on current information.

Many biological control projects, especially in the oceanic Pacific, are run on budgets that are too small to permit extensive host testing and other background work. Such requirements would stop many biological control projects. Some critics may feel that extensive testing is the best way to avoid introductions that might threaten endemic species. However, this assumes that the target species itself is not causing any environmental problems for endemic species. Few negative impacts of non-host specific parasites have been properly documented and there is almost no data to indicate what the impacts of accidentally introduced, highly abundant insects are on native insect communities. In our example, the biological control agents ameliorated the adverse effect of the dominant herbivore and allowed increase in abundance of the rest of the community. This situation may not be atypical. On islands, exotic herbivores may increase to vast numbers and have dramatic impacts on their hosts. Often they are not host specific and attack native plants as well as exotics. This affects other insects, including native species that are dependent on these plants. The effect can be through direct competition or mediated through their mutual host plant by reduced flowering or seed production. There may also be other effects, such as augmentation of general predators or parasitoids that may spill over into the native fauna. It is easy to concentrate on the potential for attacks on nontargets by biological control agents and overlook or undervalue the ecological benefits of controlling the pest species. In the face of limited budgets and shortages of skilled manpower, requirements for additional studies will likely often result in a failure to take action. This failure is in itself a management option that has various positive and negative consequences that will happen regardless of whether or not they are studied.

References

Amman G. D. & C. F. Spears. 1965. Balsam wooly aphid in the Southern Appalachians. J. For. 63: 18–20.

Beardsley, J. W. 1979. New immigrant insects to Hawaii: 1962 through 1976. Proc. Hawaii. Entomol. Soc. 23: 35–44.

Blakely, N. R. & H. Dingle. 1978. Competition: butterflies eliminate milkweed bugs from a Caribbean Island. Oecologia 37: 133–136.

Clausen, C. P. 1978. Introduced Parasites and Predators of Arthropods Pests and Weeds: a World Review. U.S.D.A. Agriculture Handbook 480.

Funasaki, G. Y., P. Y. Lai, L. M. Nakahara, J. W. Beardsley, & A. K. Ota. 1988. A review of biological control introductions in Hawaii: 1890–1985. Proc. Hawaii Entomol. Soc. 28: 105–160.

Fullaway, D. T. 1912. Entomological notes. Guam Agr. Exp. Sta. Rpt. 1911.

Groves, G. R. 1955. The Bermuda cedar. Unasylva 9:169–172.

Howarth, F. G. 1983. Classical biological control: panacea or Pandora's box. Proc. Hawaii. Entomol. Soc. 24: 239–244.

Howarth, F. G. 1991. Environmental impacts of classical biological control. Ann. Review of Entomol. 36: 485–509.

Kumar, N. & R. P. Yadev. 1987. Records of *Blepharella lateralis* Macquart and *Carcelia* sp. two indigenous parasitoids of *Spilosoma obliqua* Walker from Bihar India. Current Science (Bangalore) 56: 1192–1193.

Loope, L. L., A. C. Medeiros & F. R. Cole. 1988. Effects of the Argentine ant on the endemic biota of subalpine shrubland, Haleakala National Park, Hawaii. *In* L. K. Thomas, Jr., (ed.) Management of Exotic Species in Natural Communities, Vol. 5, pp. 52–62 . National Park Service and George Wright Society, Honolulu.

McClure, M. 1980. Competition between exotic species: scale insects on hemlock. Ecology 61: 1391–1401.

Medeiros, A. C., L. L. Loope, & F. R. Cole. 1986. Distribution of ants and their effects on endemic biota of Haleakala and Hawaii Volcanoes National Parks: a preliminary assessment. *In* Proceedings 6th Conference in Natural Sciences, Hawaii Volcanoes National Park, pp. 39–52. Univ. Hawaii, Honolulu.

Nafus, D. 1991a. Movement of new insects into the Carolines and Marshalls in recent years. Micronesica Suppl. 3: 15–31.

Nafus, D. 1991b. Biological control of the mango shoot caterpillar *Penicillaria jocosatrix* Guenée (Lepidoptera: Noctuidae) with notes on the biology of its parasitoids. Environ. Entomol. 20: 1725–1731.

Nafus, D. & I. Schreiner. 1989. Biological control activities in the Mariana Islands from 1911 to 1988. Micronesica 22: 65–106.

Nafus, D. M., I. H. Schreiner & N. Dumaliang. 1991. Survival and development of the mango shoot caterpillar (Lepidoptera: Noctuidae) in relation to leaf age, host and distribution on the host in tropical Anacardiaceae. Environ. Entomol. 20: 1620–1626.

Paine, R. T. 1966. Food web complexity and species diversity. American Naturalist 100: 65–75.

Risch, S. J. & C. R. Carroll. 1982. Effects of a keystone predacious ant, *Solenopsis geminata*, on arthropods in a tropical ecosystem. Ecology 63:1979–1983.

Robinson, G. S. 1975. Macrolepidoptera of Fiji and Rotuma: A Taxonomic and Biogeographic Study. E. W. Classey Ltd., Oxon., Great Britain.

Schreiner, I. 1989. Biological control introductions in the Caroline and Marshall Islands. Proc. Hawaii. Entomol. Soc. 29: 57–69.

Schreiner, I. 1991. Sources of new insects established on Guam in the post-WW II period. Micronesica Suppl. 3: 5–13.

Schreiner, I. & D. Nafus. 1986. Accidental introductions of insect pests to Guam, 1945–1985. Proc. Hawaii. Entomol. Soc. 27: 45–52

Schreiner I. H. & D. M. Nafus. 1991. Defoliation of mango trees by the mango shoot caterpillar (Lepidoptera: Noctuidae) and its effect on foliage regrowth and flowering. Environ. Entomol. 20: 1556–1561.

Schreiner, I. H & D. M. Nafus. 1992a. Changes in a moth community mediated by biological control of the dominant species. Environ. Entomol. 21: 664–668.

Schreiner, I. & D. Nafus. 1992b. Impact of mealybugs on an endangered tree, *Serianthes nelsonii*, in Guam and Rota. Pacific Science 46: 393

Swezey, O. H. 1946. Geometridae, Arctiidae, Agrotidae, and Pyralidae of Guam. *In* Insects of Guam II. B. P. Bishop Museum. Bull. 189.

Simberloff, D. 1981. Community effects of introduced species. pp. 53–81. *In* M. H. Nitecki (ed.), Biotic crises in ecological and evolutionary time. Academic Press, N. Y.

Zimmerman, E. C. 1948. Insects of Hawaii. Vol. 1. Introduction. Univ. Hawaii Press, Honolulu.