ILL Number: 162485192

Borrower: JFI

In Process Date: 20160108
OCLC Number: 1380794

Lending String:
LACAL,DNN,COF,*IBS,KFH,MZF,NWQ,UDJ,AGL

Patron:

Journal Title: Bulletin of the Entomological Society of America.
Volume: 34
Issue:
Month/Year: 1988
Pages: 27-32

Article Author: Entomological Society of America M.J. Raupp, J A. Davidson, C. S. Koehler, C. S. Sadof, K. Reichelde
Article Title: Decision-Making Considerations for Aesthetic Damage Caused by Pests

Imprint: Washington, D.C. : The Society, 1955-1989.

Last Note:
Borrowing Notes: Thanks! (maxCost: 0)

Photocopy - *Regular*

Call #: BD

Location:

Charge
Maxcost: 0.00

Shipping Address:
THE MORTON ARBORETUM
STERLING MORTON LIBRARY
4100 ILLINOIS ROUTE 53
LISLE IL 60532

Fax:
Ariel: LVIS
Odyssey:

Ship Via: Odyssey/AE

Email: mmurphy@mortonarb.org

SHIPPED VIA AE

JAN 12 2016

EXPOSURES 6
CHARGE 0
INVOICE TO FOLLOW
VS

Bulletin

of the Entomological Society of America

The *Bulletin of the Entomological Society of America* (ISSN 0013-8754) is published quarterly (March, June, September, and December) by the Entomological Society of America, 4603 Calvert Road, College Park, Md. 20740. The *Bulletin* is printed by Sheridan Press, Fame Avenue, Hanover, Pa. 17331. Second class postage is paid at College Park, Md., and at additional mailing offices. POSTMASTER: Send change of address forms to *Bulletin,* ESA, 4603 Calvert Road, College Park, Md. 20740.

Inquiries regarding content, subscriptions, advertising, availability of back issues, change of address, and general business matters, and manuscripts and other copy should be sent to the managing editor, 4603 Calvert Road, College Park, Md. 20740. Unsolicited manuscripts are welcome, but ESA can assume no responsibility for them. Manuscripts should be of general interest to entomologists. For information about preparing manuscripts, authors are urged to refer to "Information for Contributors," which is printed on the inside back cover of most issues, or to send for *Publications Policies and Guide for Authors,* which is available free of charge from ESA.

Subscription prices for 1988: members, $15; nonmember individuals, $30; institutions, $55. To the above add $8 for shipping outside the continental U.S.; $12 for shipping to India. Send payment to ESA, P.O. Box 177, Hyattsville, Md. 20781. Back issues can be ordered from ESA or from University Microfilms International, 300 North Zeeb Road, Ann Arbor, Mich. 48106.

Erratum. During the final typesetting of the article "Everything Unique or Unusual about Scale Insects" (Kosztarab, M., *Bulletin,* Winter 1987, pp. 215–220) a series of errors was introduced. The superfamily name Coccoidea was changed to Coccoidae throughout. This affected the subtitle, portions of the text, and the following references: Boratynski 1970, Habib 1957, Nur 1980, Robison 1977, and Vinis & Kozár 1981. The staff of the *Bulletin* apologizes for these errors.

LETTERS

Concern Over Employment

I read with interest "Reflections on Employment in Entomology" (Miller, R. H., *Bulletin,* Spring 1987, p. 4) and C. Beegle's letter (*Bulletin,* Summer 1987, p. 62) on the same topic.

When I was president of the Entomological Society of Canada in 1981, I chose a similar theme for my presidential address to the 31st annual meeting of that organization (Bull. Ent. Soc. Canada, 1981, 13 (4): 102). Deans and heads of departments of entomology and biology at various Canadian universities assured me that their graduate students found employment. They did not, however, specify in what field or for how long. I know of several bright persons of research scientist caliber—who have doctoral degrees—who are driving taxi cabs, selling real estate, or doing other work totally unrelated to their training. Others are on short-term contracts.

Miller's article reinforces my opinion that nothing has changed since 1981. In my address I stated that my predecessors in Canada and the United States were similarly concerned about the career opportunities for graduates in entomology and other biological disciplines. Our concerns are still valid.

S. R. Loschiavo
Research Branch
Agriculture Canada
Winnipeg, Man.

Solution for Keyboarding Woes

The Spring 1987 *Bulletin* (Letters, p. 2) carried a letter from Richard H. Foote regarding the keyboarding of printed programs. Anyone who has done this knows that typing in a program is fraught with woes. Although I agree that printing them larger would be of considerable help, I also believe that maybe we should look to existing technology for assistance.

Cauzin Systems of Waterbury, Conn., has developed the Stripper soft strip system, which stores computer files on paper. The system consists of a printing process that creates a printed strip from computer files; a data strip, which is a printed black-and-white pattern that stores computer data; a Cauzin soft strip reader, a hardware device that reads the data strip into the computer; and software that converts the data back into the original file.

Many publishers are beginning to use the data strips for printing programs. I suggest this technology would be worthwhile for publishers to evaluate.

John R. Strayer
Entomology and Nematology Department
University of Florida
Gainesville, Fla.

Comments on Chemophobia

This letter is in response to Donald G. Cochran's Forum article, "Our Chemophobic Society," (*Bulletin,* Fall 1987, pp. 128-133). Let me say at the outset that in my opinion this article was not only wrongheaded, it was the most offensive article that I've read anywhere recently. It was an insult to the sensibilities of clear-thinking people.

The article was based on the premise that our society in general has become chemophobic—fearful of chemicals—and that this phobia is unjustified. I take issue with this point of view, on both counts. First, fear of synthetic chemicals is not so widespread as Cochran asserts, and second, what fear people do have of chemicals does have a rational basis. It is interesting that although Cochran relies heavily on statistical arguments, he gives no statistical support for his initial premise—that our society in general has an "almost hysterical fear of chemicals." It seems to me that almost the opposite is true—our society is more chemophilic than chemophobic. Synthetic chemicals are so fundamental to our modern lifestyle that most Americans take them for granted—everything from food additives to synthetic fibers, cosmetics to medicines, cleaning supplies to weed killers. These items are synonymous with the current nature of our society.

Although some groups are almost radical in their intolerance of chemicals, our society in general accepts them with extreme tolerance—almost indifference. A point that most entomologists can appreciate is that our society is far more entomophobic than chemophobic. People are far more tolerant of pesticide residues that they can't see (that are perhaps dangerous) than they are of superficial insect damage to fruits and vegetables (which, if anything, indicates that the food is safe to eat). Part of the problem with pesticides is the result of our society's entomophobia, which forces us to use chemical pesticides beyond what is needed to protect the crop—to protect the consumer from the visible effects of any insect.

But let us move on to the real issue here: Is society justified in being alarmed about synthetic chemicals, insecticides in particular? Of course we should be alarmed! Cochran goes to considerable length to argue that the dangers of insecticides have been overrated, citing figures on accidental deaths and cancer rates and showing that insecticides account for only a small percentage of each. What is he trying to prove? Is he actually arguing that we should be more tolerant of insecticides because they are relatively less dangerous than other threats to our society? I believe our society has a right to be concerned about any synthetic chemicals added to the biosphere at annual rates measured in millions of pounds. We should not try to minimize the facts that most insecticides are directly poisonous to humans and that many have been found to be carcinogens, teratogens, or mutagens. So what if industrial chemicals account for only 5% of cancer deaths? That, to me, is a matter of

RESEARCH

Decision-Making Considerations for Aesthetic Damage Caused by Pests

M. J. RAUPP, J. A. DAVIDSON, C. S. KOEHLER, C. S. SADOF, AND K. REICHELDERFER

ABSTRACT The lack of decision-making guidelines for pests causing aesthetic damage continues to be a serious impediment to the development and implementation of integrated pest management programs for many systems. A common ornamental shrub, American arborvitae, and a key insect pest of woody ornamentals, the bagworm, were used to demonstrate a methodology for estimating a modified economic injury level (EIL) based on aesthetic perceptions of customers at retail nurseries. A similar approach, based on customer perceptions of damage, was used to estimate an aesthetic injury level (AIL). Both the EIL and AIL are relatively low for the model system; this confirms previous suggestions about pests that cause aesthetic damage. The possibility of estimating aesthetic thresholds (AT) is discussed, as are some of the limitations to estimating and applying these decision-making rules.

OVER THE PAST THREE DECADES, many regions in the country have experienced rapid urbanization. In states such as California, Connecticut, Florida, Maryland, Massachusetts, New Jersey, New York, and Rhode Island, more than 90% of the population lives in metropolitan areas (U.S. Department of Commerce 1986). Like their rural counterparts, urbanites face problems caused by pests of their ornamental trees, shrubs, lawns, and domiciles. Traditional management programs designed to deal with urban problems often have shortcomings similar to those of agricultural pest management programs that rely heavily on the use of synthetic organic pesticides. Urban dwellers frequently depend on routine or calendar-based applications of insecticides or on crisis treatments for pest control. The not-surprising results have been a rise in pesticide resistance and disruption to beneficial organisms (Luck & Dahlsten 1974, 1975; Nelson & Wood 1982; Tashiro 1982; Merritt et al. 1983).

Recently, several extension-based pilot and demonstration projects have tried to use an integrated approach to managing pests in residential environments. The results of these efforts have been encouraging. Researchers have documented dramatic reductions in the amounts of pesticides applied, in the number of plants treated, and in the costs of pest control, all without sacrifice to the appearance or well-being of vegetation (Olkowski et al. 1976, 1978; Davidson et al. 1981; Hellman et al. 1982; Short et al. 1982; Holmes & Davidson 1984; Raupp & Noland 1984; Smith & Raupp 1986; Cornell & Davidson 1987).

Although these programs succeeded in demonstrating the feasibility and benefits of integrated pest management (IPM) for landscape plants, they did so with one important shortcoming: They lacked rigorously defined and quantified decision-making rules analogous to those based on the concept of economic injury level (EIL), which is widely accepted in agronomic systems. This lack of decision-making rules has been identified as a major weakness of urban pest management programs (Pedigo et al. 1986, Potter 1986).

Recently, we have addressed the issues of how decisions are made concerning the management of pests of ornamental plants. Rather than add to the proliferation of terms surrounding decision-making rules, we built on the framework first proposed by Stern et al. (1959) and recently clarified by Pedigo et al. (1986). We agree with these authors that the central question for managers of ornamental plants is "How many insects cause how much damage, and is the damage significant?" We attempted to answer this question using data gathered from those who buy ornamental plants. In gathering the information, we took the perspective of the retail nursery owner who manages plants for profit. We also examined this question from the perspective of someone who manages the plant for its aesthetic value as a component of the landscape.

Estimating the EIL

Pedigo et al. (1986) proposed a general EIL model to be used for making practical decisions concerning insect management. The model is as follows:

$$\mathrm{EIL} = C/VID$$

in which EIL is the number of injury equivalents per production unit, C is the cost of management per unit of production, V is market value per unit of produce, I is the number of injury units per insect per production unit, and D is the damage per unit of injury. For a system that involves an ornamental plant, we quantified each of the four components of the model in the following way.

The plant–insect system we used in evaluating the model consisted of the American arborvitae, *Thuja occidentalis,* and the bagworm, *Thyridopteryx ephemeraeformis* (Haworth). Studies by Holmes & Davidson (1984) and Raupp & Noland (1984) indicate that arborvitae is one of the most common woody ornamental plants used in homeowner landscapes in the mid-Atlantic region. The bagworm is one of the 10 key pests of landscape plants regionally and nationally (Kielbaso & Kennedy 1983, Holmes & Davidson 1984, Raupp & Noland 1984).

The first component of the general model that we estimated was the injury units per insect per production unit (I). In clarifying the nature of the injury function, Pedigo et al. (1986) indicated that appearance may be an important component of plant quality, and as such it is a critical factor affecting injury.

The following experiment was performed to quantify the relationship between bagworm density and injury to arborvitae. Twenty container-grown, 4-ft-tall arborvitae plants, which had no defects in appearance (they were of uniform coloring and form and had no defoliation), were assigned randomly to one of four treatments. Each tree was photographed and its outline reproduced on graph paper. Treatments consisted of infesting the trees with 0, 10, 100, or 500 first-instar bagworm larvae during the first week of June 1982. The larvae were allowed to construct bags prior to infestation. This period coincides with the emergence of bagworm larvae in the field in Maryland. Trees were placed in an outdoor bed on paper sheets coated regularly with Tanglefoot (Tanglefoot Company, Grand Rapids, Mich.) to limit migration of larvae between trees.

At the end of the period of larval feeding, in early September, each tree was inspected

MICHAEL J. RAUPP, JOHN A. DAVIDSON, *and* CLIFFORD S. SADOF *are members of the Department of Entomology at the University of Maryland in College Park, Md. 20742.* CARLTON S. KOEHLER *is an entomologist with the Cooperative Extension Service of the University of California in Berkeley, Calif. 94720.* KATHERINE REICHELDERFER *is a scientist with the National Resource and Environment Division of USDA's Economic Research Service, Washington, D.C. 20005.*

0013-8754/87/0027-0032$02.00

and the area of discolored and missing foliage was traced on the paper outline of the tree. The tree was inspected from opposite profiles, and injury was expressed as the percentage of the total amount of leaf area that was discolored and missing. Injury ranged from 0 to 100% and was related to initial bagworm density (number of larvae per tree) in a strongly linear way ($y = 0.861x - 1.493$, $r^2 = 0.903$, $P < 0.001$; x is the number of first-instar bagworms per 4-ft tree, and y is the percentage of missing or discolored leaf area). The finding that the relationship between insect abundance and plant injury was linear over a certain range of densities is consistent with assumptions concerning the injury component of the general EIL model proposed by Pedigo et al. (1986).

The second component of the model that we estimated was the relationship between injury and plant utility (D). Pedigo et al. (1986) identified this as the most critical component of the EIL because it provides the fundamental link between the injury to the plant and its economic or aesthetic utility. Several factors are known to affect the response of a crop to injury. Of these factors, time of injury, plant part injured, type of injury, intensity of injury, and environmental interactions assume major importance (Pedigo et al. 1986).

The damage component of the model differs between ornamental and agricultural crops in at least two important ways. Because ornamental landscape crops are often managed for aesthetic purposes rather than for economic ones, yield is an inappropriate measure of plant response to injury. Several authors have suggested that damage to ornamental plants be measured in terms of reduced aesthetic value, quality, or use (Olkowski 1974, Pedigo et al. 1986, Potter 1986).

Pedigo et al. (1986) indicated that in the case of EILs for agricultural systems, plant stands rather than individual plants usually provide the proper scale for establishing damage relationships. In contrast, when dealing with ornamental plants, especially landscape trees and shrubs, it is the individual plant that ideally forms the management unit (Hellman et al. 1982, Olkowski et al. 1978, Nielsen 1983, Holmes & Davidson 1984, Raupp & Noland 1984, Smith & Raupp 1986). Therefore, we considered individual plants when estimating the EIL.

We used the following methodology to quantify the relationship between plant injury and aesthetic utility. An arborvitae similar in all respects to those used to estimate the density–injury relationship was artificially infested with approximately 500 first-instar bagworm larvae in early June. While it was still in excellent condition, the shrub was photographed with a 35-mm Nikon camera and Kodachrome 25 film at the time of infestation. At intervals during the period of insect injury, the amount of injury was estimated and the shrub was photographed again. The photographic procedure was standardized for distance, angle, and backdrop throughout the course of the study. The photographs were printed, enlarged to 8 by 12 in., mounted in random positions on 30- by 40-in. posterboard, and assigned numbers.

The posterboard was transported to five retail nurseries in central Maryland. At each nursery approximately 20 customers were invited to complete a questionnaire that contained several biographical questions and four questions about the customers' responses to the injured plants.

We quantified responses to different levels of injury by asking the customers how much they would pay for each plant pictured. Between injury levels of 0 and 75% the average utility of the plant declined (Fig. 1). For this study, we consider the utility of the plant to be its dollar value expressed as a percentage of the value of an aesthetically optimal plant (see discussion of value below). Over the portion of this relationship between 0 and 8% injury, there was a strongly linear relationship between injury and utility measured in units of percent utility loss per injury unit ($y = -10.2x + 0.916$, $r^2 = 0.842$, $P < 0.05$; x is the percentage of the missing or discolored leaf area, and y is the percentage of reduction in utility). The factors that influence aesthetic value are numerous and complex, and although they were not of concern in this study they have been discussed elsewhere (Olkowski 1973, Potter 1986, Zungoli & Robinson 1984, Pedigo et al. 1986).

The third critical component in estimating the EIL is the market value *(V)* of the commodity. In discussing factors that affect V, Pedigo et al. (1986) stated that utility may be strongly affected by quality. In our example the utility of the plant is associated with its appearance. In this case, the desired appearance should be the basis for determining the value of the commodity (Pedigo et al. 1986). To determine what the desired appearance of the arborvitae was, we asked the customers "Which plant or plants have damage that would prevent you from purchasing them?" The arborvitae with the most desirable appearance (0% injury) was the control plant. However, this plant was desirable to only 93.6% of those surveyed. The price of this plant, averaged over all of the consumers who were surveyed, was $20.29 ± 1.52 (mean ± SE). Thus, the commodity at full value was $20.29 per 93.6% utility.

The final parameter required for estimating the EIL is the cost of control *(C)*. With respect to pests that affect quality by altering the appearance of the commodity, Pedigo et al. (1986) suggested that the outcome of the control should be commensurate with the desired result. In the case of pests causing damage to an ornamental plant, the desired outcome would be to arrest any further plant injury. A single, well-timed insecticide treatment can completely control bagworms on an arborvitae. Acephate is a widely recommended material that is available to certified pesticide applicators and the general public, and it provides complete control of bagworms (Price et al. 1978, 1985; Pinkston et al. 1983).

As an example, we estimated the cost of control in the following way. We assumed that the pest manager was the retail nurseryman selling the plant. To estimate cost in this situ-

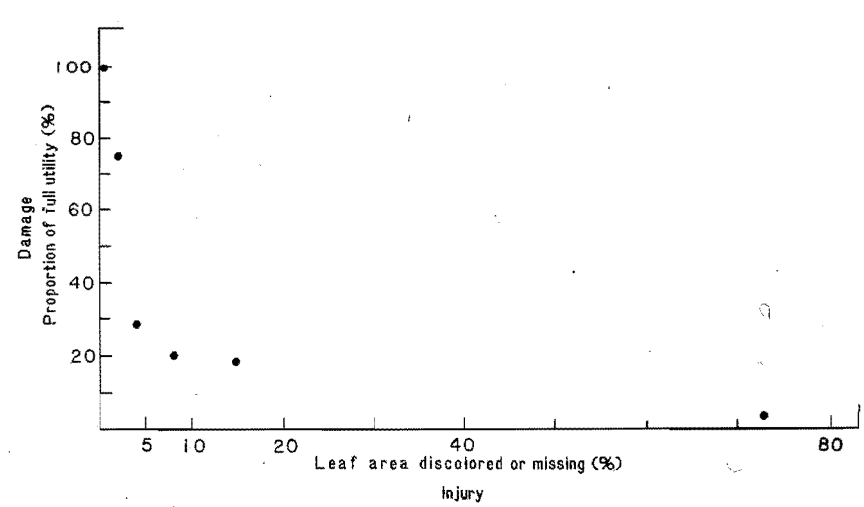

Fig. 1. *Relationship of injury to arborvitae caused by bagworms expressed as the percentage of discolored or missing leaf area and damage measured as a proportion of the full utility of the plant. Utility is the ratio of the average price customers were willing to pay at each injury level relative to the average price of the undamaged plant expressed as a percentage. Each point represents responses of 93 customers visiting retail nurseries in Maryland.*

ation, we consulted two pest control operators who work in retail nurseries. A liberal estimate of control costs for this case was $7.53: This included $0.03 for the cost of acephate to treat the plant, and $7.50 for the cost of labor to mix, apply, and clean up insecticide. The cost of the equipment involved, a 2.5-gallon mist blower, was deemed insignificant for a single treatment prorated over the life of the machine.

With these estimates, we calculated the EIL to arborvitae using the methodology of Pedigo et al. (1986):

$$\mathrm{EIL} = C/VID$$

in which EIL is the number of first-instar bagworm larvae per 4-ft tree, C is the cost of management at $7.53 per 4-ft tree, V is the market value of the plant at full utility at $20.29 per 93.6%, I is the injury per production unit at 0.861% missing or discolored leaf area/(insect/tree); and D is the damage per unit injury at 10.2% utility reduction divided by the percentage of missing or discolored leaf area. The EIL for the retail nurseryman was 3.96 first-instar larvae per 4-ft tree.

The remarkably low EIL in this case confirms suggestions made by several authors regarding the low tolerance held by the public for pests that cause aesthetic damage (National Research Council 1980, Sawyer & Casagrande 1983, Larew et al. 1984, Zungoli & Robinson 1984). This result is largely because of customers' expectations regarding plant appearance and its relationship to value. The regression analysis indicated that each percentage point drop of missing or discolored leaf area resulted in a 10% reduction in the value of the plant.

The low cost of bagworm control relative to other parameters gives the EIL a small value. This presents serious operational problems for bagworm management. A single female bagworm can produce more than 1,300 eggs (Barrows 1974). Our data and those of other researchers' accounts of the bionomics of bagworms indicate that a single female can produce an infestation that will exceed the EIL (Barrows 1974, Horn & Sheppard 1979).

This problem is further complicated by the dispersal behavior of bagworm larvae. Cox & Potter (1986) found that 9% of first-instar bagworm larvae placed on undamaged junipers dispersed aerially and that under proper conditions of wind and departure height, this dispersal could carry them relatively long distances. Based on the low EIL estimated here, it is possible that even a small number of migrant larvae could create damage in excess of the EIL. Clearly, refinements in sampling and monitoring approaches are necessary before this EIL can be applied to management programs for bagworms.

It is also noteworthy that the EIL based on aesthetic considerations will depend greatly on the objectives of the pest manager. Our analysis indicates that the retail nurseryman may have an extremely low EIL for pests that cause aesthetic damage. Even slight imperfections in plant appearance result in substantial reductions in the marketability of plants. Sadof & Raupp (in press) found that a 1% increase in missing or discolored leaf area resulted in a 9% increase in the number of customers refusing to purchase arborvitae.

This may not be the case for wholesale nurserymen. In conducting an IPM program with wholesale nurserymen, Cornell & Davidson (1987) found that some nurserymen tolerated high levels of plant injury before they initiated control. Furthermore, tolerance was related to the type of injury or plant affected. For example, one grower was willing to allow high levels of leaf discoloration injury caused by hawthorne lace bug, yet was intolerant of shoot dieback caused by the Nantucket pine tip moth. Although we did not survey perceptions of wholesale nursery customers, we would not be surprised to find that EILs for the same plant–pest system can differ from wholesalers and retailers. Homeowners also may have EILs that differ from those of nurserymen. They may place a different value on an ornamental plant once it is established in the landscape. Perceptions of injury and damage caused by pests also may differ, as will the costs of control. Any or all of these factors can affect EILs for homeowners who manage pests themselves.

AILs and Thresholds

So far we have described how economic parameters can be used for guiding management decisions concerning pests of ornamental plants. However, in the case of horticultural pests, several authors have suggested that economic considerations may not be the only factor in the decision-making process (Olkowski 1974, Sawyer & Casagrande 1983, Pedigo et al. 1986, Potter 1986). As Pedigo et al. (1986) point out, often the mere presence of the offending organism can be enough to initiate a control action. This non-economic-based response of people to pest activity or presence justifies a reexamination of the decision-making process with respect to aesthetic considerations.

Olkowski (1974) was the first to suggest the use of a decision-making rule for managing pests of aesthetic importance. He coined the term aesthetic injury level (AIL) and indicated that it is analogous to the EIL with the exception that aesthetic rather than economic considerations motivate management decisions. This approach finds its roots in earlier discussions of decision-making rules. In clarifying the relationship between insects and crop loss, Smith (1969) indicated that insect-related damage could result in a reduction in the quantity or quality of the crop. Furthermore, this loss in quality could simply be a reduction in the appearance of the crop.

Olkowski et al. (1978) drew on this idea to develop decision-making rules that proved useful for managing several pests of street trees in California cities. For example, an AIL was developed to help pest managers decide whether to apply insecticides to control the California oakworm, *Phyrganidia californica.* In this case, the AIL of 10 larvae per 25 shoots was selected because this density of larvae created leaf loss "regarded as unsightly by many people" (Olkowski et al. 1978). Although it is unclear whether rigorous data were used to construct this relationship, the concept itself proved useful and was important in the success of the program.

In the decade since the concept of AIL was introduced, some progress has been made in clarifying the relationships between insect numbers, damage, and aesthetic injury. Koehler & Moore (1983) examined the relationship between the density of cypress tipminer, *Argyresthia cupressella,* and an indicator of aesthetic injury estimated as an "unsightliness rating" scaled from 1 to 5. They demonstrated that unsightliness increased as a simple linear function of leafminer abundance. To our knowledge, this was the first time the relationship between pest abundance and the aesthetic quality of landscape plants had been quantified.

Larew et al. (1984) investigated the effect of the serpentine leafminer, *Liriomyza trifolii,* on the marketability of potted chrysanthemums. They surveyed 42 attendees at a horticultural conference. The respondants observed four potted mums that exhibited leafminer injury ranging from 0 to 45% of the leaves mined, and they were asked which plants they would be willing to buy. Results of this survey revealed a strong negative relationship between damage and willingness to purchase plants.

Parella & Jones (1987) suggested that a modified AIL be adopted for a variety of floricultural crops. Cut flowers, such as chrysanthemums, roses, carnations, and gerbera, can tolerate substantial injury to leaves and other unmarketed portions without effect to the aesthetic quality of the flowers. By tolerating aesthetic injury to nonmarketed parts, producers enjoy a much greater possibility of implementing IPM (Parella & Jones 1987).

Two recent studies have addressed the problem of decision making when the mere presence of an insect creates injury and triggers a management decision. Wood et al. (1981) surveyed 648 residents of public housing in Roanoke, Va., Norfolk, Va., and Baltimore, Md. They asked residents at what level of cockroach infestation (number observed in a kitchen during an afternoon) did a problem exist. Fifty percent of the residents perceived aesthetic injury in the form of roaches creating a problem when more than two were observed in an afternoon (Fig. 2).

Zungoli & Robinson (1984) determined the level of cockroach abundance that led residents of public housing to initiate control. Their results revealed an increasing relationship between cockroach abundance (the number observed in 24 h) and the willingness of residents to initiate control (Fig. 2). This relationship can be used to identify a decision threshold similar to the economic threshold of Stern et al. (1959). Stern et al. (1959) defined the economic threshold as "the density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level." Zungoli & Robinson (1984) argued that aesthetic considerations rather than economic ones were critical in shaping control decisions of public housing residents. If this is the case, about half of the public housing residents initiated control when one or two roaches were observed in a 24-h period. These studies indicate that residents had well-defined perceptions of when injury occurred and control was necessary. In both cases, the observation of a few roaches in a relatively short time was sufficient to cause injury and prompt a management response.

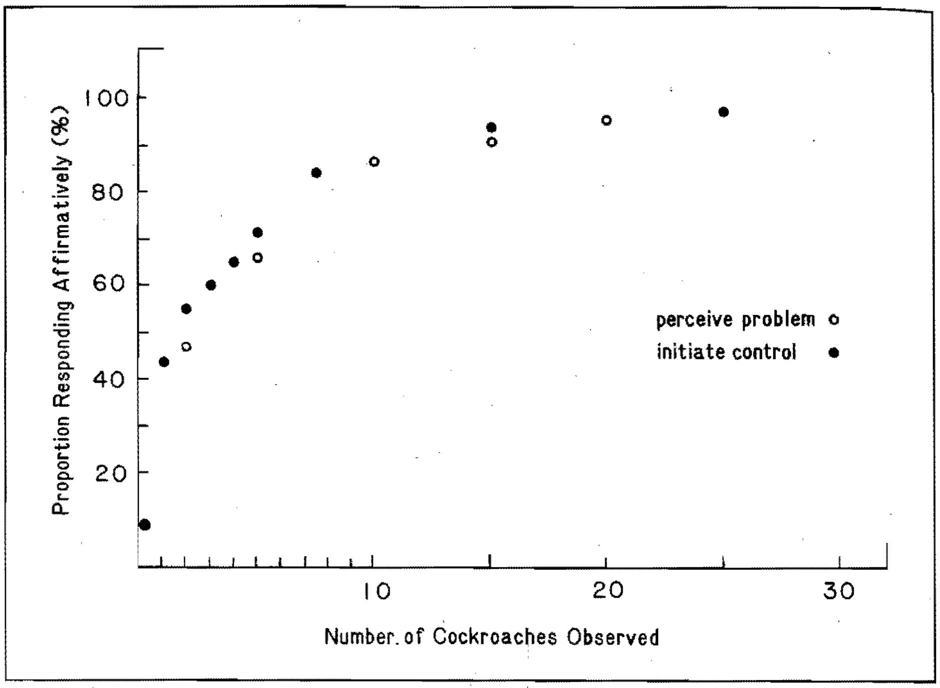

Fig. 2. *Relationship between cockroach abundance and the proportion of tenants perceiving a problem and willing to initiate control. Cockroach abundance was expressed as number observed in one afternoon for "perceived problem" and number observed in a 24-h period for "initiate control."*

Using our sample of nursery customers with respect to insect injury on an ornamental plant, we quantified perceptions of when plants had been damaged by bagworms and when they required control. In addition to asking questions related to economic parameters, we asked customers which plant or plants showed damage and which plant or plants were perceived as having enough damage to warrant control. The responses of 93 customers from five nurseries are depicted in Fig. 3. The customers perceived trees with greater levels of injury as showing more damage and being more likely to require control. Between 0 and 8% injury, there was a strong linear relationship between injury *(x)* and the response to the injury (y_1, show damage; y_2, warrant control).

$$y_1 = 10.21x + 15.43, r^2 = 0.843, P < 0.05:$$
$$y_2 = 6.93x + 5.81, r^2 = 0.923, P < 0.01$$

Using these relationships and the relationship between bagworm density and plant injury *(I),* we can estimate the number of bagworms that will cause sufficient injury to be perceived as damage by 50% of those surveyed. In this case about six first-instar bagworms per tree would cause injury perceived as damaging by half of those surveyed. Similarly, about nine first-instar bagworms per tree would create injury perceived as warranting control by half of those surveyed.

Several points of interest arise from this analysis. These data suggest that the decision to initiate control may occur at a density greater than that which causes aesthetic damage. If we consider the "show damage" density analogous to the EIL as defined by Stern et al. (1959) (i.e., the lowest population level that will cause economic damage) and the "warrant control" density analogous to the economic threshold (the density at which control measures should be determined to prevent a pest population from reaching the EIL), then we have the curious result that the pest density that triggers the control action exceeds the density that causes aesthetic damage. Although this result was not considered possible by Stern et al. (1959), in discussing the EIL and economic threshold, Pedigo et al. (1986) describe circumstances in which this may be the case in agronomic systems.

The second point of interest is the general concordance between the EIL estimated by economic parameters and the AIL estimated by perception. The EIL for retail nurserymen was estimated at four first-instar larvae per 4-ft tree. The level of aesthetic injury perceived as damaging by 50% of the respondants was about six first-instar larvae per 4-ft tree. In this case, estimates of injury levels based on economic considerations were quite similar to those based on aesthetic perceptions. The possibility that this concordance is general should be explored with other ornamental plant systems.

The task of estimating AILs would be greatly simplified if pest managers reacted as strongly to perceived plant injury as they did in this study. For example, if 50% of homeowners perceived a wide variety of plants as

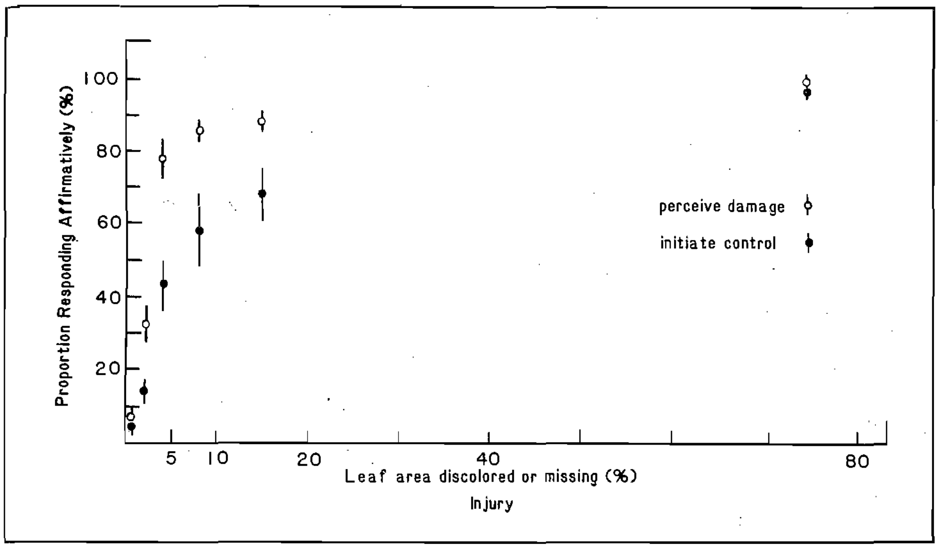

Fig. 3. *Relationship between injury to arborvitae caused by bagworms and the proportions of nursery customers perceiving damage and willing to initiate control. Each point represents responses of 93 customers visiting retail nurseries in Maryland. Vertical lines depict standard errors.*

damaged and decided to treat when a certain low level of the leaf area (e.g., 10%) was injured regardless of the causal pest, then decision-making procedures would rely primarily on establishing the relationships between pest abundance and plant injury. Variations in responses to injury could be evaluated by establishing these relationships for different pests, such as those that chew compared with those that suck, and for deciduous as opposed to evergreen plants. Quantification of AILs for a variety of pests that affect key plants could simplify the implementation of IPM programs for managed landscapes (Raupp et al. 1985).

Finally, the observation that the EIL and AIL were quite low indicates a need for a better understanding of perceived damage and true injury to the ornamental plant. The arborvitae plants used in this study were able to tolerate relatively high levels of defoliation without mortality. Many plants that suffered moderate levels of defoliation, in excess of 20%, refoliated within one to two years, at which time the injury was no longer detectable. Deciduous plants would be able to reverse these and greater levels of defoliation in a single year. A more thorough understanding of the nature and consequences of injury caused by pests of ornamental plants is needed by those who formulate management guidelines. This knowledge could form the basis for educational activities directed at increasing tolerance to injury that is largely cosmetic, causes little long-term effect on plant appearance, and is of no consequence to plant vitality. The resulting increase in AILs and EILs could greatly reduce unnecessary treatment by pest managers.

We have used standard economic methodology to demonstrate the feasibility of estimating EILs for pests that reduce the aesthetic utility of plants. This requires quantification of parameters such as the cost of control, the value of the commodity, and the relationships between pest densities and plant injury, and plant injury and damage. We suggest that aesthetic considerations alone may prove valuable in decision-making approaches for pests causing aesthetic injury. Estimating an AIL will depend on determining the relationships between pest abundance and injury, and between injury and damage. In the case of AILs, surveys of consumers' attitudes and perceptions may provide the information necessary to estimate the relationship between injury and damage. Although we used photographs of injured plants in our survey of customers at a retail nursery, Koehler & Moore (1983) and Larew et al. (1984) gathered similar data using live plants. Wood et al. (1981) and Zungoli & Robinson (1984) relied solely on peoples' attitudes to gather this information. Stern et al. (1957) considered the EIL to be the lowest population level that causes economic damage. Olkowski et al. (1978) based an AIL on a pest density that created injury regarded as unsightly by many people. From an operational standpoint it may be useful to clearly define the level of damage on which the AIL is based. In our example we defined this point to be the 50th percentile of the customers surveyed in the retail nursery. Half of those surveyed perceived damage on arborvitae when less than 8% of the shrub was discolored or defoliated. This level of injury corresponded to about six bagworm larvae per plant. The same reasoning can be applied to tenants managing cockroaches in public housing units. In this case, half of the tenants perceived a problem when more than two cockroaches were observed in an afternoon.

A similar methodology may prove useful in estimating aesthetic thresholds for pests. From an operational standpoint, if decisions to control pests are based solely or primarily on aesthetic rather than economic considerations, it is important to define the relationship between injury and the decision to initiate control. For the system of bagworms feeding on arborvitae, half of those surveyed would initiate control when about 7% leaf area is discolored or defoliated. This corresponds to a density of nine first-instar bagworms per 4-ft tree. Attitudes of tenants in public housing units indicate that half would initiate control when two cockroaches were observed in a residence in a 24-h period.

The results of the studies summarized here suggest that economic and aesthetic considerations can be quantified for pests that affect managed resources—whether they are ornamental plants or residential dwellings. It is our hope that analyses of other managed systems in urban settings will provide further useful information about decision-making procedures. ■

Acknowledgment

We thank J. J. Holmes for help in conducting the survey of nursery customers. The manuscript was improved by comments made by two reviewers. Computer support was provided by the Computer Science Center at the University of Maryland. This is scientific article A-4642 and contribution 7638 of the Maryland Agricultural Experiment Station.

References Cited

Barrows, E. M. 1974. Some factors affecting population size of *Thyridopteryx ephemeraeformis* (Lepidoptera: Psychidae). Environ. Entomol. 3: 329–332.

Cornell, C. F. & J. A. Davidson. 1987. The potential value of IPM to the nursery industry: results of the Maryland pilot nursery IPM program. Part V. M.S. Scholarly Paper. University of Maryland, College Park.

Cox, D. L. & D. A. Potter. 1986. Aerial dispersal behavior of larval bagworms, *Thyridopteryx ephemeraeformis* (Lepidoptera: Psychidae). Can. Entomol. 118: 525–536.

Davidson, J., J. L. Hellman & J. Holmes. 1981. Urban ornamentals and turf IPM, pp. 68–72. *In* Proceedings of integrated pest management workshop. National Cooperative Extension, Dallas.

Hellman, J. L., J. Davidson & J. Holmes. 1982. Urban integrated pest management in Maryland, pp. 31–38. *In* H. D. Niemczyk & B. G. Joyner [eds.], Advances in turfgrass entomology. Hammer Graphics, Picqua, Ohio.

Holmes, J. J. & J. A. Davidson. 1984. Integrated pest management for arborists: implementation of a pilot program in Maryland. J. Arboric. 10: 65–70.

Horn, D. J. & R. F. Sheppard. 1979. Sex ratio, pupal parasitism, and predation in two declining populations of the bagworm, *Thyridopteryx ephem-*

eraeformis (Haworth) (Lepidoptera: Psychidae). Ecol. Entomol. 4: 259–265.

Kielbaso, J. J. & M. K. Kennedy. 1983. Urban forestry and entomology: a current appraisal, pp. 423–440. *In* G. W. Frankie & C. S. Koehler [eds.], Urban entomology: interdisciplinary perspectives. Praeger, New York.

Koehler, C. S. & W. S. Moore. 1983. Resistance of several members of the Cupressaceae to the cypress tip miner, *Argyresthia cupressella.* J. Environ. Hort. 1: 87–88.

Larew, H. G., J. J. Knodel-Montz & S. L. Poe. 1984. Leaf miner damage. Greenhouse Manager 3: 53–55.

Luck, R. F. & D. L. Dahlsten. 1974. Bionomics of the pine needle scale *Chionaspis pinifolia* (Fitch) and its natural enemies at South Lake Tahoe, California. Ann. Entomol. Soc. Am. 67: 309–316.

1975. Natural decline of a pine needle scale (*Chionaspis pinifolia* [Fitch]) outbreak at South Lake Tahoe, California, following cessation of adult mosquito control with malathion. Ecology 56: 893–904.

Merritt, R. W., M. K. Kennedy & E. F. Gersabeck. 1983. Integrated pest management of nuisance and biting flies in a Michigan resort: dealing with secondary pest outbreaks, pp. 277–300. *In* G. W. Frankie & C. S. Koehler [eds.], Urban entomology: interdisciplinary perspectives. Praeger, New York.

National Research Council. 1980. Urban pest management. National Academy Press, Washington, D.C.

Nelson, J. O. & F. E. Wood. 1982. Multiple and cross-resistance in a field-collected strain of the German cockroach (Orthoptera: Blattellidae). J. Econ. Entomol. 75: 1052–1054.

Nielsen, D. G. 1983. Integrated pest management (IPM). Plants & Gard., Brooklyn Bot. Gard. Rec. 40: 70–72.

Olkowski, W. 1974. A model ecosystem management program. Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Manage. 5: 103–117.

Olkowski, W., H. Olkowski, R. Van den Bosch & R. Hom. 1976. Ecosystem management: a framework for urban pest control. BioScience 26: 384–389.

Olkowski, W., H. Olkowski, T. Drlik, N. Heidler, M. Minter, R. Zuparko, L. Lamb & L. Orthel. 1978. Pest control strategies: urban integrated pest management, pp. 215–234. *In* E. H. Smith & D. Pimentel [eds.], Pest control strategies. Academic, New York.

Parella, M. P. & V. P. Jones. 1987. Development of integrated pest management strategies in floricultural crops. Bull. Entomol. Soc. Am. 33: 28–34.

Pedigo, L. P., S. H. Hutchins & L. G. Higley. 1986. Economic injury levels in theory and practice. Annu. Rev. Entomol. 31: 341–68.

Pinkston, K., R. Price, E. King, & J. Foltz. 1983. Control of bagworms on Chinese arborvitae, p. 61. *In* Insecticide and Acaricide Tests, vol. 8. Entomological Society of America, College Park, Md.

Potter, D. A. 1986. Urban landscape pest management, pp. 219–252. *In* G. W. Bennett & J. M. Owens [eds.], Advances in urban pest management. Van Nostrand Reinhold, New York.

Price, R., K. Pinkston, D. Bogel & B. Ree. 1978. Pfitzer juniper, eastern red cedar, bagworm control 1977, p. 156. *In* Insecticide and Acaricide Tests, vol. 3. Entomological Society of America, College Park, Md.

Price, R., K. Pinkston, E. King & R. Freeman. 1985. Control of bagworms on Chinese juniper, 1984, p. 298. *In* Insecticide and Acaricide Tests, vol. 10. Entomological Society of America, College Park, Md.

Raupp, M. J. & R. M. Noland. 1984. Implementing landscape plant management programs in residential and institutional settings. J. Arboric. 10: 161–169.

Raupp, M. J., J. A. Davidson, J. J. Holmes & J. L. Hellman. 1985. The concept of key plants in integrated pest management for landscapes. J. Arboric. 11: 317–322.

Sadof, C. S. & M. J. Raupp. In press. Customer attitudes toward defoliation of American Arborvitae, *Thuja occidentalis,* by bagworm, *Thyridopteryx ephemeraeformis.* J. Environ. Hort.

Sawyer, A. J. & R. A. Casagrande. 1983. Urban pest management: a conceptual framework. Urban Ecol. 7: 145–157.

Short, D. E., J. A. Reinart & R. A. Atilano. 1982. Integrated pest management for urban turfgrass culture—Florida, pp. 25–30. *In* H. D. Niemczyk & B. G. Joyner [eds.], Advances in turfgrass entomology. Hammer Graphics, Picqua, Ohio.

Smith, D. C. & M. J. Raupp. 1986. Economic and environmental assessment of an integrated pest mangement program for community owned landscape plants. J. Econ. Entomol. 79: 162–165.

Smith, R. F. 1969. The importance of economic injury levels in the development of integrated pest control programs. Qual. Plant Mater. Veg. XVII 2: 81–92.

Stern, V. M., R. F. Smith, R. Van den Bosch & K. S. Hagen. 1959. The integrated control concept. Hilgardia 29: 81–101.

Tashiro, H. 1982. The incidence of insecticide resistance in soil inhabiting turfgrass insects, pp. 81–84. *In* H. D. Niemczyk & B. G. Joyner [eds.], Advances in turfgrass entomology. Hammer Graphics, Piqua, Ohio.

U.S. Department of Commerce. 1986. Statistical abstract of the United States. Washington, D.C.

Wood, F. E., W. H. Robinson, S. K. Kraft & P. A. Zungoli. 1981. Survey of attitudes and knowledge of public housing residents towards cockroaches. Bull. Entomol. Soc. Am. 27: 9–13.

Zungoli, P. A. & W. H. Robinson. 1984. Feasibility of establishing an aesthetic injury level for German cockroach pest management programs. Environ. Entomol. 13: 1453–1458.

Received for publication 13 April 1987; accepted 10 December 1987.