TECHNIQUES FOR EVALUATION OF PREDATORS OF HOMOPTERA

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ABSTRACT

The experimental evaluation of predation in biological control can be difficult, but is necessary to determine the impact of predators on pest population dynamics. These evaluative techniques document the role of existing predators, quantify the impact of previous releases, and also identify pest life stages or seasonal periods that may be targeted for additional releases. An overview of evaluation methods appropriate for Caribbean Basin biological control programs for Homopteran pests is presented. Several examples of interactions between predators and other types of natural enemies are discussed to provide a basis for interpretation of results from an evaluation study.

RESUMEN

La evaluacion de depredacion en el control biologico puede ser dificil, pero es necesario determinar el impacto de los predadores en la dinamica poblacional de las plagas. Estas tecnicas de evaluacion documentan el papel de los predadores existentes, cuantifican el impacto de liberaciones previas, y tambien identifican los estados de vida de las plagas o las estaciones en las cuales pueden efectuarse liberaciones adicionales. Se presenta una sintesis de la evaluacion de metodos apropriados para el control biologico de plagas de homopteros en la Region del Caribe. Se discuten varios ejemplos de interaccciones entre predadores y otro tipo de enemigos naturales con el fin de dar una base para la interpretacion de resultados en un estudio de evaluacion.

In classical biological control programs, evaluation studies are an often neglected, but critical, research component, that demonstrate the effectiveness of natural enemies. These post-release studies are required to document the ecological and economic benefits of a biological control program and can also identify pest life stages that may require additional releases (DeBach et al. 1976). Evaluation of the impact of arthropod predators may be more difficult than for parasitoids or pathogens because prey remains may be difficult to locate and identify or prey may be totally consumed (Whitcomb & Godfrey 1991, Greenstone 1990, Hagen et al. 1976).

In this paper, I present a brief overview of prey specificity and methods to evaluate entomophages, discuss examples of evaluation methods that have been employed with particular predator-prey systems, and finally, outline some particular areas that should be considered when conducting predator evaluation studies. The goal of this paper is to provide the participants in this workshop with the background to assess the applicability of these techniques in Caribbean Basin biological control programs directed against Homopteran pests.

One key area that relates directly to the use of predators in biological control is prey specificity. This topic has been discussed for at least 40 years in relation to the establishment of predators in classical biological control programs. For example, after conducting research in Bermuda on scale-feeding coccinellids, Thompson (1951) pointed out that, although insect predators generally have wider prey ranges than insect parasitoids, predators demonstrate a high degree of prey specificity. Predatory feeding behavior is generally adaptive, not random, and the understanding of prey specificity continues to be a critical area in biological control research (Gilbert 1990, Greenstone 1990, Hagen 1987, Tauber & Tauber 1987). Prey specificity presents a dual problem for biological control programs that involve predators. On the one hand, the interaction between the predator and target pest must be known, on the other hand, the nutritional requirements for a predator may include, not only the target prey, but alternate prey/food sources (e.g., Obrycki & Orr 1990, Ruberson et al. 1986).

As pointed out by Luck et al. (1988), clear definition of the objectives of an evaluation study will aid in the selection of the most appropriate techniques. There are strengths and weaknesses with each technique used to evaluate predators, and generally more than one method is required to adequately assess the impact of a natural enemy (Kiritani & Dempster 1973). Experimental techniques have been the most useful means to measure the effectiveness of entomophagous species. These techniques were described by Smith & DeBach (1942), summarized by DeBach & Bartlett (1964), DeBach & Huffaker (1971), and DeBach et al. (1976), and were recently reviewed by Luck et al. (1988). These reviews should be consulted for detailed descriptions of the strengths and weaknesses of the various evaluation techniques.

Six experimental evaluation techniques (following terminology of Luck et al. 1988) suitable for measuring the impact of a predatory species are:

(1) The introduction or addition of a predator into a new environment, that includes a quantitative comparison of the density of the prey before and after introduction of the predator.

(2) Exclusion or inclusion studies using mechanical barriers; for example, comparative open and closed cages or screen cages with variously sized mesh can be used to exclude predators or enclose known densities of predators and prey (see Obrycki et al. 1983).

(3) Removal techniques involving selective insecticides to eliminate predators, ants to interfere with predator activity, or hand-removal of predators. These techniques severely reduce densities of predators, but do not completely exclude them.

(4) Prey enrichment studies that place prey (e.g. eggs) in the field to estimate predation rates with minimal habitat modification.

(5) Direct observation of the target pest in the field to record predation under natural conditions. This technique provides the identity of predators and estimate of predation rates.

(6) Use of highly specific serological tests or marking techniques with rare elements or radioactive isotopes to provide chemical evidence of predation. These procedures accurately identify what predator is feeding on a prey species or a specific life stage of a target pest.

Given these techniques, I will discuss several examples of evaluations of the role of predators in different agricultural systems. These examples include a range of objectives and approaches by several researchers to demonstrate different ways to use these evaluation techniques.

The first example involves predation by *Hippodamia convergens* and *H. sinuata* (Coleoptera: Coccinellidae) on grain sorghum infested with greenbugs *Schizaphis graminum* (Homoptera: Aphididae) (Kring & Gilstrap 1984). Using three types of field cages, Kring et al. (1985) demonstrated the importance of these two coccinellid species in reducing late-season greenbug infestations. This direct measurement of greenbug predation documented suppression of greenbug densities due to the activity of the two *Hippodamia* species. Previously, because of observations of high numbers of parasitized greenbugs, aphid parasitoids were believed to be the major suppressive agent in this system. Subsequent research showed that an early-season infestation of corn leaf aphid (*Rhopalosiphum maidis*), which is not an economic pest, led to higher densities of *Hippodamia* spp. in greenbug-infested sorghum (Kring & Gilstrap 1986).

O'Neil and coworkers, although not working with predators of Homopterans, have made valuable contributions in the determination of field predation rates and quantification of the relationship between predatory searching behaviors and plant growth dynamics (O'Neil & Stimac 1988, O'Neil & Wiedenmann 1987). Using field cage studies, they determined that several arthropod predators in soybeans maintain a low constant predation rate relative to increasing prey densities. On the basis of their studies, they caution about the interpretation of laboratory functional response studies conducted at high prey densities. They point out that field studies of predation need to examine the activity of predators at low, as well as high, prey densities as predators may function at low prey densities to prevent pest outbreaks.

My third example considers serological techniques that are used to determine which predators are feeding upon target pests in the field (Greenstone 1990). Recent developments using monoclonal antibodies have made these assays more sensitive and are also the basis for a specific immunodot assay that is rapid, inexpensive and easily interpreted (Stuart & Greenstone 1990, Greenstone & Morgan 1989). Cooperative research efforts may be required because of equipment costs and the necessity to integrate these serological studies with detailed ecological field work.

As I have emphasized in this paper, several evaluation techniques are required to adequately assess the role of insect predators. Even if several techniques are used to evaluate the impact of predators, the interpretation of results of an evaluation study may be complex. For example, a recent study by McConnell & Kring (1990) quantified predation and dislodgement rates of greenbugs by adult *Coccinella septempunctata* (Coleoptera: Coccinellidae). They concluded that an estimate of the efficacy of *C. septempunctata* based solely on prey consumption would underestimate the effect of this predator on greenbug densities due to dislodgement. In the field, greenbug adults and nymphs were four to five times more likely to be dislodged, and thus exposed to additional abiotic and biotic mortality factors, than to be consumed by *C. septempunctata*. Additionally, T. J. Kring (Dept. Entomology, Univ. of Arkansas, personal communication) has shown that *C. septempunctata* will consume parasitized greenbugs at higher rates than nonparasitized individuals. Thus, in an evaluation of the impact of *C. septempunctata* on greenbug population dynamics, dislodgement and predation of parasitized individuals need to be considered to accurately measure the predator's impact.

Not only do predators interact with parasitoids, but entomopathogens may also directly infect predators or indirectly influence predators through prey (Vinson 1990). This relationship may or may not be detrimental. For example, the microsporidium *Nosema pyrausta*, which infects the European corn borer, *Ostrinia nubilalis*, has no measurable effect on the lacewing predator *Chrysoperla carnea* (Sajap & Lewis 1989). On the basis of these studies, the authors concluded that lacewing predation and infection by *N. pyrausta* were compatible mortality factors for suppression of *O. nubilalis*.

As shown by these examples, interactions of biotic mortality factors are common in biological control. The interpretation and analysis of these interacting mortality factors have been a recurring theme in insect population ecology (e.g., Morris 1965, Varley et al. 1973, Jones 1982). Recently, a new method, based upon human actuarial tables, to examine interacting mortality factors has been presented by Carey (1989). This approach allows one to separately analyze mutually exclusive causes of mortality in a life table; i.e., pathogens, parasitoids, and predators.

In summary, Luck et al. (1988) have proposed a logical framework for designing a workable evaluation program for predators of Homopterans in a Caribbean Basin biological control project,

1. Develop a sampling scheme suitable for both the predator and prey.
2. Use an insecticide disruption technique if prey has demonstrated insecticide resistance.

3. Conduct exclusion experiments that include control cages to monitor the microhabitat effects of the barriers.

4. Enhance prey levels in the field, and make direct observations of the predators attacking the target pest.

ACKNOWLEDGMENTS

I thank Harold Browning, University of Florida, Lake Alfred Experiment Station, for the invitation to speak at this workshop, the Caribbean Basin Administrative Group for financial support to attend this workshop, and Clay McCoy, University of Florida, Lake Alfred Experiment Station, for his patience. This is Journal Paper J- 14613 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Project 2755.

REFERENCES CITED

CAREY, J. R. 1989. The multiple decrement life table: a unifying framework for cause-of-death analysis in ecology. Oecologia 78: 131-137.

DEBACH, P., AND B. R. BARTLETT. 1964. Methods of colonization, recovery and evaluation, pp 402-426 *in* P. DeBach [ed.], Biological control of insect pests and weeds. Reinhold, New York.

DEBACH, P., AND C. B. HUFFAKER. 1971. Experimental techniques for evaluation of the effectiveness of natural enemies, pp. 113-140 *in* C. B. Huffaker [ed.], Biological control. Plenum Press, New York.

DEBACH, P., C. B. HUFFAKER, AND A. W. MACPHEE. 1976. Evaluation of the impact of natural enemies, pp. 255-285 *in* C. B. Huffaker and P. S. Messenger [eds.], Theory and practice of biological control. Academic Press, New York.

GILBERT, F. 1990. Size, phylogeny and life-history in the evolution of feeding specialization in insect predators, pp. 101-124 *in* F. S. Gilbert [ed.], Insect life cycles: Genetics, evolution and coordination. Springer-Verlag, London.

GREENSTONE, M. H. 1990. Foreign exploration for predators: A proposed new methodology. Environ. Entomol. 18: 195-200.

GREENSTONE, M. H., AND C. E. MORGAN. 1989. Predation on *Heliothis zea* (Lepidoptera: Noctuidae): An instar-specific ELISA assay for stomach analysis. Ann. Entomol. Soc. Am. 82: 45-49.

HAGEN, K. S. 1987. Nutritional ecology of terrestrial predators, pp. 533-577 *in* F. Slansky and J. G. Rodriguez [eds.], Nutritional ecology of insects, mites, spiders, and related invertebrates. John Wiley & Sons, New York.

HAGEN, K. S., S. BOMBOSCH, AND J. A. MCMURTRY. 1976. The biology and impact of predators, pp. 93-142 *in* C. B. Huffaker and P. S. Messenger [eds.], Theory and practice of biological control. Academic Press, New York.

JONES, D. 1982. Predators and parasites of temporary row crop pests: Agents of irreplaceable mortality or scavengers acting prior to other mortality factors? Entomophaga 27: 245-266.

KIRITANI, K., AND J. DEMPSTER. 1973. Different approaches to the quantitative evaluation of natural enemies. J. Appl. Ecol. 10: 323-340.

KRING, T. J., AND F. E. GILSTRAP. 1984. Efficacy of the natural enemies of grain sorghum aphids (Homoptera: Aphididae). J. Kansas Entomol. Soc. 57: 460-467.

KRING, T. J., AND F. E. GILSTRAP. 1986. Beneficial role of corn leaf aphid, *Rhopalosiphum maidis* (Fitch) (Homoptera: Aphididae), in maintaining *Hippodamia* spp. (Coleoptera: Coccinellidae) in grain sorghum. Crop Prot. 5: 125-128.

KRING, T. J., F. E. GILSTRAP, AND G. J. MICHELS, JR. 1985. Role of indigenous coccinellids in regulating greenbugs (Homoptera: Aphididae) on Texas grain sorghum. J. Econ. Entomol. 78: 269-273.

LUCK, R. F., B. M. SHEPARD, AND P. E. KENMORE. 1988. Experimental methods for evaluating arthropod natural enemies. Annu. Rev. Entomol. 33: 367-391.

McCONNELL, J. A., AND T. J. KRING. 1990. Predation and dislodgement of *Schizaphis graminum* (Homoptera: Aphididae), by adult *Coccinella septempunctata* (Coleoptera: Coccinellidae). Environ. Entomol. 19: 1798-1802.

MORRIS, R. F. 1965. Contemporaneous mortality factors in population dynamics. Canadian Entomol. 97: 1173-1184.

OBRYCKI, J. J., AND C. J. ORR. 1990. Suitability of three prey species for Nearctic populations of *Coccinella septempunctata*, *Hippodamia variegata*, and *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae). J. Econ. Entomol. 83: 1292-1297.

OBRYCKI, J. J., M. J. TAUBER, AND W. M. TINGEY. 1983. Predator and parasitoid interaction with aphid-resistant potatoes to reduce aphid densities: A two-year field study. J. Econ. Entomol. 76: 456-462.

O'NEIL, R. J., AND J. L. STIMAC. 1988. Measurement and analysis of arthropod predation on velvetbean caterpillar, *Anticarsia gemmatalis*, Hubner, in soybeans. Environ. Entomol. 17: 821-826.

O'NEIL, R. J., AND R. N. WIEDENMANN. 1987. Adaptations of arthropod predators to agricultural systems. Florida Entomol. 70: 40-48.

RUBERSON, J. R., M. J. TAUBER, AND C. A. TAUBER. 1986. Plant feeding by *Podisus maculiventris* (Heteroptera: Pentatomidae): Effect on survival, development, and preoviposition period. Environ. Entomol. 15: 894-897.

SAJAP, A. S., AND L. C. LEWIS. 1989. Impact of *Nosema pyrausta* (Microsporida: Nosematidae) on a predator, *Chrysoperla carnea* (Neuroptera: Chrysopidae). Environ. Entomol. 18: 172-176.

SMITH, H. S., AND P. DEBACH. 1942. The measurement of the effect of entomophagous insects on population densities of their hosts. J. Econ. Entomol. 35: 845-849.

STUART, M. K., AND M. H. GREENSTONE. 1990. Beyond ELISA: A rapid, sensitive, specific immunodot assay for identification of predator stomach contents. Ann. Entomol. Soc. Am. 83: 1101-1107.

TAUBER, C. A., AND M. J. TAUBER. 1987. Food specificity in predacious insects: a comparative ecophysiological and genetic study. Evol. Ecol. 1: 175-186.

THOMPSON, W. R. 1951. The specificity of host relationships in predaceous insects. Canadian Entomol. 83: 262-269.

VARLEY, G. C., G. R. GRADWELL, AND M. P. HASSELL. 1973. Insect population ecology. University of California Press, Berkeley.

VINSON, S. B. 1990. Potential impact of microbial insecticides on beneficial arthropods in the terrestrial environment, pp. 43-64. *in* M. Laird, L. A. Lacey, and E. W. Davidson [eds.], Safety of microbial insecticides. CRC Press, Boca Raton, Fl.

WHITCOMB, W. H., AND K. E. GODFREY. 1991. The use of predators in insect control, pp. 215-241 *in* D. Pimental [ed.], CRC Handbook of pest management in agriculture, 2nd Ed., Vol II. CRC Press, Boca Raton, Fl.