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TEMPORAL AND SPATIAL DISTRIBUTION AND DISPERSAL PATTERNS OF PARAPHLEPSIUS IRRORATUS (SAY) (HOMOPTERA: CICADELLIDAE), A VECTOR OF X-DISEASE IN MICHIGAN

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by

Kirk Jon Larsen

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ABSTRACT

TEMPORAL AND SPATIAL DISTRIBUTION AND DISPERSAL PATTERNS OF *PARAPHLEPSIUS IRRORATUS* (SAY)(HOMOPTERA: CICADELLIDAE), A VECTOR OF X-DISEASE IN MICHIGAN

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Populations of leafhopper vectors of X-disease, a major disease problem of the Michigan peach industry, were monitored by yellow sticky board traps and sweepnet samples during 1985 and 1986. *Paraphlepsius irroratus* represented over 70% of all known vectors found. The appearance of symptomatic chokecherry indicated X-disease transmission was occurring throughout the state.

Daily activity of *P. irroratus* was monitored by light-trap and sweepnet sampling orchard sub-habitats. *P. irroratus* is found in the groundcover during the day, has a crepuscular flight into cherry trees at night, and returns to the groundcover in the morning.

Rate and extent of *P. irroratus* dispersal within peach and cherry orchards was studied by a mark, release and recapture experiment. The overall recapture rate was 2.35%, with an average dispersal rate of 3.42 m/day. The major factor influencing leafhopper dispersal was wind, with temperature influencing activity.

DEDICATION

To Dr. Harvey Blankespoor,

who is responsible for introducing me to a beautiful and

complex part of God's creation, the insects.

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GENERAL INTRODUCTION AND LITERATURE REVIEW

Review of X-disease

In the United States in 1982, Michigan ranked first in sour cherry production, third in sweet cherry production, and sixth in peach production (Fedewa & Psocodna 1982). In a 1981 report from Michigan cooperative extension agents, X-disease was considered a major peach disease problem in southwestern Michigan. An annual loss to X-disease of $1.5-$3.0 million in peach production (M. Whalon, personal communication) is estimated from Michigan Department of Agriculture (MDA) survey data from 1977-82 and 1985-86. The MDA annual survey indicates the incidence of X-disease has increased in peach orchards of southwest Michigan during the past several years with 83% of the peach orchards inspected during 1985 showing the presence of X-disease (Robinson 1985).

The causal agent of X-disease is a mycoplasmalike organism (MLO) (Granett & Gilmer 1971, Jones et al. 1974) that can be transmitted by several species of leafhoppers. MLO's are microscopic, single-celled prokaryotic organisms similiar to mycoplasmas (Agrios 1978). Two hypotheses have been proposed as to how MLO's cause disease (Razin 1978). The MLO's either clog up the phloem tubes, thus inhibiting nutrient translocation through the plant, and/or produce toxins which kill the plant.

Leafhopper vectors of X-disease (*Homoptera: Cicadellidae*) are primarily of the subfamily *Deltocephalinae*

(Gilmer & Blodgett 1976). At least 18 species are known to be capable of transmitting X-disease either naturally or experimentally (Table 1). The species of greatest importance in the spread of X-disease in peach and cherry varies in different regions of the U.S. and Canada (Elliott & Dirks ND). The seasonal distribution and abundance of different leafhopper vectors within the same geographical region also varies considerably (McClure 1980b).

The most important vector of X-disease in the eastern U.S. is *Scaphytopius acutus* (Say) (Palmiter et al. 1960), while *Collodonus montanus* (VanD.) is the major vector in the western U.S. (Gilmer & Blodgett 1976). In Michigan, the most important vector of X-disease is presumed to be *Paraphlepsius irroratus* (Say) (Taboada et al. 1975).

There are thought to be at least two separate strains of X-disease MLO's, eastern and western, because of variation in symptom development between eastern and western orchards. More recent DNA hybridization research (Kirkpatrick 1986, M. Whalon, personal communication) indicates a lack of homology between California and Michigan isolates of X-disease MLO's (Whalon, unpublished data). Research is ongoing in the genomic DNA hybridization approach for differentiating the X-disease isolates in host plants and insect vectors.

Peach X-disease symptom development begins in mid-June. Healthy and sick trees are most easily distinguished by symptoms during August (Palmiter & Hildebrand 1943). There

Table 1. Known leafhopper vectors (Homoptera: Cicadellidae) of Peach X-disease in North America (after Nielson 1979 and Chiykowski 1981).

Strain Species	Transmission Field	 Greenhouse	Author & Date
Eastern			
Collodonus clitellarius (Say)	x	x	Thornberry 1954, Gilmer 1954
Fieberiella florii (Stal.)		x	Gilmer & McEwen 1958
Gyponana lamina DeLong		x	Gilmer & McEwen 1958
Norvellina seminuda (Say)		x	Gilmer et al. 1966
Orientus ishidae (Mat.)		x	Rosenberger & Jones 1978
Paraphlepsius irroratus (Say)[a]	x	x	Gilmer et al. 1966
Scaphoideus melanotus Osb.		x	Rosenberger & Jones 1978
S. titanus Ball		x	Rosenberger & Jones 1978
Scaphytopius acutus (Say)[b]		x	Hildebrand 1953
Western			
Acinopterus angulatus Lawson		x	Purcell 1979
Collodonus geminatus (Van Duzee)	x	x	Wolfe et al. 1950
C. montanus (Van D.)[c]		x	Wolfe 1955
Euscelidius variegatus Kirsh.		x	Jensen 1969
Fieberiella florii (Stal.)	x	x	Wolfe et al. 1951
Keonolla confluens (Uhler)	x	x	Anthon & Wolfe 1951
Osbornellus borealis DeL. & Mohr		x	Jensen 1957
Scaphytopius acutus (Say)	x		Anthon & Wolfe 1951
S. delongi Young		x	Swenson 1971
S. nitridus (DeLong)		x	Purcell 1979

[a] *P. irroratus* is the most important vector of X-disease in Michigan (Taboada et al. 1975).

[b] *S. acutus* is the most important vector of X-disease in Eastern North America (Palmiter et al. 1960).

[c] *C. montanus* is the most important vector of X-disease in Western North America (Gilmer & Blodgett 1976).

is a slight delay in the foliation of diseased trees which is often missed (Gilmer et al. 1954). Peach X-disease has similiar yet distinct symptoms to nitrogen deficiency, bacterial spot (*Xanthomonas pruni*), and *Leucostoma* canker (Dhanvantari & Kappel 1978).

Peach X-disease symptom expression begins with rolling and yellowing of the leaves on infected branches. Blotchy, irregular, and water-soaked spots then develop across the leaf veins which become brittle and fall out, giving the leaf a shot-holed and tattered appearance. The older leaves on infected branches fall off, leaving the branches with a small rosetted tuft of leaves at the end. The peach fruit either aborts and drops early or is smaller and more pointed than usual. Fruit that remain on the tree ripen prematurely, and are bitter and unpalatable. Peach trees rarely survive three years after symptoms are noted unless treated with tetracycline. Dieback begins with the diseased branches and spreads branch by branch to the entire tree (Dhanvantari & Kappel 1978, Gilmer et al. 1966, Palmiter & Hildebrand 1943).

X-disease agent has a wide variety of woody and herbaceous host plants. The economically important hosts include *Prunus persica* Batsch (peach), *P. cerasus* L. (sour cherry) and *P. avium* L. (sweet cherry) (Gilmer et al. 1966). Wild hosts can serve as an outside source of X-disease inoculum. Chokecherry (*P. virginiana* L.) is the most important wild woody host (Gilmer et al. 1954). Other plants known as experimental hosts include over twenty herbaceous species in eleven families (Chiykowski & Sinha 1982), many of which are common within and near most orchards.

Insect transmitted plant diseases such as X-disease are difficult to control due to the interactions between plant, pathogen, and insect vector. Historically, control of X-disease has involved eradication of alternate hosts such as chokecherry, application of tetracycline antibiotics, removal of diseased trees, and vector control (Lacy et al. 1979, Rosenberger 1977). Control of MLO diseases by killing insect vectors with insecticides after they have arrived at the crop has seldom proved effective. Even with good insect control, enough insects survive for sufficiently long periods to spread the pathogen (Agrios 1978). The presence of orchard groundcover often reduces the effectiveness of insecticides used in leafhopper control efforts, and the continuous presence of vectors from June until November makes insecticide use economically impractical (Palmiter & Adams 1957). Current management methods of X-disease in Michigan such as alternate host eradication and unilateral insecticide control of leafhoppers have been ineffective means of X-disease control (Robinson 1985). Under most insecticide programs, peach orchards are not sprayed when vector populations peak in the fall (Taboada et al. 1975).

Integrated pest management (IPM) is the best approach to disease control, yet is often difficult to implement due to the complexity of the disease transmission cycle and the interaction of the various disciplines involved (Whalon & Croft 1984). IPM requires a holistic approach to the problem, integrating the knowledge of MLO's by plant pathologists, insect vectors by entomologists, and the host plants by horticulturalists.

Current distributions of the disease problem must be known to determine the best management strategy. Information is needed on the occurence of X-disease in the host plants and alternate hosts, vector presence, vector biology and behavior as it relates to disease transmission, and the effect any control tactics may have on X-disease transmission. This information is obtained by monitoring the incidence of infective vectors, X-disease in host plants and in alternate hosts such as chokecherry. From this information, appropriate control tactics can be defined.

In order to implement an IPM program for X-disease, several tools are still needed. Probes for detection of MLO's are necessary to evaluate the relationship of MLO's to both the host plants and insect vectors. A better understanding of the incidence of X-disease in host plants and insect vectors, the biology, distribution and abundance of vector leafhopper populations, and the short-term and long-term movement behavior of these leafhopper vectors of X-disease is therefore necessary.

Biology of *Paraphlepsius irroratus* (Say)

P. irroratus is a major vector of X-disease in Michigan peach and cherry orchards (Taboada et al. 1975). Little is known about the daily movement and distribution or biology of *P. irroratus*, as the first paper on the biology of *P. irroratus* was not published until 1985 (Chiykowski).

Previous surveys have shown that *P. irroratus* was the most common X-disease vector leafhopper in Michigan peach and cherry orchards (Taboada et al. 1975) and the most efficient vector of X-disease in greenhouse tests (Rosenberger & Jones 1978). *P. irroratus* was thought to be primarily an herbaceous species, although it has been observed and collected on a wide variety of woody hosts (Hamilton 1975, Chiykowski 1985). Nymphs of *P. irroratus* have been observed on grasses in cherry orchards (Phillips 1951), and raised experimentally on a combination of barley and clover (Chiykowski 1985). *P. irroratus* was more common in sour cherry than in peach orchards (Rosenberger 1977) and was bivoltine in Michigan, with the two periods of adult activity being late-June to July and late-September to October (Taboada et al. 1975). *P. irroratus* is thought to overwinter in Michigan in the egg stage.

Rosenberger and Jones (1978) suspected that adult *P. irroratus* were most active in the early evening when they routinely collected leafhoppers at twilight around yellow lights. Increased activity during twilight has been documented in many insects, including leafhoppers (Harker 1961).

Yellow is known to attract certain leafhopper species (Alverson et al. 1977) and has proven to be an excellent means of capturing large numbers of *P. irroratus* during their crepuscular active periods (Larsen & Whalon 1987). Indirect methods of leafhopper sampling have been compared and contrasted with direct censusing of leafhoppers in fruit trees and orchard groundcover (Mowry 1982). Although indirect sampling methods have distinct drawbacks (DeLong 1932, Southwood 1978), relative methods such as light trapping and sweep net sampling were the best methods of obtaining frequent relative density estimates of mobile leafhopper populations (Mowry & Whalon 1984).

Leafhopper Movement Behavior

Movement behavior is an important aspect of the distribution and abundance of insect populations. Insect movement is often described as migratory or dispersive. *Migration* can be defined as an adaptive departure from a breeding area or other habitat which is no longer fit to support a population. It is often a persistent, unidirectional and long distance movement, during which all activities but flight are ceased, necessary to ensure the survival of a species (Kennedy 1961). *Dispersal* is an accidental, continuous movement within a habitat, during which insects become scattered over a wider area than originally occupied (Johnson 1969).

Since X-disease MLO's are transmitted only by leafhoppers, understanding the movement of these vectors is necessary to learn more about the epidemiology of X-disease (Purcell 1985). Leafhopper movement may be local, as between plants in a field, dispersive, as from area to area within a habitat, or migratory, in which the leafhoppers may move considerable distances (Chiykowski 1981). Factors that may influence these movements are many and involve biotic factors such as the normal life history of the insect, its host range and preferences, the availability of these hosts and their status as disease reservoirs, and physical factors of the environment (Carter 1961).

P. irroratus is not known to be involved in long distance, migration type movements, although *P. irroratus* adults have been trapped in low numbers at altitudes of 137.2 m (450 ft) (Osborn 1932) and more than 14.5 km (9 mi) from land (Sterns & MacCreary 1938). Examples of leafhoppers which do migrate over long distances include the aster or six-spotted leafhopper, *Macrosteles fascifrons* (Stal), a vector of aster yellows (Chiykowski & Chapman 1965, Drake & Chapman 1965, Nichiporick 1965), the beet leafhopper, *Circulifer tenellus* (Baker), the principle vector of curly top virus (Severin 1933, Dorst & Davis 1937, Lawson et al. 1951), and the potato leafhopper, *Empoasca fabae* (Harris), a major pest of such crops as potatoes, soybeans and alfalfa (Glick 1960, Pienkowski & Medler 1964).

Local insect movement, which usually includes dispersal, often involves a systematic daily or seasonal oscillation between areas, not unlike the human activity of commuting (Taylor 1985). Studies on adult feeding and ovipostion of *S. acutus*, the major vector of X-disease in Connecticut, indicate the adults mature on wild hosts, fly to peach trees to feed, and then return to wild herbaceous hosts to oviposit (McClure 1980a). This "commute", if occurring daily, would significantly affect transmission of any leafhopper-borne pathogen.

Dispersal of insects is known to be influenced by meteorological conditions (Taylor 1985). Dispersal behavior of leafhoppers has been studied using mark and recapture techniques for both the western X-disease vector *Collodonus montanus* Van Duzee (Purcell & Suslow 1982) and the blueberry stunt disease vector *Scaphytopius magdalensis* (Provancher) (Whitney & Meyer submitted). Mark and recapture movement data allow application to an insect dispersal model (Taylor 1978) and can also give absolute population estimates (Southwood 1978).

Conclusion

Knowledge of the temporal and spacial distribution and dispersal patterns of *P. irroratus*, the suspected major vector of X-disease in Michigan, is needed. This research attempts to quantify local movement, such as daily distributions and host preferences in the orchard, and dispersive movement of *P. irroratus*. With this information, evaluation of established control procedures will help in the development of new X-disease management strategies.

References Cited

Agrios, G.N. 1978. Plant diseases caused by mycoplasmalike organisms. Pp. 511-536. In: Plant Pathology. 2nd ed. Academic Press, N.Y. 703 pp.

Alverson, D.R., J.N. All and R.W. Matthews. 1977. Response of leafhoppers and aphids to variously colored sticky traps. J. Georgia Entomol. Soc. 12:336-341.

Anthon, E.W. and H.R. Wolfe. 1951. Additional insect vectors of western X-disease. Plt. Dis. Rep. 35:345-346.

Carter, W. 1961. Ecological aspects of plant virus transmission. Ann. Rev. Entomol. 6:347-370.

Chiykowski, L.N. 1981. Epidemiology of diseases caused by leafhopper-borne pathogens. Pp. 105-159. In: Plant Diseases and Vectors: Ecology and Epidemiology. eds. K. Maramorosch and K.F. Harris. Academic Press, N.Y. 368 pp.

Chiykowski, L.N. 1985. Biology and rearing of *Paraphlepsius irroratus* (Homoptera: Cicadellidae), a vector of Peach X-disease. Can. Entomol. 117:717-726.

Chiykowski, L.N. and R.K. Chapman. 1965. Migration of the six-spotted leafhopper *Macrosteles fascifrons* (Stal). Part 2. Migration of the six-spotted leafhopper in central North America. Univ. Wisconsin Res. Bull. 261:21-45.

Chiykowski, L.N. and R.C. Sinha. 1982. Herbaceous host plants of peach eastern X-disease agent. Can. J. Plt. Pathology 4: 8-15.

DeLong, D.M. 1932. Some problems encountered in the estimation of insect populations by the sweeping method. Ann. Entomol. Soc. Am. 25:13-17.

Dhanvantari, B.N. and F. Kappel. 1978. Peach X-disease in southwestern Ontario. Can. Plt. Dis. Survey. 58:65-68.

Dorst, H.E. and E.W. Davis. 1937. Tracing long-distance movements of the beet leafhopper in the desert. J. Econ. Entomol. 30:948-954.

Drake, D.C. and R.K. Chapman. 1965. Migration of the six-spotted leafhopper *Macrosteles fascifrons* (Stal). Part 1. Evidence for long distance migration of the six-spotted leafhopper into Wisconsin. Univ. Wisconsin Res. Bull. 261:1-20.

Elliott, W.M. and V.A.Dirks. ND. Flight periods of two leafhopper vectors of peach X-disease, *Scaphoideus titanus* Ball and *S. melanotus* Osb. (Homoptera: Cicadellidae), and related species in Ontario. Unpublished mimeo.

Fedewa, D.J. and S.J. Psocodna. 1982. Michigan Orchard and Vineyard Survey. 1982. Michigan Depart. Agric. 49pp.

Gilmer, R.M. 1954. Insect transmission of X-disease virus in New York. Plt. Dis. Rep. 38:628-629.

Gilmer, R.M. and E.C. Blodgett. 1976. X-Disease. Pp. 145-155. In: Virus diseases and noninfectious disorders of stone fruits in North America. U.S. Dept. Agric. Handbook 437. 433pp.

Gilmer, R.M. and F.L. McEwen. 1958. Insect transmissions of X-disease virus. Phytopath. 48:262.

Gilmer, R.M. J.D. Moore and G.W. Keitt. 1954. X-disease virus: Host range and pathogenesis in chokecherry. Phytopath. 44:180-185.

Gilmer, R.M., D.H. Palmiter, G.A. Schaefers, and F.L. McEwen. 1966. Leafhopper transmission of X-disease virus of stone fruits in New York. N.Y. State Agric. Exp. Sta. (Geneva) Bull. 813. 22 pp.

Glick, P.A. 1960. Collecting insects by airplane, with special reference to the dispersal of the potato leafhopper. USDA Tech. Bull. 1222. 16 pp.

Granett, A.L. and R.M. Gilmer. 1971. Mycoplasmas associated with X-disease in various *Prunus* species. Phytopath. 61:1036-1037.

Hamilton, K.G.A. 1975. *Paraphlepsius irroratus* (Say). Pp. 30. In: Revision of the genera *Paraphlepsius* Baker and *Pendarus* Ball (Rhynchota: Homoptera: Cicadellidae). Memoirs of the Entomol. Soc. of Canada, No. 96. 129 pp.

Harker, J.E. 1961. Diurnal rhythms. Ann. Rev. Entomol. 6:131-146.

Hildebrand, E.M. 1953. Yellow-red or X-disease of peach. Cornell Univ. Agric. Exp. Stn. Memoir No. 323. 54 pp.

Jensen, D.D. 1957. Transmission of peach yellow leaf roll virus by *Fieberiella florii* (Stal.) and a new vector, *Osbornellus borealis* Del & M. J. Econ. Entomol. 50:668-672.

Jensen, D.D. 1969. Comparative transmission of western X-disease virus by *Colladonus montanus*, *C. geminatus*, and a new leafhopper vector, *Euscelidius variegatus*. J. Econ. Entomol. 62:1147-1150.

Johnson, C.G. 1969. Migration and dispersal of insects by flight. Methuen & Co. Ltd., London. 763 pp.

Jones, A.L., G.R. Hooper and D.A. Rosenberger. 1974. Association of mycoplasmalike bodies with Little Peach and X-disease. Phytopath. 64:755-756.

Kennedy, J.S. 1961. A turning point in the study of insect migration. Nature 189:785-791.

Kirkpatrick, B.C. 1986. Characterization of western X-disease mycoplasmalike organisms. Ph.D. Dissertation. University of California, Berkley, CA. 196 pp.

Lacey, G.H., M.S. McClure and T.G. Andreadis. 1979. Reducing populations of vector leafhoppers is a new approach to X-disease control. Frontiers of Plant Science 32:2-4.

Larsen K.J. and M.E. Whalon. 1987. Crepuscular movement of *Paraphlepsius irroratus* (Say)(Homoptera: Cicadellidae), between groundcover and cherry trees. Env. Entomol. (accepted for publication).

Lawson, F.R., J.C. Chamberlin and G.T. York. 1951. Dissemination of the beet leafhopper in California. USDA Tech. Bull. 1030. 59 pp.

McClure, M.S. 1980a. Role of wild host plants in the feeding, oviposition, and dispersal of *Scaphytopius acutus* (Homptera: Cicadellidae), a vector of peach X-disease. Env. Entomol. 9:283-292.

McClure, M.S. 1980b. Spatial and seasonal distributions of leafhopper vectors of peach X-disease in Connecticut. Env. Entomol. 9:668-672.

Mowry, T.M. 1982. Leafhopper sampling in Michigan peach orchards and serological detection of a spiroplasma associated with X-disease in plant and insect tissue. M.S. Thesis. Michigan State University, East Lansing, MI. 134 pp.

Mowry, T.M. and M.E. Whalon. 1984. Comparison of leafhopper species complexes in the groundcover of sprayed and unsprayed peach orchards in Michigan. Great Lakes Entomologist 17:205-209.

Nichiporick, W. 1965. The aerial migration of the six-spotted leafhopper and the spread of the virus disease aster yellows. Int. J. Biomet. 9:219-227.

Nielson, M.W. 1979. Taxonomic relationships of leafhopper vectors of plant pathogens. Pp. 3-27. In: Leafhopper vectors and plant disease agents. eds. K. Maramorosch and K.F. Harris. Academic Press, N.Y. 654 pp.

Osborn, H. 1932. Supplemental records and notes on Ohio leafhoppers. Ohio J. Sci. 32:513-517.

Palmiter, D.H. and J.A. Adams. 1957. Seasonal occurrence of leafhopper vectors of X-disease virus in sprayed and unsprayed peach blocks. Phytopath. 47:531.

Palmiter, D.H. and E.M. Hildebrand. 1943. The yellow-red virosis of peach: its identification and control. N.Y. State Agric. Exp. Sta. Bull. 704. 17 pp.

Palmiter, D.H., W.J. Coxeter and J.A. Adams. 1960. Seasonal history and rearing of *Scaphytopius acutus* (Say) (Homoptera: Cicadellidae). Ann. Ent. Soc. Am. 53:843-846.

Phillips, J.H.H. 1951. An annotated list of Hemiptera inhabiting sour cherry orchards in the Niagara Peninsula, Ontario. Canad. Entomol. 83:194-205.

Pienkowski, R.L. and J.T. Medler. 1964. Synoptic weather conditions associated with long-range movement of the potato leafhopper, *Empoasca fabae*, into Wisconsin. Ann. Entomol. Soc. Am. 57:588-591.

Purcell, A.H. 1979. Transmission of X-disease agent by the leafhoppers *Scaphytopius nitridus* and *Acinopterus angulatus*. Plt. Dis. Rep. 63:549-552.

Purcell, A.H. 1985. The ecology of bacterial and mycoplasma plant diseases spread by leafhoppers and planthoppers. Pp. 351-380. In: The Leafhoppers and Planthoppers. eds. L.R. Nault and J.G. Rodriguez. John Wiley & Sons, N.Y. 500 pp.

Purcell, A.H. and K.G. Suslow. 1982. Dispersal behavior of *Colladonus montanus* (Homoptera: Cicadellidae) in cherry orchards. Env. Entomol. 11:1178-1182.

Razin, S. 1978. The mycoplasmas. Microbiol. Rev. 42:414-470.

Robinson, G. 1985. 1985 Peach virus annual report. Michigan Dept. Agric. 4 pp.

Rosenberger, D.A. 1977. Leafhopper vectors, epidemiology and control of peach X-disease. Ph.D. Dissertation. Michigan State University, East Lansing, MI. 95 pp.

Rosenberger, D.A. and A.L. Jones. 1978. Leafhopper vectors of the peach X-disease pathogen and its seasonal transmission from chokecherry. Phytopath. 68:782-790.

Severin, H.H.P. 1933. Field observations on the beet leafhopper *Eutettix tenellus*, in California. Hilgardia 7:281-360.

Southwood, T.R.E. 1978. Ecological Methods. 2nd ed. Chapman and Hall, N.Y. 524pp.

Sterns, L.A. and D. MacCreary. 1938. Leafhopper migration across Delaware Bay. J. Econ. Entomol. 31:226-229.

Swenson, K.G. 1971. Environmental biology of the leafhopper *Scaphytopius delongi*. Ann. Entomol. Soc. Am. 64:809-812.

Taboada, O., D.A. Rosenberger and A.L. Jones. 1975. Leafhopper fauna of X-diseased peach and cherry orchards in southwest Michigan. J. Econ. Entomol. 68:255-257.

Taylor, R.A.J. 1978. The relationship between density and distance of dispersing insects. Ecol. Entomol. 3:63-70.

Taylor, R.A.J. 1985. Migratory behavior in the Auchenorrhyncha. Pp. 259-288. In: The Leafhoppers and Planthoppers. eds. L.R. Nault and J.G. Rodriguez. John Wiley & Sons, N.Y. 500 pp.

Thornberry, H.H. 1954. Preliminary report on insect transmission of eastern X-disease virus in Illinois. Plt. Dis. Rep. 38:412-413.

Whalon, M.E. and B.A. Croft. 1984. Apple IPM implementation in North America. Ann. Rev. Entomol. 29:435-470.

Whitney, S.P. and J.R. Meyer. 1987. Movement between wild and cultivated blueberry by two species of sharpnosed leafhoppers in North Carolina. J. Entomol. (submitted).

Wolfe, H.R. 1955. Transmission of the western X-disease virus by the leafhopper, *Colladonus montanus* (Van D.). Plt. Dis. Rep. 39:298-299.

Wolfe, H.R., E.W. Anthon and L.S. Jones. 1950. Transmission of western X-disease of peaches by the leafhopper *Colladonus geminatus* (Van D.). Phytopath. 40:971.

CHAPTER I

FIELD MONITORING OF X-DISEASE LEAFHOPPER VECTORS AND SYMPTOMATIC CHOKECHERRY

Introduction

The X-disease research effort of the current stone fruit decline project (USDA grant no. 85-CRSR-2-2551) requires up-to-date field monitoring of the abundance of X-disease vector leafhoppers and chokecherry. These data are needed to aid in assessing year to year variation in X-disease and leafhopper incidence, evaluating established control procedures and in developing new X-disease management strategies.

Past research (Taboada et al. 1975, Rosenberger 1977, Rosenberger & Jones 1978) has demonstrated that at least nine species of leafhoppers (*Homoptera: Cicadellidae*) that occur in Michigan are vectors of X-disease. *Paraphlepsius irroratus* (Say) is the most common known vector of X-disease in Michigan peach and cherry orchards (Taboada et al. 1975, Rosenberger 1977). It is also the most efficient vector in greenhouse tests (Rosenberger & Jones 1978). Both *P. irroratus* and *Scaphytopius acutus* (Say) are bivoltine in Michigan, with the two periods of adult activity being late June to July and late September to October (Taboada et al. 1975).

Michigan Department of Agriculture (MDA) annual peach surveys indicate the incidence of X-disease has increased in peach orchards of southwest Michigan during the past several years. Chokecherry as an alternate host of X-disease (Gilmer et al. 1954) is considered the major source of X-disease inoculum outside the orchards. For this reason, MDA X-disease regulation No. 612 requires the removal of all chokecherry within 500 ft of peach and cherry orchards.

X-disease is a major peach disease problem in southwestern lower Michigan, but has not been a severe problem north of Kent County. Many factors may be limiting the distribution of X-disease. Past monitoring of X-disease in Michigan (Taboada et al. 1975, Rosenberger 1977, Mowry 1982) has not been done north of the Peach Ridge area on a regular basis. About 58% of Michigan's peach acreage is located in Berrien and Van Buren Counties (Fedewa & Pscodna 1982), and these are the counties hardest hit by X-disease (Robinson 1985).

The leafhopper monitoring reported here was a survey of the entire southern Michigan stone fruit belt. The objectives of this survey were to determine how the abundance and distribution of X-disease vector leafhoppers and symptomatic chokecherry differ temporally and spatially throughout the west coast of Michigan.

Materials and Methods

Field Season and Research Sites

During the 1985 and 1986 field seasons, traps were placed in the field during the first week of May. Monitoring occurred weekly in 1985 and biweekly in 1986 and ended ca. November 15 after several hard frosts and the first snow.

Five sites were monitored in 1985 and six sites in 1986 (Table 1). All sites were located in Michigan's lower penninsula (Fig. 1). Weather data such as temperature and the resulting degree day accumulations for each site were obtained from the M.S.U. Cooperative Crop Monitoring Service (CCMS) using agricultural weather observation stations located at or near each field site (Table 1).

Symptomatic Chokecherry Survey

The abundance of wild sources of X-disease inoculum in Michigan was surveyed by biweekly monitoring of chokecherry. In 1986, a 8 km route leaving each field site along two lane roadways was selected and all chokecherry clumps or individual bushes visually observed exhibiting X-disease symptoms were counted. The average number of symptomatic chokecherry/km was then calculated for each site.

X-disease Vector Leafhopper Survey

The abundance and distribution of known X-disease vector leafhoppers were monitored. In 1985, monitoring was performed weekly at the Lawrence, Hartford, Fennville, Clarksville, and East Lansing sites. In 1986, monitoring was performed biweekly at the Lawrence, Bainbridge Center, Fennville, Walkerville, Manistee, and Northport sites.

Monitoring was performed with yellow sticky board traps and by sweep net sampling. Six yellow sticky board traps were hung at each site ca. 1.5 m above the orchard groundcover. The traps were 12.5 x 25 cm made of 0.25 in

Table 1. List of X-disease sites for the 1985 and 1986 field seasons with fruit type, weather station, and site location data.

Year	Site	County	Fruit	Weather Station	Distance[a] (km)	Coordinates N. Lat.	Coordinates W. Long.
86	Bainbridge Center	Berrien	Peach	Watervliet	8.0	42° 7'	86° 17'
85	Clarksville	Ionia	Peach	Clarksville	0.0	42° 52'	85° 15'
85	East Lansing	Ingham	Cherry	MSU Hort Farm	1.6	42° 41'	84° 30'
85,86	Fennville	Allegan	Peach	Fennville	0.0	42° 36'	86° 9'
85	Hartford	Van Buren	Peach	Watervliet	5.6	42° 14'	86° 10'
85,86	Lawrence	Van Buren	Peach	Paw Paw	6.4	42° 12'	86° 4'
86	Manistee	Manistee	Cherry	Bear Lake	4.8	44° 19'	86° 14'
86	Northport	Leelanau	Peach	Lk. Leelanau	8.0	45° 6'	85° 38'
86	Walkerville	Oceana	Cherry	Mears	13.5	43° 43'	86° 10'

[a]Distance (km) between site and weather station.

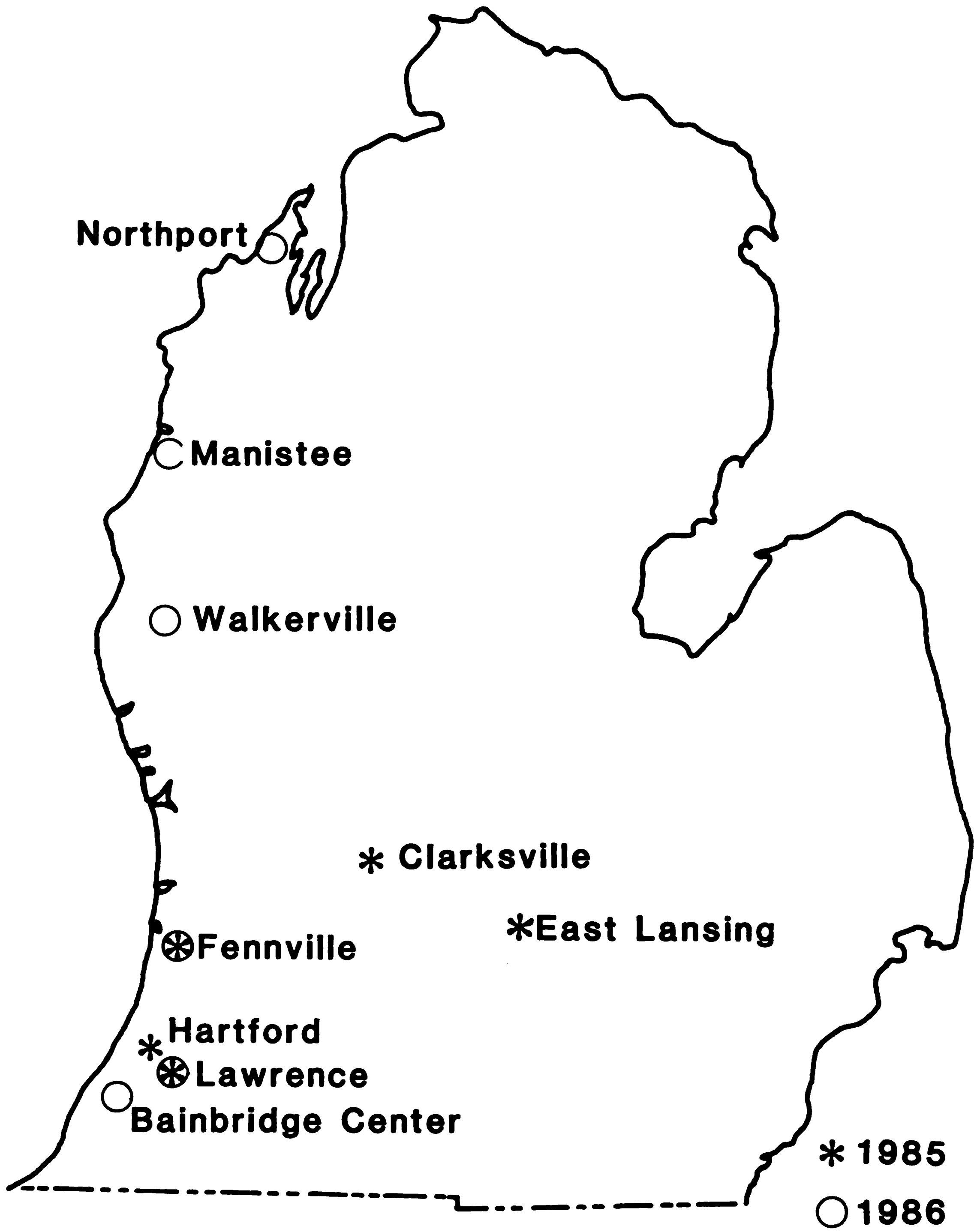


Fig. 1. The field sites monitored for leafhopper vectors of X-disease during 1985 and 1986, and monitored for the appearance of symptomatic chokecherry during 1986.

plywood and painted with sun yellow enamel (Benjamin Moore & Co., Montvale, NJ) and coated with Tree Tanglefoot™ (The Tanglefoot Company; Grand Rapids, MI). These traps were replaced each visit to the site and returned to the lab for examination and removal of captured leafhoppers. Sweep net samples were taken from different areas in and around each orchard site. Four sweep samples were taken, each consisting of 25 sweeps with a 37.5 cm dia net. Each sweep was ca. a 1.5 m pass through the groundcover foliage. The sweep samples were deposited in plastic bags, placed in a cooler for transport back to the laboratory, and then frozen at -20° C in the lab to kill all insects. Sorting, leafhopper identification to species, and counts of abundance and sex took place in the laboratory.

Results

Field Season

During 1985, temperature effects as measured by degree day accumulations (Baskerville & Emin 1969) was similiar at all sites (Fig. 2). The 1986 total accumulations are similiar to the 1985 total accumulations for both the Lawrence and Fennville sites. Generally higher temperatures were experienced in both mid-July and early-October of 1986. The difference in total degree day accumulation between the Northport (1820 DD) and Lawrence (2585 DD) sites was dramatic, where an average accumulated difference of 765 DD was realized. Average accumulated degree days showed a 478

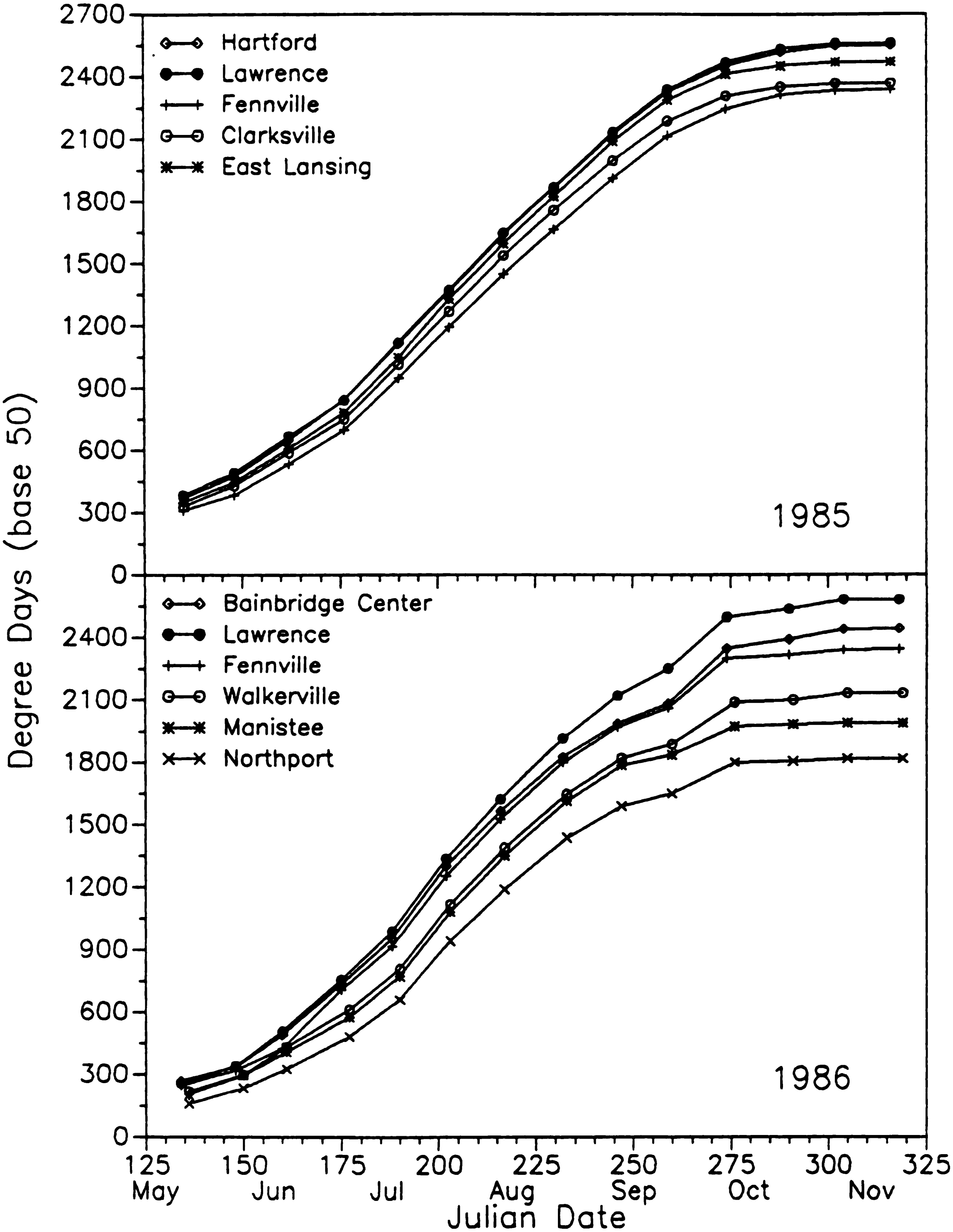


Fig. 2. Accumulation of degree day (base 50) heat units (Baskerville & Emin 1969) over time at the sites during both 1985 and 1986 field seasons.

DD difference between the average of northwestern (1980 DD) and southwestern (2458 DD) weather stations (Fig. 3).

Symptomatic Chokecherry Survey

During 1986, chokecherry exhibiting symptoms of X-disease were first observed in southwestern lower Michigan in late-June and in northwestern lower Michigan in mid-July (Fig. 4). By early September, up to six symptomatic chokecherry/km were visually evident. This delay in symptom expression between southwest and northwest is similiar to the mean degree day accumulation for those areas.

Vector Leafhopper Survey

Leafhopper populations were about five times greater in 1985 than in 1986 (Fig. 5). Although the generations peaked at different dates in 1985 and 1986, the peaks did occur at approximately the same number of accumulated degree days (Fig. 6). Differences in X-disease vector leafhopper density occurred both between field sites ($P \leq 0.05$, LSD test of data)(Fig. 7) and between 1985 and 1986 field seasons ($P \geq 0.05$, ANOVA).

Representatives of all leafhopper species known to vector X-disease in Michigan were found during both the 1985 and 1986 field seasons. Only four of these, ***P. irroratus***, ***S. acutus***, ***C. clitellarius***, and ***N. seminuda*** were present in numbers greater than 1% of all the known vector leafhoppers captured (Table 2). The relative abundance of these

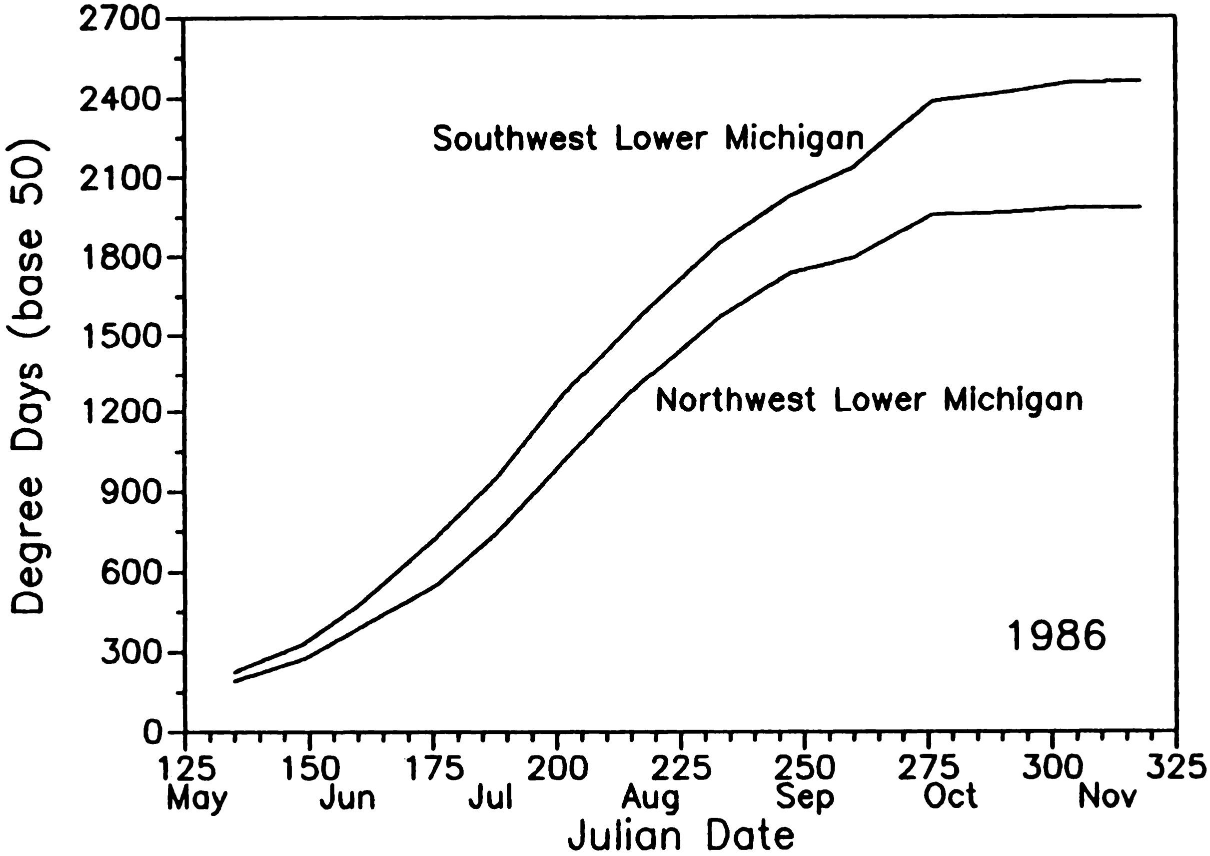


Fig. 3. Mean degree day (base 50) accumulation for the southwest (Bainbridge Center, Lawrence & Fennville sites) and northwest (Walkerville, Manistee & Northport sites) areas of lower Michigan in 1986.

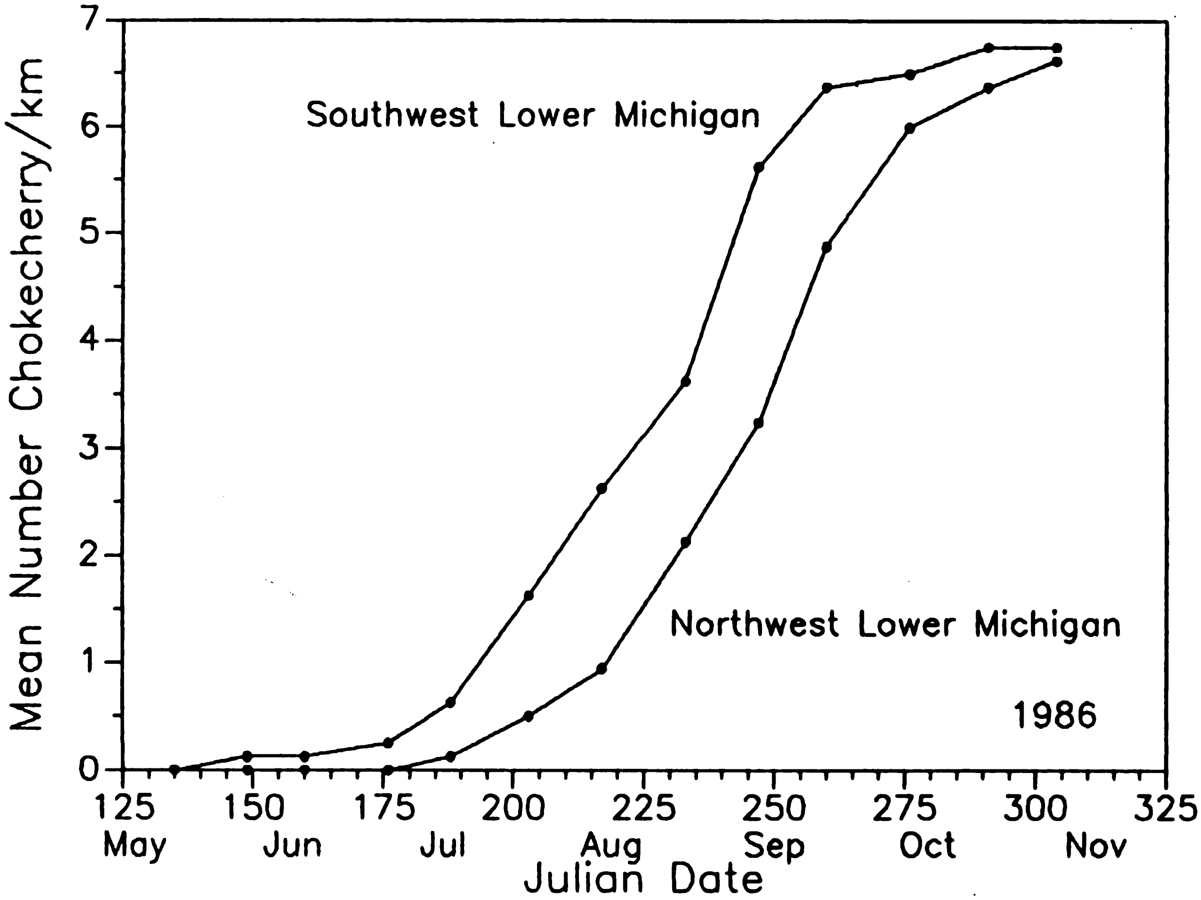


Fig. 4. Mean number of symptomatic chokecherry visually observed/km of two lane roadway in the southern and northern regions of the western Michigan stone fruit belt during 1986.

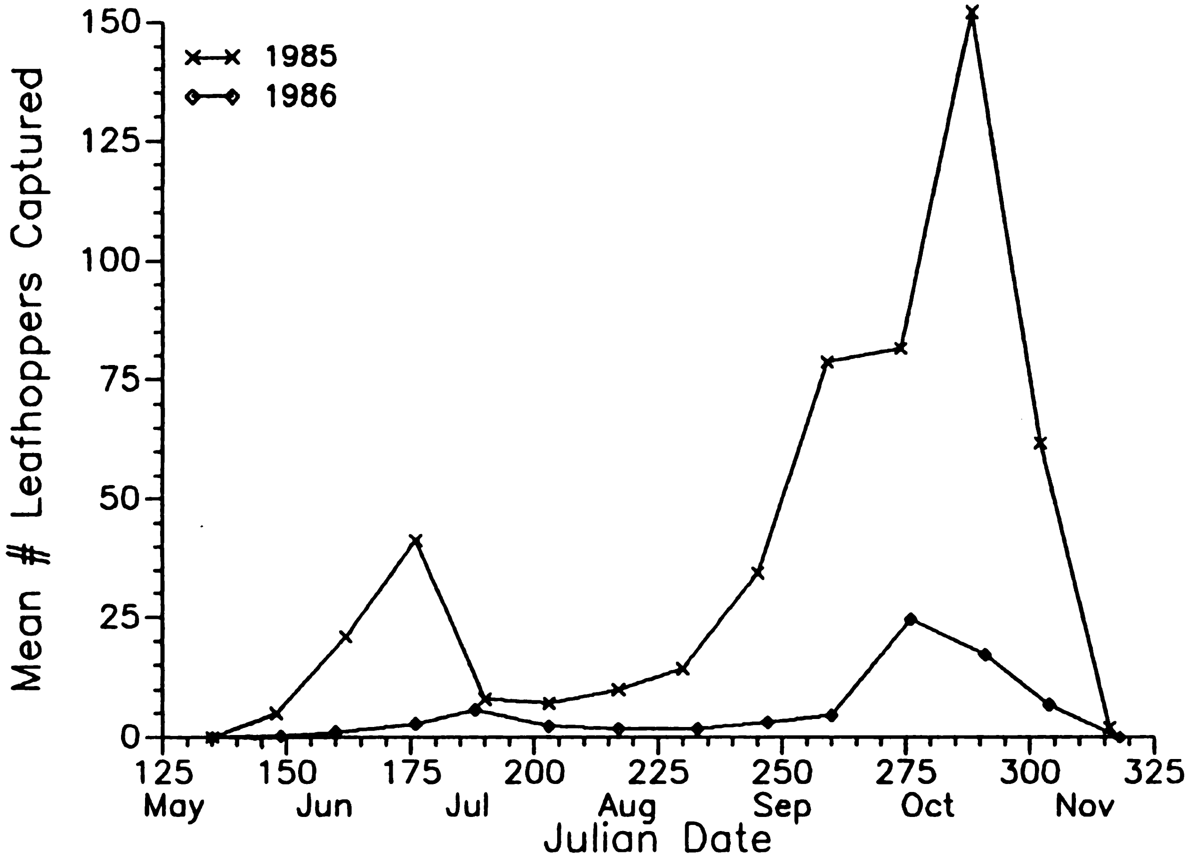


Fig. 5. Mean number of X-disease vector leafhoppers captured by yellow board traps and in sweep nets over time in 1985 and 1986 at all sites.

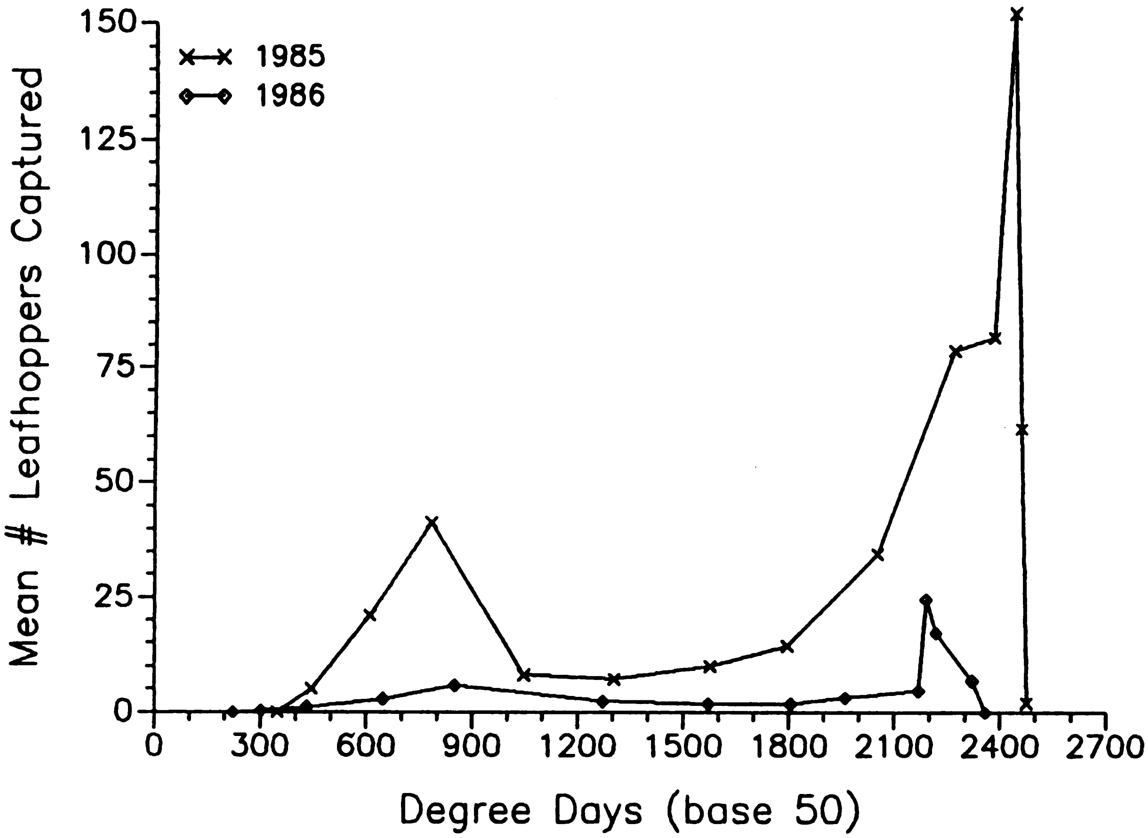


Fig. 6. Mean number of X-disease vector leafhoppers captured by yellow sticky board traps and in sweep nets, based on average degree day accumulations in 1985 and 1986 at all sites.

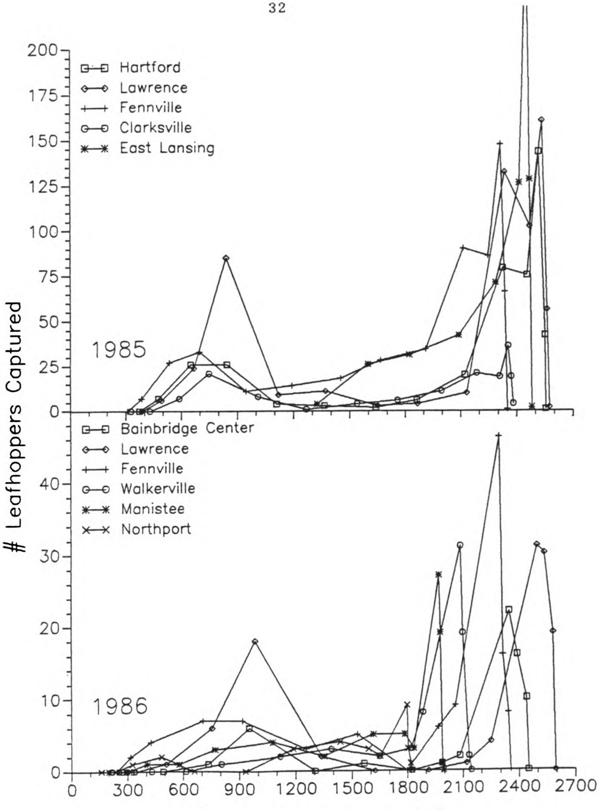


Fig. 7. Total number of X-disease vector leafhoppers captured by yellow sticky board traps and in sweep nets at each site during the 1985 and 1986 field seasons. Note: The y-axis is expanded in 1986 to accentuate lower leafhopper counts.

Table 2. Total number of X-disease vector leafhoppers captured by yellow sticky board traps and sweep nets, and percent relative abundance of each found in Michigan for both 1985 and 1986 field seasons.

	1985		1986	
Species	Total	% of total	Total	% of total
P. irroratus	1790	72.47	278	60.57
S. acutus	529	21.42	144	31.37
C. clitellarius	20	0.81	17	3.70
N. seminuda	92	3.72	5	1.09
Scaphoideus spp.	23	0.93	4	0.87
F. florii	2	0.08	3	0.65
O. ishidae	1	0.04	4	0.87
G. lamina	13	0.53	4	0.87
Totals	2470		459	

leafhoppers in the field during 1985 and 1986 was *P. irroratus*: 73.1%, *S. acutus*: 22.0%, *C. clitellarius*: 1.5%, and *N. seminuda*: 3.4%.

Some sites supported larger populations of these vectors than others (Fig. 8, Table 3). *P. irroratus* was very common in the East Lansing, Lawrence, Hartford, and Fennville sites. *S. acutus* was found easily at the Hartford site and in good numbers in Lawrence and Fennville. *C. clitellarius* was found most commonly at the Manistee site, while *N. seminuda* was found easily in East Lansing and often in Fennville, but was not found at or north of Walkerville.

Yellow sticky board traps captured 90.3% of all known X-disease vector leafhoppers captured during 1985 and 1986. There was no significant difference in this monitoring method capture rate between the two generations ($P>0.05$, ANOVA). The sex ratio of *P. irroratus* leafhoppers did not significantly differ between the yellow board trap and sweep net monitoring methods (Fig. 9), with male leafhoppers accounting for 65% of the captures on yellow sticky board traps, and 42% of the captures in sweep nets. There was no significant difference in this captured leafhopper sex ratio between the two generations ($P>0.05$, ANOVA).

Discussion

The similarity of the degree day accumulations during 1985 was due to the concentration of all 1985 field sites in

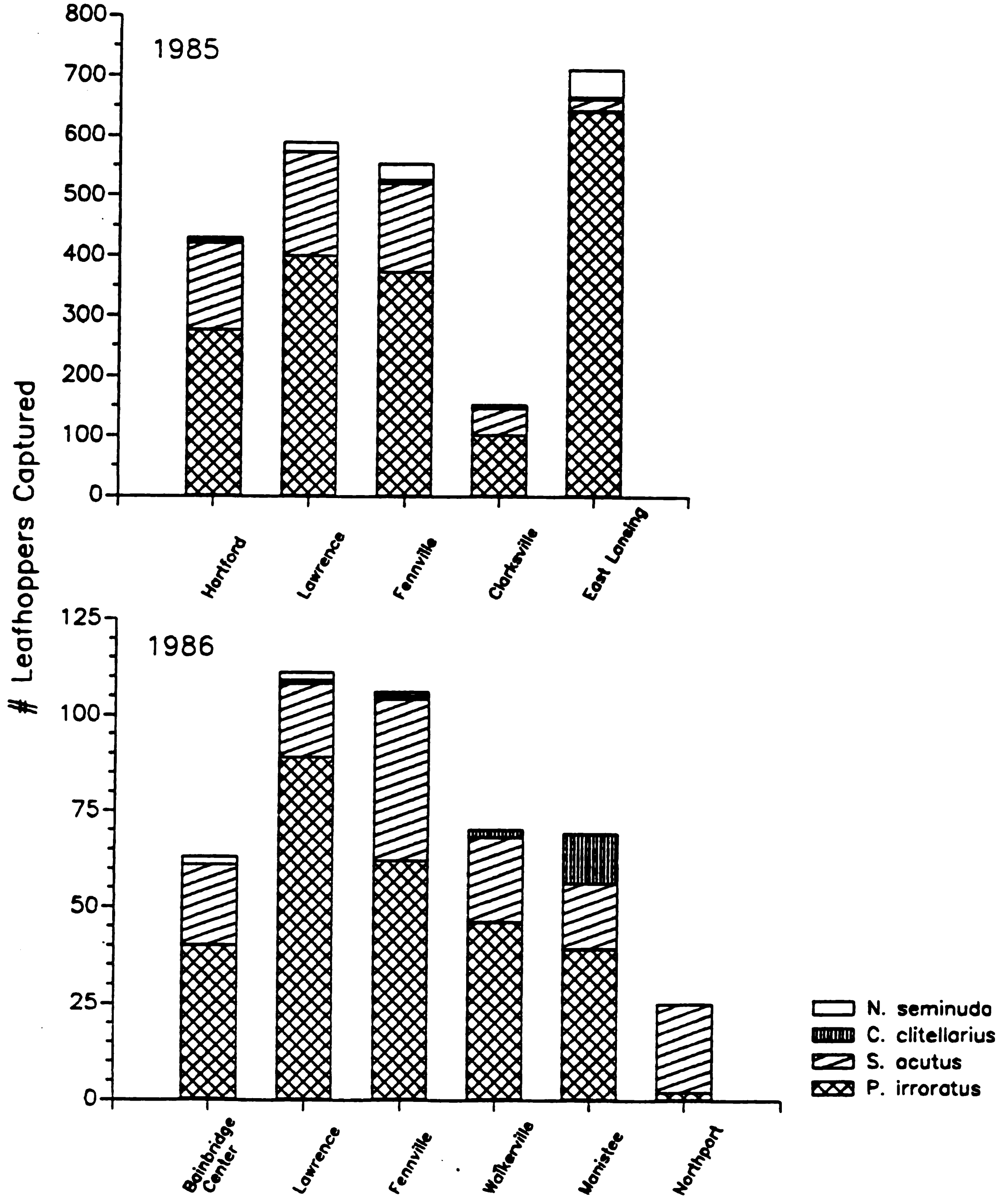


Fig. 8. Total number of common X-disease vector leafhoppers captured by yellow sticky board traps and in sweep nets at each site during the 1985 and 1986 field seasons. Note: The y-axis is expanded in 1986 to accentuate lower leafhopper counts.

Table 3. Number of X-disease vector leafhoppers captured at each field site during 1985 and/or 1986.

Site	*P. irroratus*	*S. acutus*	*C. clitellarius*	*N. seminuda*
Bainbridge Center[c]	40	21		2
Clarksville[b]	101	45	3	3
East Lansing[b]	641	19	4	45
Fennville[a]	217.5	94.5	3.5	13.5
Hartford[b]	276	145	5	3
Lawrence[a]	244	96	1.5	8.5
Manistee[c]	39	17	12	
Northport[c]	2	23		
Walkerville[c]	46	22	2	
Totals	1606.5	482.5	32.0	75.0
Means	178.5	53.6	3.6	8.3
% of total	73.1	22.0	1.5	3.4

[a]average of 1985 and 1986 data.
[b]1985 data.
[c]1986 data.

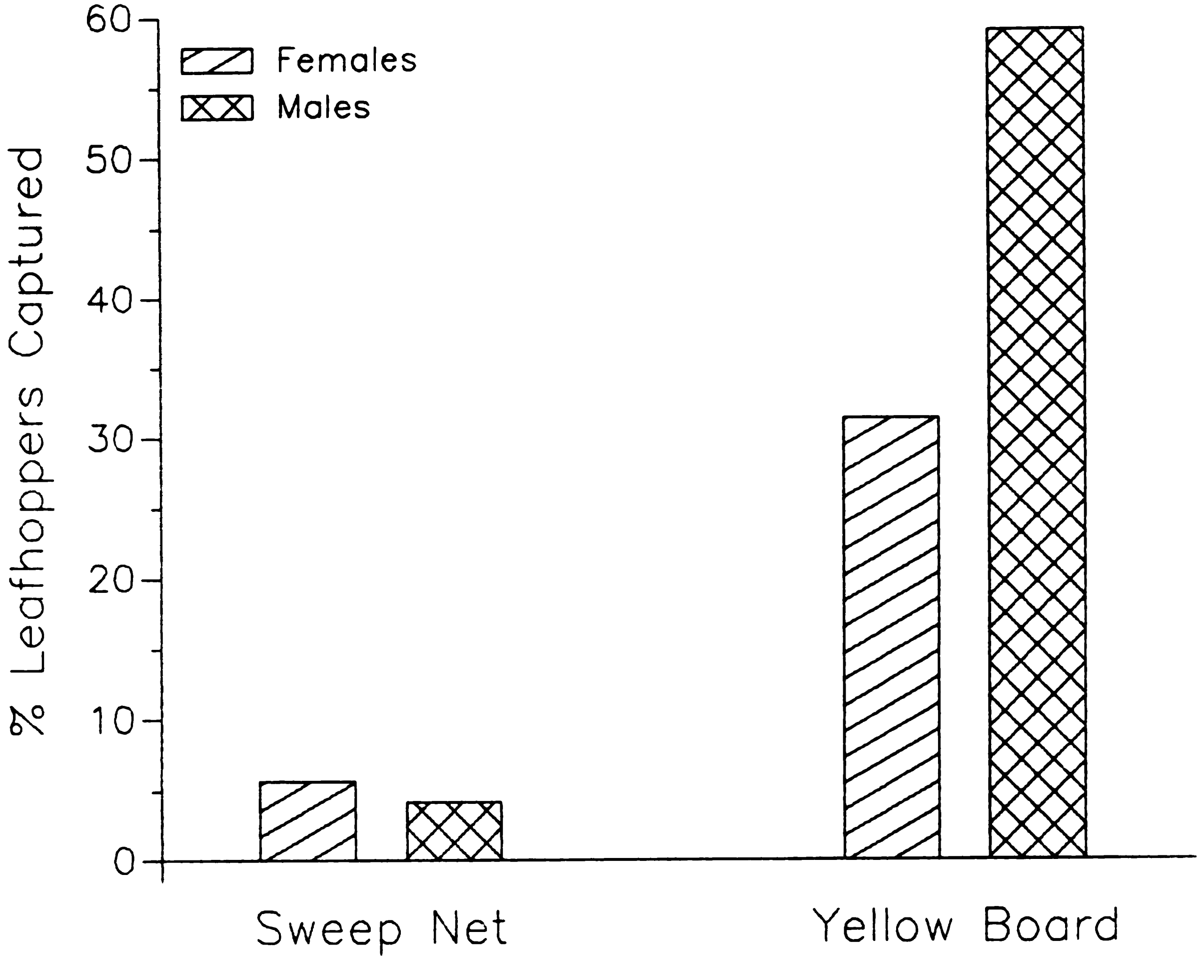


Fig. 9. Percent of male and female *P. irroratus* leafhoppers captured by monitoring method (sweep net or yellow sticky board trap) for both 1985 and 1986 field seasons.

the southwestern and central lower penninsula. The 1986 sites had greater latitude differences from south to north and a corresponding decrease in degree day accumulation with distance north.

The two week lag in degree day accumulation probably explains the delay in chokecherry development and X-disease symptom expression. The presence of chokecherry along roadways indicates that many bushes are not being eradicated per MDA regulations and therefore may once again be serving as a major alternate host of X-disease pathogen.

Of all the known species of X-disease vector leafhoppers found present in 1985 and 1986, only four seem to be common enough to warrant our attention unless one of the rare species is found to have a very high MLO infection rate or its feeding behavior predisposes it to transmit more frequently. *P. irroratus* is still the most common vector leafhopper in Michigan, representing 73% of the total number caught, with *S. acutus* second most common at 22%. This confirms the earlier work by Taboada et al. (1975) and Rosenberger (1977) that *P. irroratus* is the most numerous X-disease vector in Michigan. The graphical evidence (Figs. 5, 6 & 7) that X-disease vectors are bivoltine is largely influenced by the two generations of *P. irroratus*, which constitutes the largest portion of the vector population. Further work on the number of generations of other vector species found in Michigan would help to clarify this observation.

Distributions of leafhopper populations was influenced by sample location in the state. *P. irroratus* was commonly found in the southwest and central sites. Since the second generation of *P. irroratus* occurs at degree day accumulations greater than 2200 DD (Fig. 7), areas that do not reach this degree day accumulation probably do not have a second generation. This is most likely the reason why *P. irroratus* is rare in Leelanau County, where less than 1900 DD (base 50) were accumulated in 1986, and only in exceptional years are more than 2000 DD accumulated (CCMS data).

C. clitellarius was found in significant numbers only at the Manistee site, and thus may be an important vector in that area. Since the most common vector leafhopper found in Leelanau County was *S. acutus*, but at a low density when compared with other sites, the chance of X-disease transmission by leafhoppers there seems low.

Sampling methods used in future X-disease monitoring efforts should reflect the effectiveness of the yellow sticky board traps, with over 90% of all vector leafhoppers captured by this method. Although sweep net sampling is the best method of detecting leafhoppers moving into and out of orchards in a short period of time (Mowry & Whalon 1984), sweep net sampling alone is of minor importance and an inefficient, labor-intensive, and incomplete sampling method for long-term X-disease vector monitoring.

Presence in the northwest area of symptomatic chokecherry indicates that a wild source of X-disease inoculum is present, and that transmission among chokecherry does occur. However, the limited distribution of populations of vector leafhoppers in this region may be preventing the vector transmission of X-disease to peach and cherry in the northwest part of the state.

References Cited

Baskerville, G.L. and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecology 50:514-517.

Fedewa, D.J. and S.J. Pscodna. 1982. Michigan orchard and vineyard survey 1982. Michigan Dept. Agric. 49 pp.

Gilmer, R.M. 1954. Insect transmission of X-disease virus in New York. Plant Dis. Rep. 38:628-629.

Gilmer, R.M., J.D. Moore, and G.W. Keitt. 1954. X-disease virus: I. Host range and pathogenesis in chokecherry. Phytopath. 44:180-185.

Gilmer, R.M., D.H. Palmiter, G.A. Schaefers, and F.L. McEwen. 1966. Leafhopper transmission of X-disease virus of stone fruits in New York. N.Y. State Agric. Exp. Sta. (Geneva) Bull. 813. 22 pp.

Hildebrand, E.M. 1953. Yellow-red or X-disease of peach. Cornell Univ. Agric. Exp. Sta. Memoir No. 323. 54 pp.

Jensen, D.D. 1957. Transmission of peach yellow leaf roll virus by *Fieberiella florii* (Stal.) and a new vector, *Osbornellus borealis* DeL. & M. J. Econ. Entomol. 50:668-672.

McClure, M.S. 1980. Spatial and seasonal distributions of leafhopper vectors of peach X-disease in Connecticut. Env. Entomol. 9:668-672.

Mowry, T.M. 1982. Leafhopper sampling in Michigan peach orchards and serological detection of a spiroplasma associated with X-disease in plant and insect tissue. M.S. Thesis. Michigan State University, East Lansing, MI. 134 pp.

Mowry, T.M. and M.E. Whalon. 1984. Comparison of leafhopper species complexes in the groundcover of sprayed and unsprayed peach orchards in Michigan. Great Lakes Entomologist 17:205-209.

Robinson, G. 1985. 1985 Peach virus annual report. Mich. Dept. Agric. Memorandum of October 4, 1985. 4 pp.

Rosenberger, D.A. 1977. Leafhopper vectors, epidemiology and control of peach X-disease. Ph.D. Dissertation. Michigan State University, East Lansing, MI. 95 pp.

Rosenberger, D.A. and A.L. Jones. 1978. Leafhopper vectors of the peach X-disease pathogen and its seasonal transmission from chokecherry. Phytopath. 68:782-790.

Taboada, O., D.A. Rosenberger, and A.L. Jones. 1975. Leafhopper fauna of X-diseased peach and cherry orchards in southwest Michigan. J. Econ. Entomol. 68:255-257.

CHAPTER II

CREPUSCULAR MOVEMENT OF *PARAPHLEPSIUS IRRORATUS* (SAY) BETWEEN THE GROUNDCOVER AND CHERRY TREES

Introduction

Little is known about the daily movement of *P. irroratus* and its distribution within orchards. Rosenberger and Jones (1978) suspected that adult *P. irroratus* were most active in the early evening when, and previous studies have shown increased activity in many insects during twilight (Harker 1961). Based on field observations, we hypothesized that *P. irroratus* moves daily from orchard groundcover to fruit tree foliage and back again.

The purpose of this study was to determine how populations of *P. irroratus* fluctuate temporally and spatially between the different orchard sub-habitats of groundcover and the foliage of sweet cherry, sour cherry and apple trees.

Materials and Methods

Light trapping and sweep sampling were performed on six separate occasions in a 1 ha unsprayed orchard located on the Michigan State University campus in East Lansing, Michigan. The orchard was composed of blocks of apple, sour cherry, and sweet cherry trees ca. 7 yr old, with a mixed groundcover of rye fescue, red clover, and broadleaf weeds. The experiment was replicated three times during each of the two population peaks of *P. irroratus* as determined by weekly monitoring with yellow sticky board traps. The traps were 12.5 x 25 cm made of 0.25 in plywood and painted with sun yellow enamel (Benjamin Moore & Co.; Montvale, NJ) and coated with tree tanglefoot (The Tanglefoot Company; Grand Rapids, MI).

Light trapping samples were taken at 0.5 hr intervals beginning 1.5 hr before sunset until 1.5 hr after sunrise and blocked by three separate dates during each generation. Sample locations were randomly selected from a grid layed out on the orchard. The light trap was a 30.5 x 66 x 91 cm wooden box painted flat black with the exception of the interior back which was a glossy white and illuminated by two yellow 60 watt "Bug Lites" (General Electric; Cleveland, Ohio) mounted on the white surface. The trap was situated ca. 1.8 m above the orchard floor and located between tree rows. The lights were turned on or off at 15 min intervals throughout the sampling period. All attracted *P. irroratus* were immediately aspirated by hand, counted, and retained to eliminate recaptures.

Monitoring for leafhoppers in the sub-habitats was accomplished by sweep sampling, organized as a split plot design. The sub-habitat was the whole plot factor and time was the split plot within each sub-habitat. Randomization was by sample location selection within each sub-habitat, and the experiment was blocked by the three sampling dates in each generation. The four orchard sub-habitats were groundcover, sour cherry foliage, sweet cherry foliage, and apple tree foliage. Sweep samples consisted of 25 sweeps with a 37.5 cm dia net. Each sweep was a 1.5 m pass through the groundcover or fruit tree foliage. Each sub-habitat was sampled at 0.5 hr intervals over the entire 24 hr sampling period and numbers of *P. irroratus* were counted.

The data were subjected to analysis of variance and multiple comparison of the means by Scheffe's test of data (SAS Institute 1985). All data were analyzed by individual generations before any combining of generations occurred. Periodicity of the data was analyzed by non-parametric circular-linear rank correlation (Batschelet 1981) which gives a correlation coefficient D_n, and its test-statistic U_n.

Results

Periodic sampling of *P. irroratus* adults with light traps indicated that the daily flight period is crepuscular. *P. irroratus* fly for ca. 2 hr after sunset with peak flight time ca. 45 min after sunset (Fig. 1). Sunset was at ca. 21:15 first generation and ca. 19:45 second generation. The mean time of flight first generation was 22:05 and 20:34 second generation. During the peak 0.5 hr flight period, well over 100 *P. irroratus* adults were captured per light trap. Low numbers of leafhoppers were captured during other times of the night. No leafhoppers were captured during morning twilight. The number of leafhoppers captured 0.5 and 1 hr after sunset were statistically different ($P \leq 0.05$, ANOVA) from numbers captured during all other trapping times both first generation ($D_n=0.938$, $n=24$, $U_n=18.76$, $P<0.01$, rank correlation) and second generation ($D_n=0.973$, $n=24$,

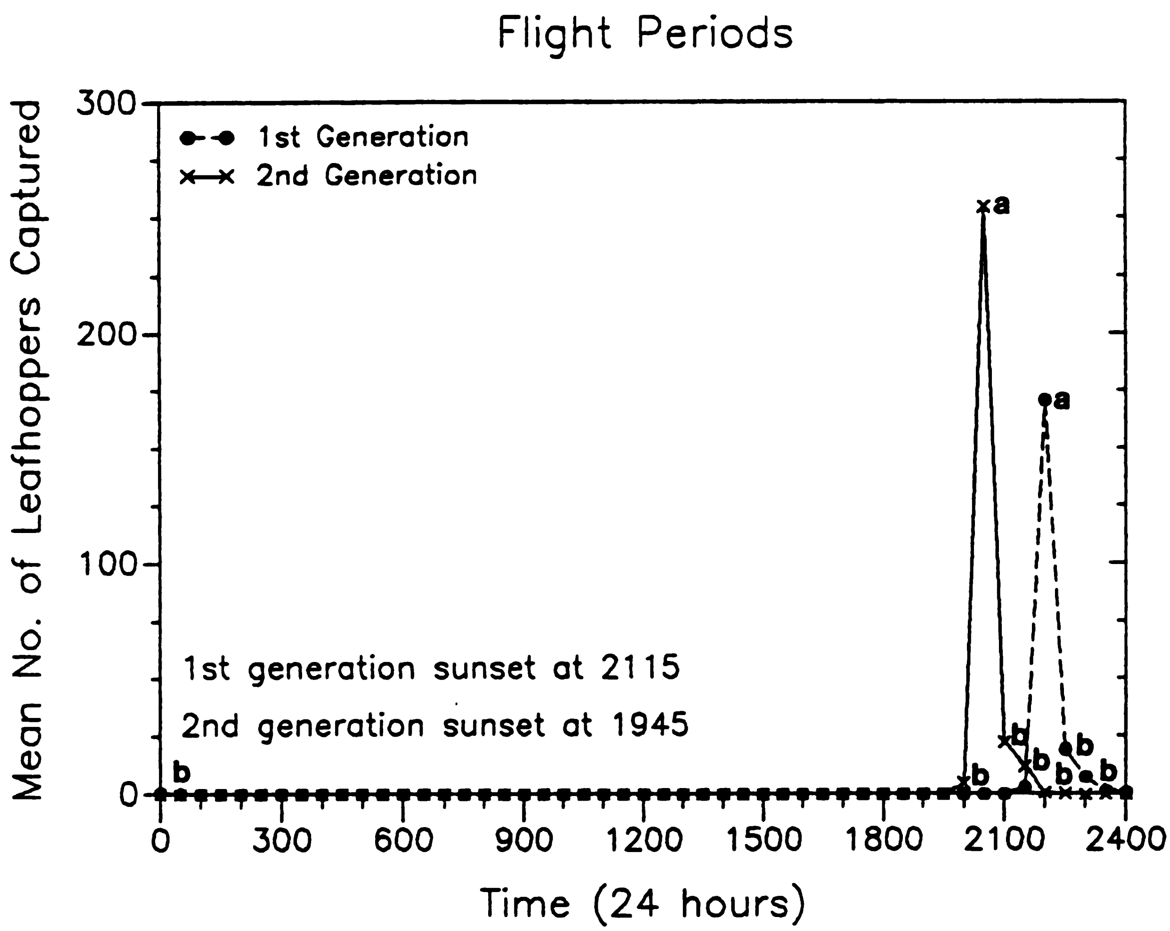


Fig. 1. Mean number of *P. irroratus* leafhoppers sampled by light trapping over a 24 hr period for both generations. Means followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's test of data).

U_n=19.46, P<0.01, rank correlation). The mean number of *P. irroratus* leafhoppers captured each 0.5 hr sampling period for 24 hrs by light trapping was 4.2 and 6.2 for the first and second generations respectively. These means were not significantly different ($P \geq 0.05$, ANOVA). There were no significant differences between sample dates ($P \geq 0.05$, ANOVA).

Sweep net samples of the groundcover indicated leafhopper density was highest during the day and began rapidly declining until 2 hr after sunset. During the night, the highest leafhopper densities were detected on sour and sweet cherry. At sunrise the groundcover leafhopper density began to increase, returning to its highest density by 15:00 (Fig. 2). Very few *P. irroratus* were detected on apple at any time. There was no significant difference in number of leafhoppers between the sample dates within a generation ($P \geq 0.05$, ANOVA). Sweep sampling indicated that the leafhopper densities between the four sub-habitats were significantly different ($P \leq 0.05$, ANOVA). The density was highest in sour cherry first generation and in sweet cherry second generation (Fig. 3). The mean density in the groundcover was the same both generations, lower than that of either sweet or sour cherries but greater than the apple (Table 1). Circular-linear rank correlation indicated the number of leafhoppers captured in the groundcover (P<0.05), sour cherry (P<0.01) and sweet cherry (P<0.01) correlated significantly with the

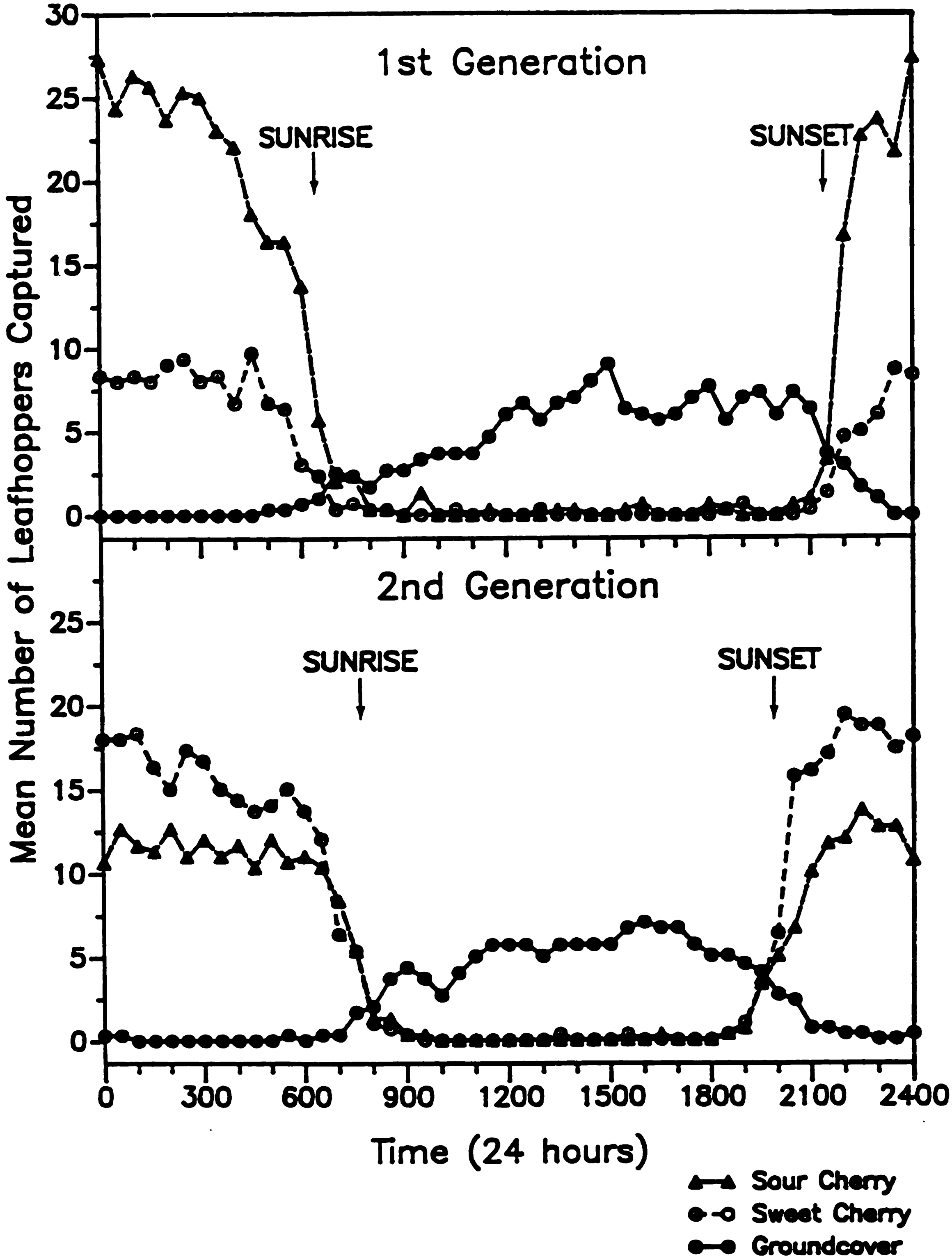


Fig. 2. Mean number of *P. irroratus* leafhoppers collected in sweep nets every 0.5 hr over a 24 hr period in each sub-habitat type for both generations.

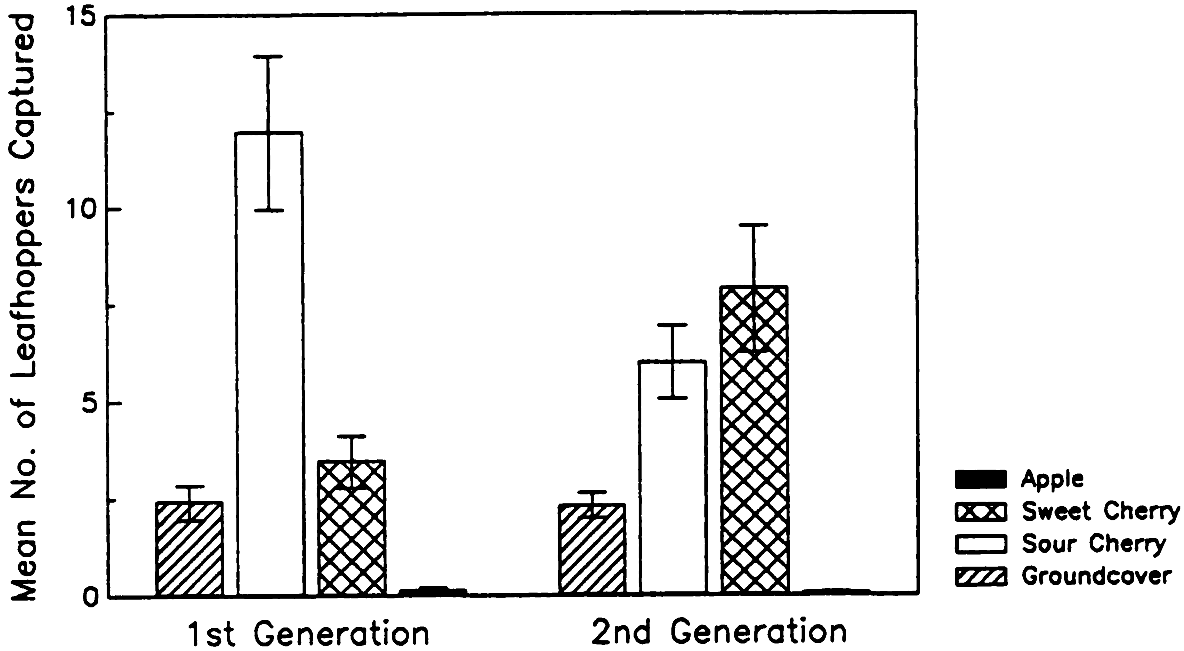


Fig. 3. Mean number (±SE) of *P. irroratus* leafhoppers collected over 24 hrs in sweep nets in the four sub-habitats during first and second generations.

Table 1. Mean number of *P. irroratus* leafhoppers captured by 25 sweeps each 0.5 hr over 24 hrs, three replications in two generations

Sub-habitat type	No. adults per 25 sweeps		
	1st Generation	2nd Generation	Combined Generations
Sour cherry	8.18a	5.53cd	6.86e
Sweet cherry	2.76b	7.56c	5.16e
Groundcover	2.84ab	2.68d	2.76ef
Apple	0.07b	0.03d	0.05f

Means followed by the same letter are not significantly different ($P<0.05$; Scheffe's test of data).

time of day sampled for both generations, but was not significantly correlated with time of day sampled in the apple (Table 2).

Discussion

Earlier work by Mowry and Whalon (1984) on absolute and relative sampling methods, indicated that relative sampling methods were the best way to detect leafhoppers moving into and out of orchards within a short period of time. Although sweep samples have distinct drawbacks (DeLong 1932), they were an effective means of getting frequent relative density estimates of a highly mobile leafhopper population. After the leafhoppers had dropped off the trees down to the ground during the early morning hours, they were unable to be collected efficiently by sweeping. Sweep sampling appears to be increasingly effective until ca. 15:00, when the leafhopper density in the groundcover is greatest.

The current study was limited to a single site for several reasons, including a known high population of *P. irroratus* and our ability to control pesticide spray applications. A systematic bias in the spacial position caused by the three blocks of fruit trees was unavoidable and created factors unable to be addressed by our experimental design. Sweep samples taken from groundcover indicated the groundcover leafhopper density was uniform throughout the orchard.

Table 2. Circular-linear rank correlation (Batschelet 1981) of the number of leafhoppers captured over a 24 hr period in 4 sub-habitats. Significance indicates the number of leafhoppers captured correlated with the time of day sampled.

Sub-habitat type	n	D_n	U_n	P
Sour Cherry				
1st generation	48	0.983	10.66	<0.01
2nd generation	48	0.970	10.53	<0.01
Sweet Cherry				
1st generation	48	0.985	10.66	<0.01
2nd generation	48	0.963	10.45	<0.01
Groundcover				
1st generation	48	0.885	7.86	<0.05
2nd generation	48	0.872	7.75	<0.05
Apple				
1st generation	48	$6.4x10^{-3}$	$4.2x10^{-2}$	n.s.
2nd generation	48	$6.4x10^{-3}$	$4.3x10^{-2}$	n.s.

D_n=correlation coefficient, U_n=test statistic.

At this site, *P. irroratus* had an evening crepuscular activity period both generations during which they were responsive and attracted to the light traps. Movement out of the trees back into the groundcover the following morning occurred when leafhoppers were visually observed dropping out or gliding down from the orchard trees. Leafhoppers were generally inactive until the sun came up and temperatures rose. Leafhoppers were then active during the day within the orchard groundcover. Observations at other sites during the 1986 field season support these conclusions.

Differences in host suitability may be why apple trees were not occupied at any time, and why first generation *P. irroratus* seem to prefer sour cherry during the night while second generation leafhoppers seem to prefer sweet cherry. Circular-linear correlation coefficients support the conclusion that the leafhopper density in the groundcover, sour cherry and sweet cherry sub-habitats is correlated with the time of day. The lower mean leafhopper density in the groundcover is due to possible movement by *P. irroratus* into and out of the orchard from outside habitats, and the large volume of groundcover foliage compared with the volume of the young fruit tree foliage present in this orchard. Groundcover was the major orchard sub-habitat occupied by *P. irroratus* during the day. This observation supports

McClure's (1982) assertion that groundcover type may have an important influence on the distribution and abundance of leafhoppers within the orchard.

Groundcover manipulation and other management techniques may indirectly influence the transmission of X-disease by the night feeding leafhoppers. Knowing that *P. irroratus* visits cherry trees will aid in evaluating established control procedures and developing new X-disease management strategies. Recommendations to spray orchards after sunset with a quick-knockdown insecticide to reduce leafhopper populations have already been made (Whalon & Larsen 1985). Crepuscular movement by these leafhoppers helps them avoid being hit directly by daytime spray applications and could therefore be providing a mechanism of resistance to insecticides.

References Cited

Batschelet, E. 1981. Circular statistics in Biology. Academic Press, N.Y. 371 pp.

DeLong, D.M. 1932. Some problems encountered in the estimation of insect populations by the sweeping method. Ann. Entomol. Soc. Am. 25:13-17.

Harker, J.E. 1961. Diurnal rhythms. Ann. Rev. Entomol. 6:131-146.

McClure, M.S. 1982. Factors affecting colonization of an orchard by leafhopper vectors of peach X-disease. Env. Entomol. 11:695-700.

Mowry, T.M. and M.E. Whalon. 1984. Comparison of leafhopper species complexes in the groundcover of sprayed and unsprayed peach orchards in Michigan. Great Lakes Entomol. 17:205-209.

Rosenberger, D.A. and A.L. Jones. 1978. Leafhopper vectors of the peach X-disease pathogen and its seasonal transmission from chokecherry. Phytopath. 68:782-790.

SAS Institute. 1985. SAS User's Guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary NC. 956 pp.

Whalon, M.E. and K.J. Larsen. 1985. X-disease leafhopper vector alert. Pest Alerts 24:85.

CHAPTER III

DISPERSAL OF *PARAPHLEPSIUS IRRORATUS* (SAY) IN PEACH AND CHERRY ORCHARDS

Introduction

Understanding vector leafhopper movement is necessary to learn more about X-disease epidemiology. Until now, dispersal of *P. irroratus*, a major vector of peach X-disease in Michigan, has not been examined. *P. irroratus* is known to spend the day within the orchard groundcover, and at twilight it moves into fruit tree foliage (Larsen & Whalon 1987).

The purpose of this research was to estimate population density and evaluate the temporal and spatial distribution and dispersal patterns of local populations of *P. irroratus* around peach and cherry orchards. Mark, release and recapture techniques can be used to estimate population densities (Southwood 1978), and have also been used to study dispersal behavior of leafhoppers (Ito & Miyashita 1961, Purcell & Suslow 1982, Whitney & Meyer submitted). Using fluorescent dye dusts to mark the leafhoppers, we evaluated their dispersal rate, distance and direction of movement within, into, and out of the orchards.

Materials and Methods

Leafhopper Capture and Marking

Leafhoppers to be marked and released were captured during the evenings of the two generation peaks of *P. irroratus*. First generation adult activity peaks between late-June and July, while second generation activity occurs from late-September to October. Leafhoppers were captured from natural populations near East Lansing and Lawrence, MI by aspirating leafhoppers from box light traps. Each light trap was a 30.5 x 66 x 91 cm wooden box painted flat black with the exception of the interior back which was glossy white and illuminated by two yellow 60 watt "Bug Lites" (General Electric; Cleveland, Ohio) mounted on the white surface. The traps were situated ca. 1.8 m above the ground and powered by a 12 volt automotive battery connected to a 12v DC to 120v AC inverter. The light traps were set up at capture sites located at least 1 km away from the release sites.

Leafhopper capture began at 0.5 hrs before sunset and continued until 2 hrs after sunset to sample during the peak flight period of *P. irroratus* which occurred ca. 0.75 hr after sunset (Larsen & Whalon 1987). Leafhoppers were aspirated into holding vials in groups of 100 for marking. The leafhoppers were marked using six Day-Glo™ fluorescent powder dyes (Day-Glo Color Corporation, Cleveland, Ohio). Different colors were used to indicate a release date and location. Rocket Red, Signal Green, Arc Yellow, Horizon Blue, Creme, and Corona Magenta were the colors used. The groups of 100 aspirated leafhoppers were placed in a dry 1 qt mason jar with 1/8 teaspoon of dye. The jar was then gently agitated for one minute. The undusted controls used in some of the tests were handled in the same manner, except that the control insects were not dusted. The marked leafhoppers were immediately removed from the jar by dumping the contents onto an open petri dish cover placed on the ground at the release point or in the middle of the laboratory flight cage. Only those leafhoppers that flew away were counted as released.

Effects of Marking on Survival

To test the effect of the marking method on leafhopper survival, seven sets of 3 male and 3 female leafhoppers were treated with one of the six colors of flourescent dye or were an undusted control. The experimental design was randomized block, replicated in six cages each generation. Test leafhoppers were released into small 30.5 cm tall x 20.25 cm dia cages on clover and barley host plants housed in a walk-in growth chamber. The experiment was conducted in a light-dark regime of 15:9 LD for the first generation or 12:12 LD for the second generation. Daily counts of leafhopper survival were made for 21 days by searching the cages and removing dead leafhoppers, then identifying and recording leafhopper treatment and sex in the laboratory.

Effects of Marking on Flight Activity

To test the effect of the marking method on flight activity, seven sets of 25 male and 25 female leafhoppers were marked with a flourescent dye color or were an undusted control. These leafhoppers were released together on clover and barley host plants in a 0.6 x 1.0 x 2.0 m cage in the greenhouse under a light-dark regime of 15:9 LD for the first generation and 12:12 LD for the second generation. Four yellow sticky board traps were hung in the cage and trapped leafhoppers were monitored for 21 days following release.

Field Release and Recapture

The leafhopper field release and recapture study was performed at research sites in East Lansing and Lawrence, MI (Fig. 1). The first research site was a 1 ha unsprayed mixed orchard of apple, sour cherry and sweet cherry blocks ca. 7 yrs old located on the Entomology research farm at Collins Road on the Michigan State University campus in East Lansing, Michigan (location: 42° 41' N. Lat. 84° 30' W. Long.) (Fig. 2). The second research site was a commercial orchard of peach, tart cherry and apple near Lawrence, Michigan in VanBuren County (location: 42° 12' N. Lat. 86° 4' W. Long.) (Fig. 3). Each orchard research area contained two release sites, one within a peach or tart cherry block and the other 10 m outside the edge of the same orchard block. At the Lawrence site, the edge release location and recapture traps were set up in what we considered a large field, recently planted with widely spaced young apple trees.

At each release site, yellow sticky board traps were hung ca. 1.5 m above the groundcover at distances of 5, 10, 20, 40, and 60 m in six directions, radiating from the release point (fig. 4). The yellow sticky board traps were 12.5 x 25 cm made of 0.25 in plywood and painted with sun

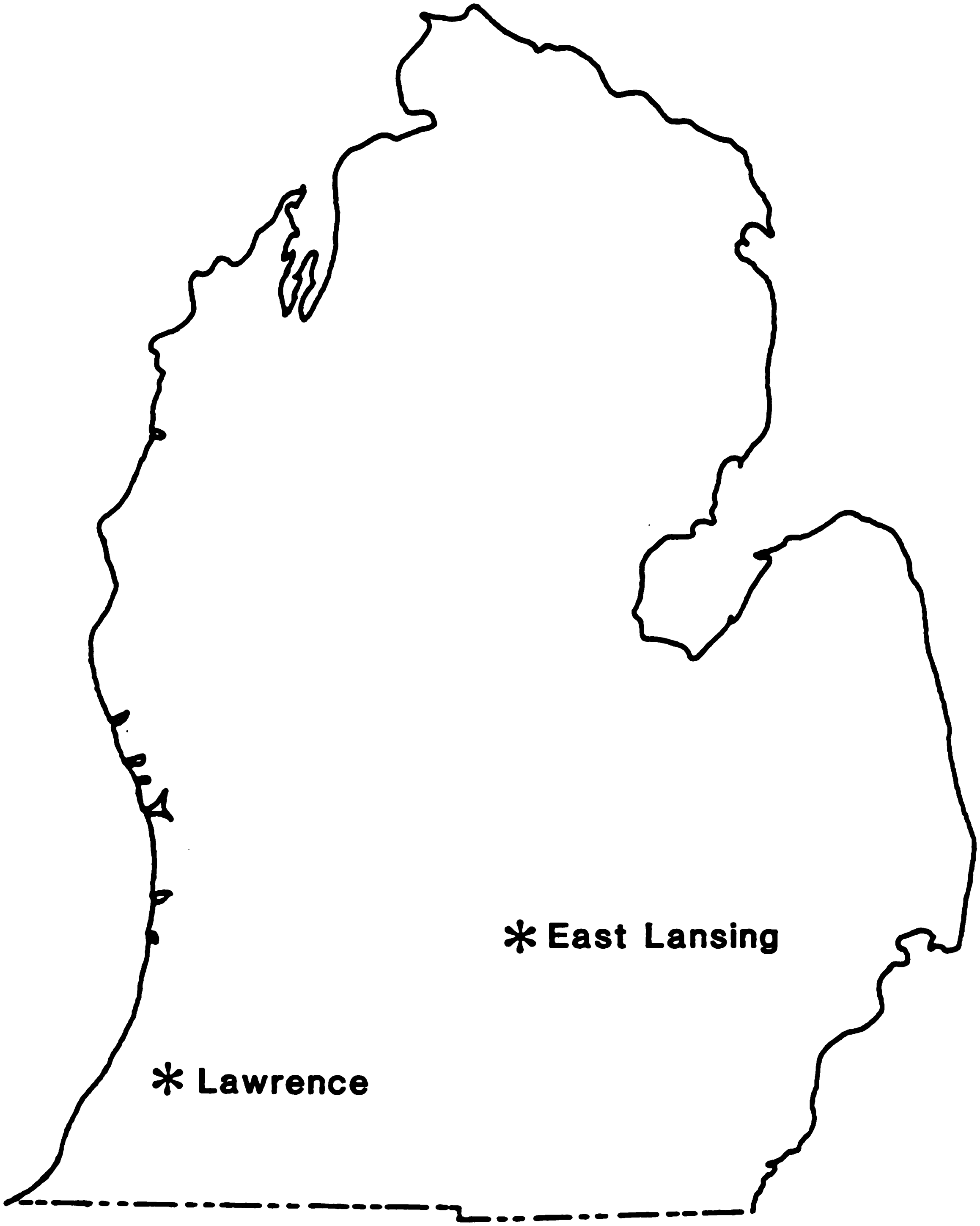


Fig. 1. Location of the two field research sites used in this leafhopper dispersal study.

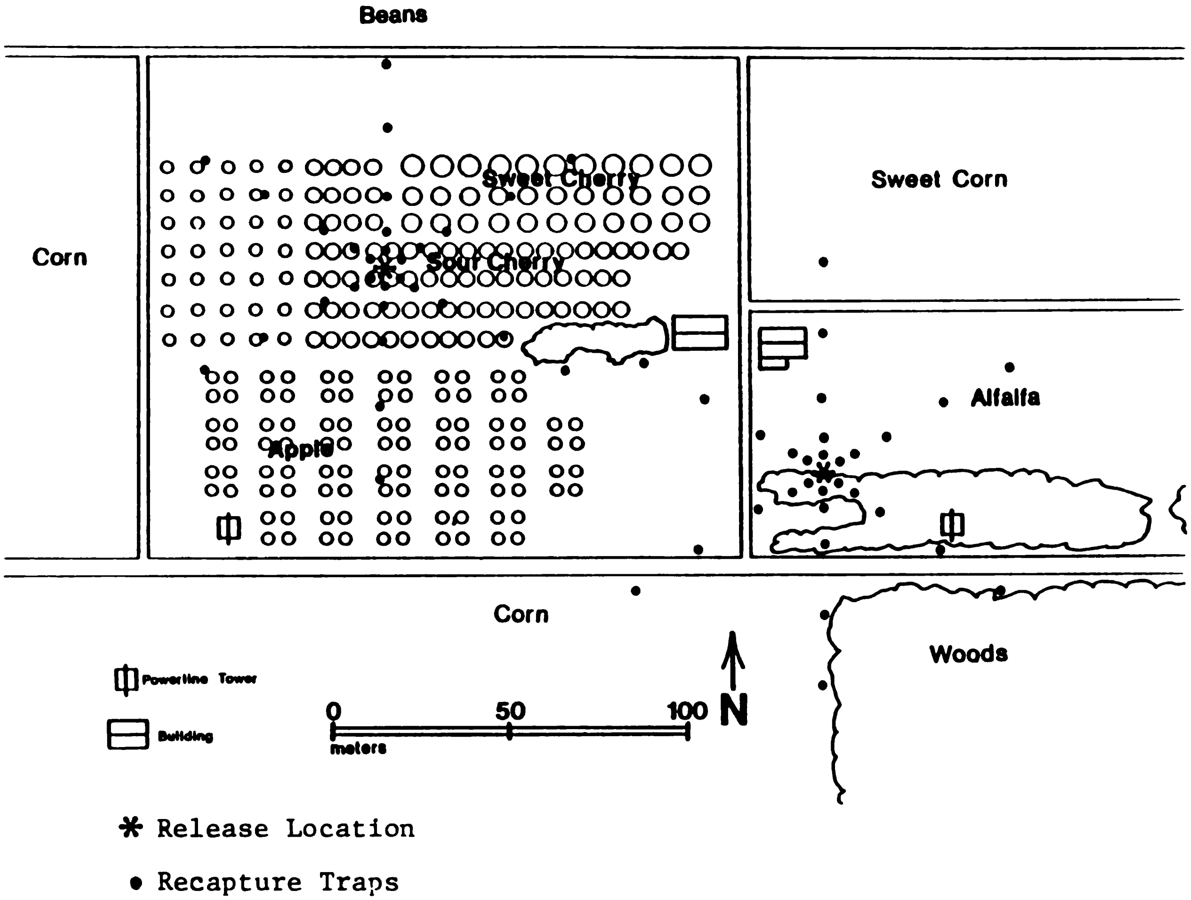
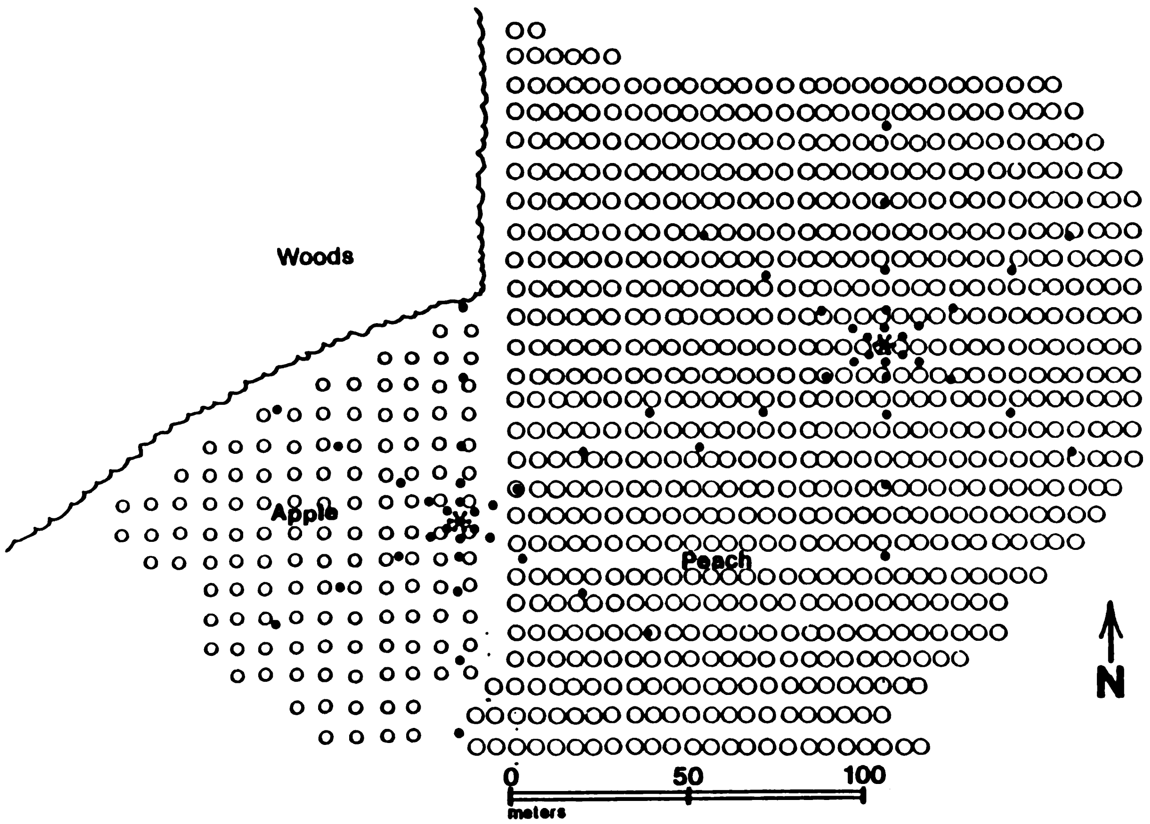


Fig. 2. Release locations, recapture trap layout and surrounding area at the East Lansing, MI research site (location: T4N R2W Sec 36 W 1/2).



* Release Location

● Recapture Traps

Fig. 3. Release locations, recapture trap layout and surrounding area at the Lawrence, MI research site (location: T3S R15W Sec 20 SE 1/4).

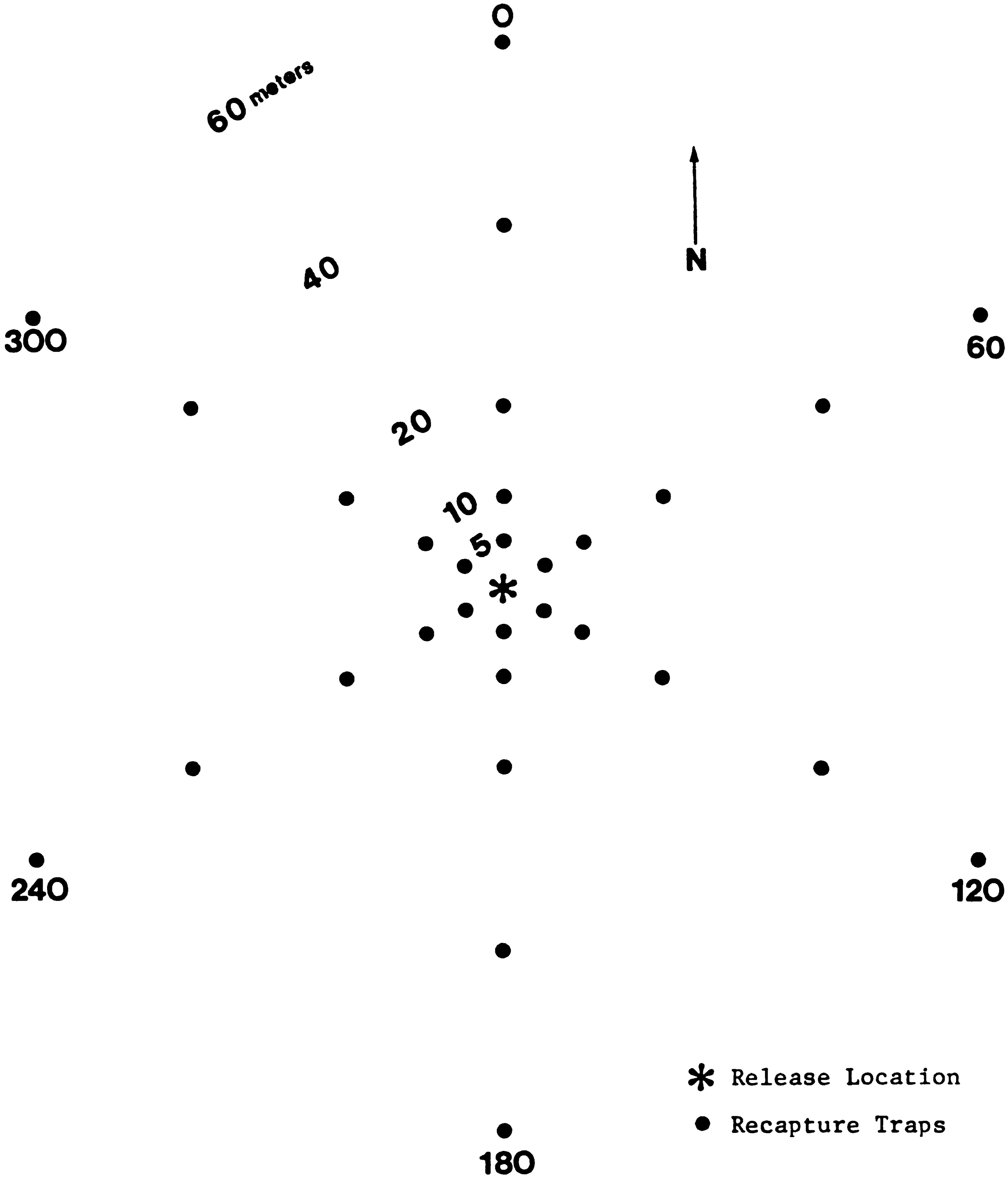


Fig. 4. Arrangement of the yellow sticky board traps used to recapture marked *P. irroratus* leafhoppers around each release location.

yellow enamel (Benjamin Moore & Co.; Montvale, NJ) and coated with Tree Tanglefoot™ (The Tanglefoot Company; Grand Rapids, MI). Leafhoppers captured on yellow sticky boards were monitored daily for 21 days following a release. Leafhoppers were removed from the yellow sticky boards carefully with a small spatula and placed in a coded petri dish. A black light was used to determine marked and unmarked leafhoppers. Weather data were obtained from nearby agricultural weather observation stations at Paw Paw and the M.S.U. Horticultural farm in East Lansing.

The mark/recapture field experimental design was a randomized block, 4 factor factorial combined over 2 sites. Three dates of release (the blocks or replicates) occurred during each generation. The four factors were release location, direction, distance, and time following release. Randomization occurred by random assignment of the marked leafhoppers to release site and location. Field data were entered into R:Base System V (Microrim 1986) for data management and analysis. Data were subjected to further analysis of variance and multiple comparison of means using SAS (SAS Institute 1985). Directionality of the data was analyzed by circular correlation and circular-linear rank correlation tests (Batschelet 1981). Dispersal equations describing the distance data were fitted and analyzed using GLIM (Baker & Nelder 1978).

Results

Effects of Marking on Survival and Flight Activity

Survival of the leafhoppers treated with the six dyes was not significantly different ($P \geq 0.05$, ANOVA) than that of the undusted control group for either generation. For first generation, the average days of survival following treatment was 12.9-blue, 12.1-green, 11.9-magenta, 11.6-yellow, 11.4-creme, 10.7-unmarked control, and 9.3-red. For the second generation survival was 16.5-red, 15.4-yellow, 15.4-green, 15.0-unmarked control, 13.7-creme, 13.5-magenta, and 12.7-blue.

Capture on yellow sticky board traps, as a measure of flight activity was also not significantly different ($P \geq 0.05$, ANOVA) between marked and unmarked leafhoppers for either generation. The average days until capture for first generation was 4.2-yellow, 3.4-green, 2.8-red, 2.4-magenta, 2.4-blue, 2.2-unmarked control, and 2.1-creme. For second generation, average days until capture was 3.6-unmarked control, 3.2-creme, 3.1-magenta, 2.7-yellow, 2.5-blue, 2.5-green, and 2.3-red.

Temporal Patterns of Trap Catches

The recapture rates for released leafhoppers (Table 1) ranged from 1.47% first generation at the Lawrence orchard release location, to 3.68%, also first generation, at the East Lansing orchard release location. Over both sites, release locations, and generations, 16,237 marked

Table 1. Number of marked leafhoppers released and recaptured and the recapture rate for both sites, release locations, and generations.

Release Location	East Lansing		Lawrence		Totals	
Generation 1						
Orchard	1440/53	(3.68)	1975/29	(1.47)	3415/82	(2.40)
Edge	1347/47	(2.46)	1975/35	(1.77)	3322/82	(2.47)
	2787/100	(3.59)	3950/64	(1.62)	6737/164	(2.43)
Generation 2						
Orchard	2400/64	(2.67)	2350/52	(2.21)	4750/116	(2.44)
Edge	2400/59	(2.46)	2350/43	(1.83)	4750/102	(2.15)
	4800/123	(2.56)	4700/95	(2.02)	9500/218	(2.29)
Totals						
Orchard	3840/117	(3.05)	4325/81	(1.87)	8165/198	(2.42)
Edge	3747/106	(2.85)	4325/78	(1.80)	8072/184	(2.28)
	7587/223	(2.94)	8650/159	(1.84)	16237/382	(2.35)

released/# recaptured (% recapture rate)

leafhoppers were released and 382 recaptured for an overall recapture rate of 2.35%. There were significant differences in leafhopper recaptures over time between release dates at each site during each generation ($P \leq 0.05$, ANOVA).

There was an exponential decrease in the number of leafhoppers recaptured over the 21 days following their release (Fig. 5), with the largest number of leafhoppers recaptured in the first several days following release.

Temperature influenced the total number of leafhoppers (both marked and unmarked) captured each day. The average temperature for similiar leafhopper capture between the two generations was lower in the second generation than in the first (Fig. 6). For example, to trap 1 leafhopper/trap/day first generation required temperatures near 85°F (29°C), while the same results second generation required temperatures ca. 20°F (11°C) colder near 65°F (18°C).

Spacial Patterns of Trap Catches

There were significant differences in leafhopper recaptures over time between research sites both generations ($P \leq 0.05$, ANOVA), but not between the two release locations within a site for either generation. No leafhoppers released at the orchard location were captured in the edge location trapping network, and neither were any leafhoppers released at the edge location recaptured in the orchard trap network.

Trap catches of marked leafhoppers was highest at traps nearest the release location and decreased linearly with

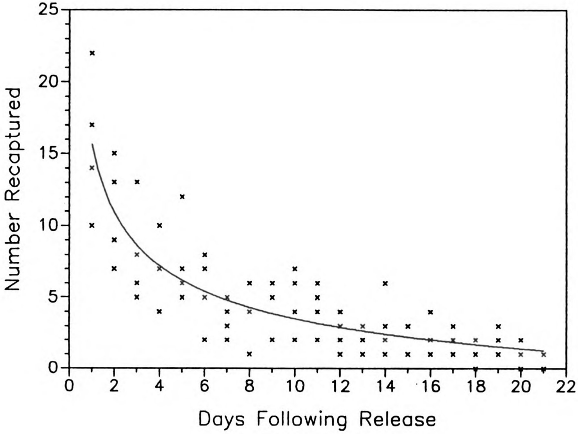


Fig. 5. Number of *P. irroratus* leafhoppers recaptured each day for the 21 days following their release.

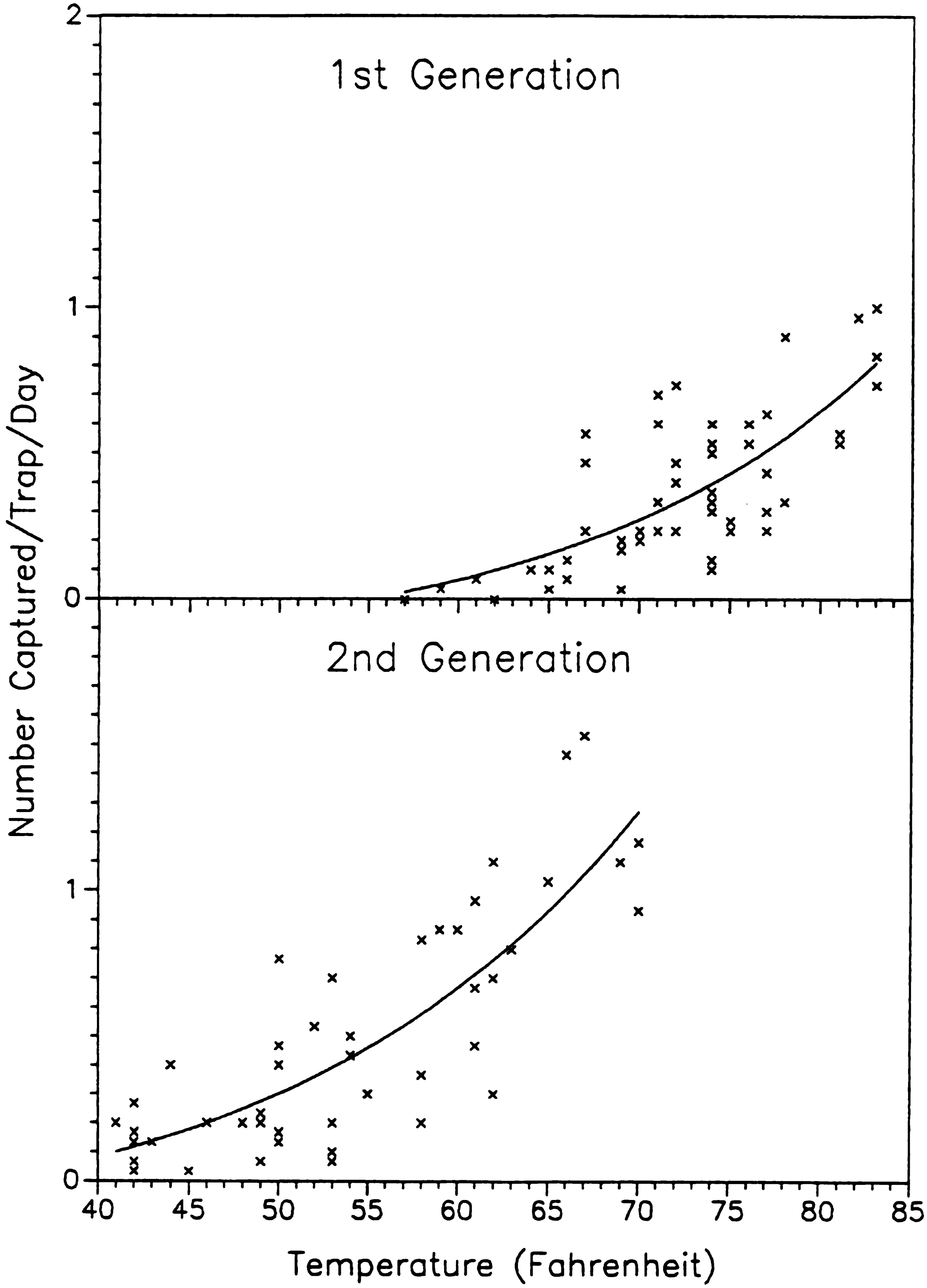


Fig. 6. Number of marked and unmarked *P. irroratus* leafhoppers captured per yellow sticky board trap per day over the mean temperature during the daily two hour crepuscular flight period following sunset.

distance (Fig. 7). Equations which were a special form of Taylor's general dispersal model $n=\exp(a+bX^c)$ were fitted to the data. The dispersal model (Taylor 1980) which best fit the actual data was:

$$n = \exp\ (3.503 + -0.133 * \ln(X) + -0.28*10^{-6} * X^{3.7})$$

where 'n' is the number of insects at distance X, 'exp' is exponent, and 'ln' is natural logarithm.

Interference by other recapture traps close to the release location was assumed to occur because of the recapture trap layout and the increasing numbers of unmarked, endemic leafhoppers captured with increasing distance from the release point (Table 2). An interference factor (I_t) was computed for each set of traps at different distances from the release location. This factor incorporated both the number of and distance to nearby traps, with traps closer influencing the interference factor more than traps further away. The interference factor was determined by the equation:

$$I_t = 1 + \sum_{1-i} (1/d)$$

Where 'I_t' is the interference factor for all recapture traps at distance 't' from the release point, 'd' is the distance (m) to each interfering trap within 30 m of the recapture trap, and 'i' is the number of interfering traps. The '1' was included in the I_t equation as traps with no interference from other recapture traps could not transform capture counts.

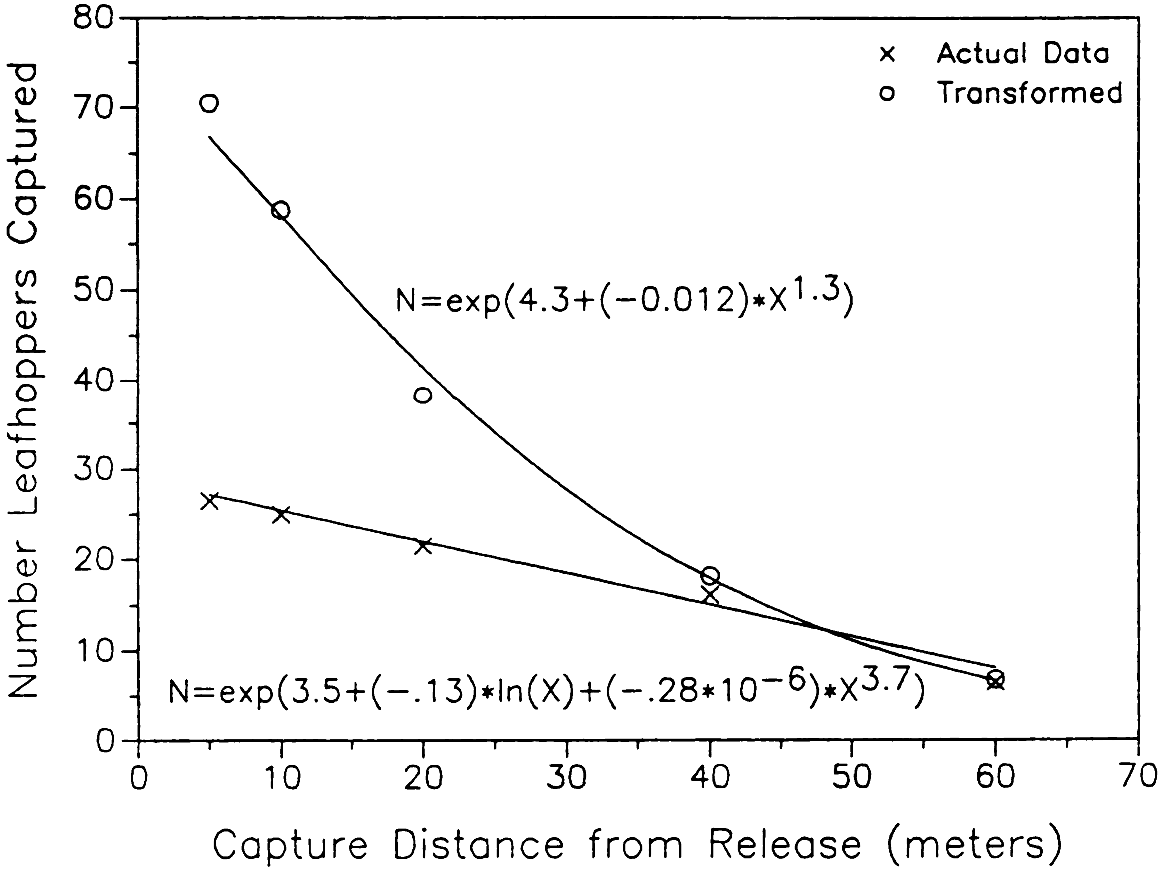


Fig. 7. **Actual and transformed mean number of *P. irroratus* leafhoppers recaptured at different trapping distances, for both sites, generations and release locations, with the dispersal equation and expected line.**

Table 2. Mean number of marked and unmarked *P. irroratus* leafhoppers recaptured at different trapping distances from release location, with the count following transformation by the interference factor.

Trap Distance=d	Count Marked	Count Unmarked[a]	Interference Factor=I_t[b]	Transformed Count
5	26.5	17.4c	2.6586	70.5
10	25.0	20.3bc	2.3498	58.7
20	21.5	24.8b	1.7759	38.2
40	16.0	32.6a	1.1333	18.1
60	6.5	32.9a	1.0513	6.8

[a]Means within column followed by the same letter are not significantly different ($P \leq 0.05$; Scheffe's test of data).

[b]Interference factor was determined from the equation:

$$I_t = 1 + \sum_{1-i} (1/d)$$

Where 'I_t' is the interference factor for all recapture traps at distance 't' from the release point, 'd' is the distance (m) to each interfering trap within 30 m of the recapture trap, and 'i' is the number of interfering traps.

Transformation of the actual data by multiplying by the interference factor resulted in the expected exponential decrease with increasing distance from the release location (Table 2). The dispersal equation (Taylor 1978) which best fit the transformed data was:

$$n = \exp (4.297 + -0.0117 * X^{1.3})$$

where 'n' is the number of insects at distance X and 'exp' is exponent.

Trap captures of marked leafhoppers were highest to the southeast (120° from north) for all releases and lowest to the northwest (300° from north)(Table 3). The mean dispersal direction and mean wind direction were significantly correlated (circular correlation coefficient r=0.87) for both sites and both generations (Fig. 8).

Rate of movement of the dispersing leafhoppers was greater at the Lawrence site than at the East Lansing site, and also greater second generation than first generation. At the Lawrence site, marked leafhoppers were moving 3.35 and 4.12 m/day for the first and second generations respectively, and at the East Lansing site they were moving 2.66 and 3.57 m/day for the first and second generations.

Rate of movement also varied with both recapture direction and distance. The mean rate of movement (m/day) for each capture direction was fastest to the southeast (3.96m/day at 120° from north) and was slowest to the northwest (2.59m/day at 300° from north) (Fig. 9). The mean

Table 3. Total number of marked *P. irroratus* leafhoppers recaptured each direction from the release location for both orchard and edge locations at each site during the two generations.

Dispersal Direction	Generation 1		Generation 2		Totals	Means
	EL	Law	EL	Law		
0°						
Orchard	5	6	6	6		
Edge	4	4	7	3		
	9	10	13	9	41	10.25
60°						
Orchard	11	6	7	9		
Edge	11	9	8	12		
	22	15	15	21	73	18.25
120°						
Orchard	14	9	22	13		
Edge	14	12	18	15		
	28	21	40	28	117	29.25
180°						
Orchard	12	4	17	7		
Edge	12	5	19	9		
	24	9	36	16	85	21.25
240°						
Orchard	6	3	4	8		
Edge	3	3	7	6		
	9	6	11	14	40	10.00
300°						
Orchard	5	2	3	4		
Edge	3	1	5	3		
	8	3	8	7	26	6.50
Totals	100	64	123	95	382	

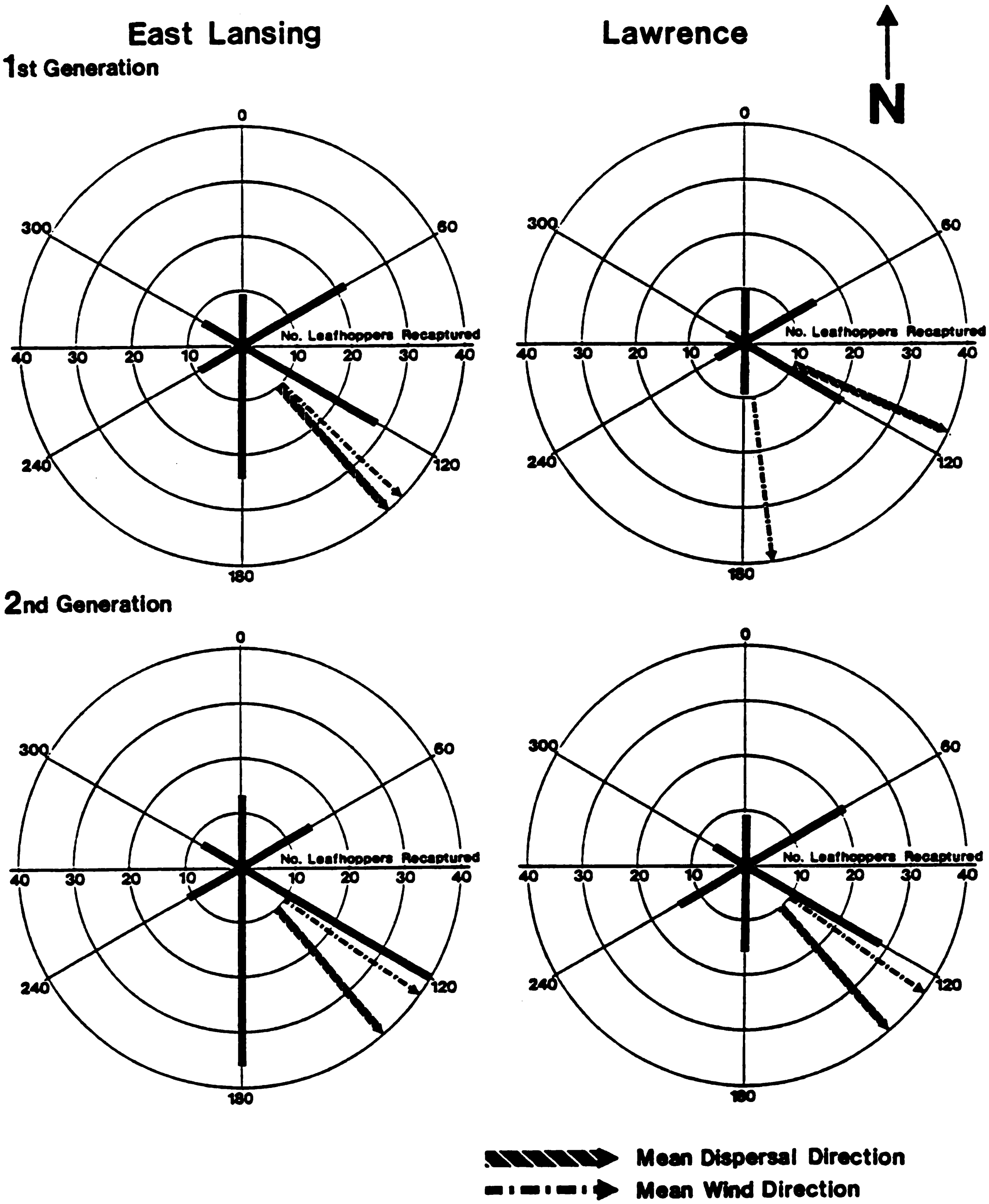


Fig. 8. Number of *P. irroratus* leafhoppers recaptured each direction with the mean dispersal and mean wind direction during flight times for recaptured leafhoppers (circular correlation coefficient r=0.87).

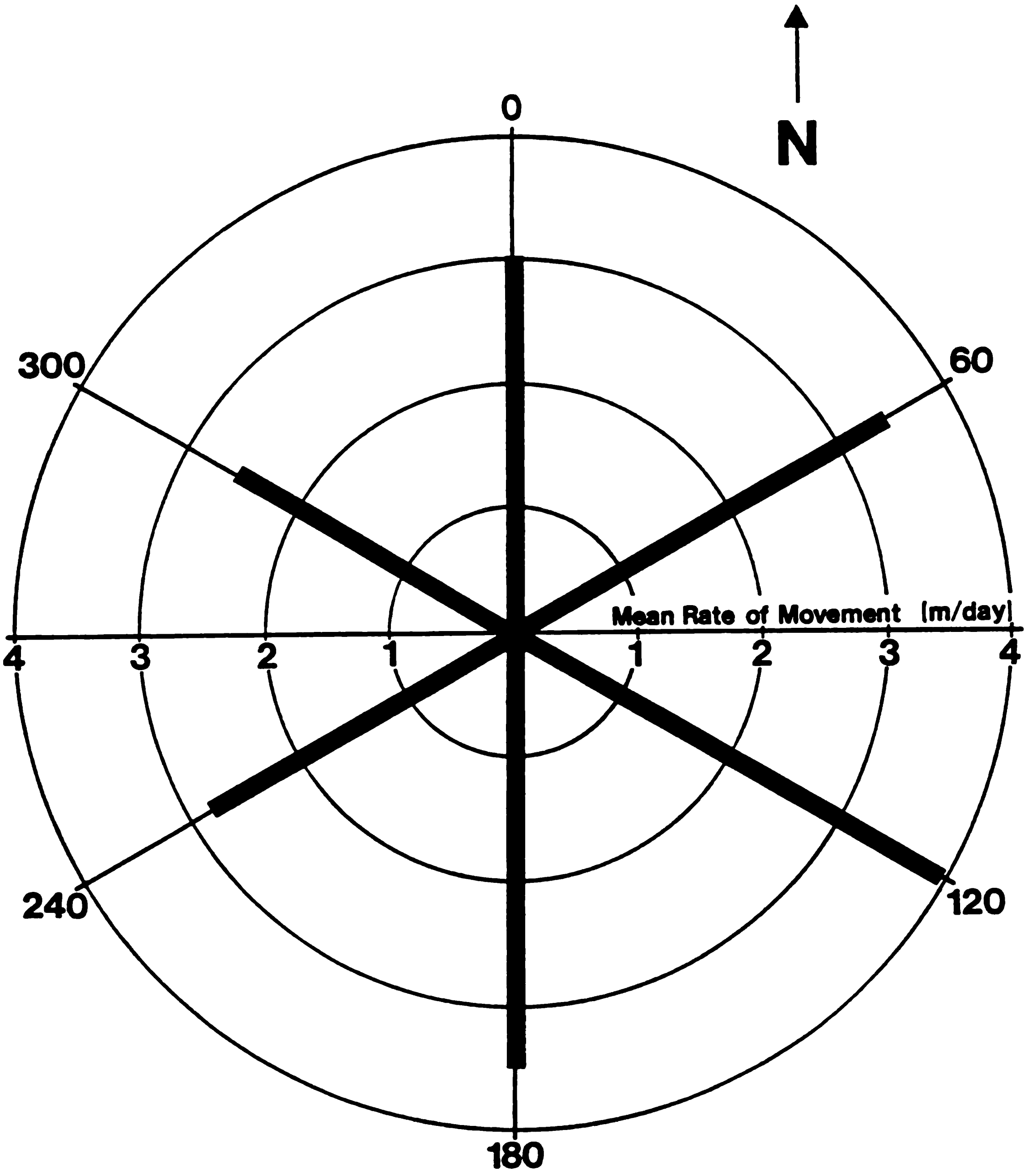


Fig. 9. Mean rate of movement (m/day) of marked *P. irroratus* leafhoppers recaptured each direction from release for both sites, release locations, and generations.

rate of movement (m/day) for each capture distance increased with distance from release (Fig. 10) from 2.86m/day at 5m to 5.09m/day at 60m.

Population estimates were made using the Lincoln Index method (Lincoln 1930) based on the numbers of recaptured marked leafhoppers and numbers of unmarked leafhoppers captured while monitoring dispersal. The index equation used was:

$$N = a * n / r$$

where 'N' is the estimated number of individuals in a population, 'a' is the total number of individuals marked and released, 'n' is the number of marked and unmarked individuals captured, and 'r' is the number of marked individuals recaptured. The estimated leafhopper density at the Lawrence site was $0.292/m^2$ and $0.395/m^2$ for the first and second generations respectively, and similarly $0.251/m^2$ and $0.328/m^2$ at the East Lansing site.

Discussion

The marking method had no significant affect on leafhopper survival or attraction to yellow sticky board traps. Concern that the marking method would disturb the leafhoppers (Southwood 1978) was diminished by the release of the marked leafhoppers as soon after capture as possible during the post crepuscular inactive period. Marked leafhoppers were easily distinguished as the dye was neither

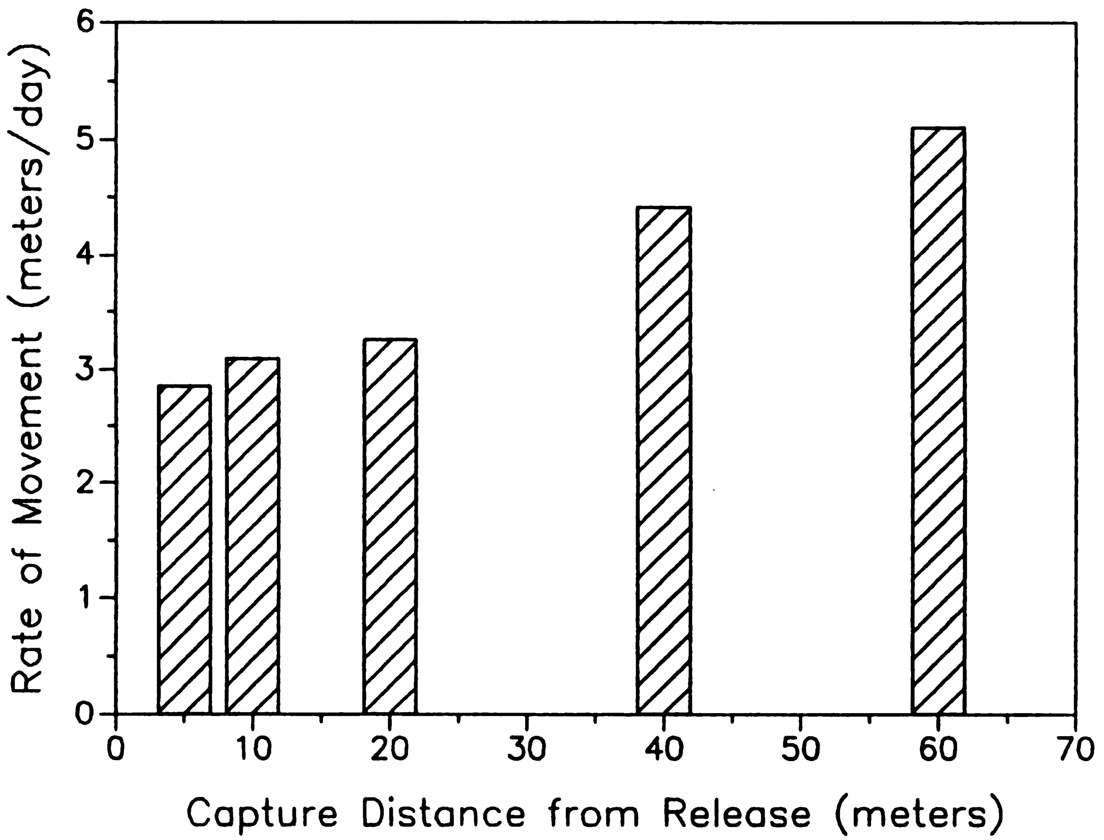


Fig. 10. Mean rate of movement (m/day) of marked *P. irroratus* leafhoppers recaptured each distance from release for both sites, release locations, and generations.

washed or groomed off from the neck area between the head and thorax, or from the thoracic sterna between the bases of the legs on the thorax.

The recapture rate was low (1.47-3.68%) compared to some past leafhopper mark/release/recapture studies (26.0-36.4%; Ito & Miyashita 1961, 17.3-43.7%; Whitney & Meyer submitted), but similiar to the study by Purcell & Suslow (1-9%; 1982).

Differences in dispersal activity between release dates at each site were due to temperature effects. When combined, the different temperatures cancel out the release date differences. This effect gives an expected smooth decrease in leafhopper recaptures over time.

Temperature plays an important role in insect development and behavior (Tschinkel 1985). Ambient temperature influences activity of *P. irroratus*, and this influence differs significantly between first and second generations. The results indicate that second generation adult *P. irroratus* are active in temperatures as low as 40°F (4°C). These temperatures are not uncommon in Michigan during late-September and October and would indicate that cold nights will not necessarily reduce *P. irroratus* activity.

Differences between the Lawrence and East Lansing research sites may be due to several factors. The Lawrence site is a commercial orchard which is regularly treated with pesticides, while the East Lansing site is an unsprayed research orchard. Other differences included peach orchard vs. cherry orchard, and the configuration of the surrounding habitat. Inspite of these differences, the dispersal patterns were remarkably similiar.

The position of the yellow sticky board traps used for recapture (Fig. 4) simplified our data analysis, but generated problems in that the effective trapping space of each trap interfered with that of other traps, especially those close to the release location. For this reason, distance capture data were transformed using the interference factor (I_t) which was specific for each set of traps at different distances from the release location. The increasing number of randomly distributed, unmarked, endemic leafhoppers captured with increasing distance and decreasing interference support our hypothesis of trap interference.

The dispersal models derived from these data do not represent functional forms of dispersal, but rather are empirical descriptions of the dispersal by *P. irroratus* in this study.

Differences in sites or release dates did not influence the direction the leafhoppers were moving. Wind seems to be the major factor influencing the leafhopper dispersal direction, not the presence nearby of *P. irroratus* habitats such as clover fields, meadows, fence rows, or wood lots.

The rate of movement may be influenced by site differences. The suspected presence of insecticide residues in the Lawrence orchard may possibly encourage the leafhoppers to move faster than in the unsprayed East Lansing orchard. It also appears that rate of movement increases with increasing recapture distance from the release point. Wind also influences the rate of movement, as it increases with downwind direction of dispersal. Average rate of dispersal does not imply that the leafhoppers are incapable of moving further and faster than this speed, but that under the conditions present in the field, the leafhopper average movement is a certain straight line distance per unit of time. Visual observations during light capture for marking indicate *P. irroratus* is a strong flyer and easily capable of quick flights over 10 m in length.

The population estimates using the Lincoln Index method gave a rough idea of the leafhopper density and allowed comparisons between generations and sites. Problems with using this method (Southwood 1978) include ignoring the mortality rate, addition of emerging adults, and immigration and emmigration of unmarked individuals from the population. The predicted densities ranged from 0.25 to 0.395 leafhoppers/m^2. A leafhopper density of 0.25/m^2 would yield a population of 2500 leafhoppers/ha, but if 5% of those leafhoppers are infective vectors of X-disease, 125 leafhoppers would be present inoculating their host plants in the area.

P. irroratus outside the orchard are not making significant contributions to endemic orchard populations because of the lack of any cross captures between orchard or edge released leafhoppers. The lack of a daily movement by *P. irroratus* into and out of the orchard contrasts with predicted movement patterns (Mowry & Whalon 1984) and past research on other eastern X-disease vectors which invade orchards often from outside sources (McClure et al. 1982).

Further research is needed to quantify the flight distance, duration, and speed capabilities of *P. irroratus* to complete the picture of the movement and dispersal of this leafhopper. This could include both flight mill and wind tunnel studies to determine flight characteristics such as speed and length of flight, physiological flight capabilities and dispersal behavior tendencies of adult leafhoppers from both generations. One significant concern is the possible non-random selection of *P. irroratus* adults attracted to yellow. This selection could account for behavioral differences not evident in this study. Research into the effects of age, sex and the vector or non-vector status on the behavior of *P. irroratus* is needed.

As the differences in rate of movement between the two sites indicate, current control methods, such as applications of insecticides may actually be increasing X-disease transmission by encouraging leafhopper movement. In

Michigan, cultural practices such as clean-till or short cut, grass-only groundcover, as suggested by Rosenberger (1977) may create unfavorable habitats for *P. irroratus* and may lower populations to a level which would significantly reduce X-disease transmission.

References Cited

Baker, R.J. and J.A. Nelder. 1978. Generalised Linear Interactive Modelling (*GLIM*) System, Release 3, User's Manual. Royal Statistical Society, Rothamsted Experimental Station, Herts, England. 257 pp.

Batschelet, E. 1981. Circular Statistics in Biology. Academic Press, N.Y. 371 pp.

Ito, Y. and K. Miyashita. 1961. Studies on the dispersal of leaf- and planthoppers. I. Dispersal of *Nephotettix cincticeps* Uhler on paddy fields at the flowering stage. Jap. J. of Ecol. 11:181-186.

Larsen, K.J. and M.E. Whalon. 1987. Crepuscular movement of *Paraphlepsius irroratus* (Say)(Homoptera: Cicadellidae), between the groundcover and cherry trees. Env. Entomol. (accepted for publication).

Lincoln, F.C. 1930. Calculating waterfowl abundance on the basis of banding returns. USDA Circ. 118:1-4.

McClure, M.S., T.G. Andreadis, and G.H. Lacy. 1982. Manipultaing orchard groundcover to reduce invasion by leafhopper vectors of peach X-disease. J. of Econ. Entomol. 75:64-68.

Microrim. 1986. R:Base System V User's Manual, Version 1.0. Microrim Inc., Redmond, WA. 413 pp.

Mowry, T.M. and M.E. Whalon. 1984. Comparison of leafhopper species complexes in the groundcover of sprayed and unsprayed peach orchards in Michigan. Great Lakes Entomol. 17:205-209.

Purcell, A.H. and K.G. Suslow. 1982. Dispersal behavior of *Collodonus montanus* (Homoptera: Cicadellidae) in cherry orchards. Env. Entomol. 11:1178-1182.

Rosenberger, D.A. 1977. Leafhopper vectors, epidemiology and control of peach X-disease. Ph.D. Dissertation. Michigan State University, East Lansing, MI. 95 pp.

SAS Institute. 1985. SAS User's Guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary NC. 956 pp.

Southwood, T.R.E. 1978. Ecological Methods. 2nd ed. Chapman and Hall, N.Y. 524 pp.

Taylor, R.A.J. 1978. The relationship between density and distance of dispersing insects. Ecol. Entomol. 3:63-70.

Taylor, R.A.J. 1980. A family of regression equations describing the density distribution of dispersing organisms. Nature 286:53-55.

Tschinkel, W.R. 1985. Behavior and physiology. Pp. 391-435. In: Fundamentals of Insect Physiology. ed. M.S. Blum. John Wiley & Sons, N.Y. 598 pp.

Whitney, S.P. and J.R. Meyer. submitted. Movement between wild and cultivated blueberry by two species of sharpnosed leafhoppers in North Carolina. J. Entomol.

GENERAL CONCLUSION

This research has supplied information regarding the temporal and spatial distribution and dispersal patterns of leafhopper vectors of X-disease. This information is essential in the continuing development of a management plan for X-disease of stone fruits in Michigan.

The monitoring of leafhopper populations has confirmed earlier work that *P. irroratus* is the most common known vector present in Michigan, and that vector population density can change considerably from year to year. Populations of vector leafhoppers vary between different regions, with *P. irroratus* being present in high numbers in the southern portion of the state. Other leafhopper species, such as *S. acutus* and *C. clitellarius*, may be important vectors in other areas of Michigan. The observations of symptomatic chokecherry throughout the state indicate X-disease is present and transmission does occur.

The daily movement cycle of the most common vector species in Michigan, *P. irroratus*, is now understood. The leafhopper is found during the day in the orchard groundcover and has a crepuscular flight into the fruit trees, where it spends the night. Certain fruit trees, such as sweet or sour cherry, are preferred woody hosts of *P. irroratus*.

The dispersal of *P. irroratus* within, into and out of the orchards is now known. The leafhoppers are not moving as fast, or moving into and out of the orchards from outside habitats daily as we had previously hypothesized. Thus, *P. irroratus* populations outside the orchard are not making significant contributions to endemic orchard populations. Factors within the orchard, such as the presence of insecticides or cultural practices seem to influence dispersal. Wind is the major environmental factor in leafhopper dispersal direction, while temperature has a major influence on *P. irroratus* activity.

The presence of symptomatic chokecherry may indicate a need for renewed enforcement of the MDA chokecherry eradication regulations, as chokecherry could be serving as the major source of X-disease inoculum outside the orchards. With the known dispersal behavior of *P. irroratus*, some other vector may be much more effective in importing X-disease inoculum into orchards from outside sources.

Cultural practices, such as clean tilling or short mowing of a groundcover of unfavorable leafhopper host plants, as suggested by Rosenberger (1977), may significantly reduce endemic orchard leafhopper populations. Biological and behavioral timing of insecticide applications is very important. Application during the two adult populations, and use of a quick knock-down insecticide after dark during the post-crepuscular inactive period when the leafhoppers are exposed on the trees could possibly reduce present and future leafhopper populations.

Further information is needed regarding the biology and behavior of the Michigan leafhopper vectors of X-disease. Leafhopper species should be closely examined to determine the most efficient and economically important vector. Effects X-disease MLO's may have on the physiology and behavior of the Michigan vectors following ingestion is unknown. Of particular importance is whether some leafhopper vector species other than *P. irroratus* may be importing X-disease inoculum into orchards from outside sources.

The natural habitat of immature stages of leafhopper vectors, particularly *P. irroratus* must be discovered. This will aid in the search for any natural biological control factors which may exist, including natural enemies such as parasitic wasps or nematodes, and any fungal pathogens. Further work into the flight capabilities and quantification of the effect of color on the behavior of *P. irroratus* is needed to complete our understanding of the movement behavior of this leafhopper.

APPENDIX A

LEAFHOPPER VOUCHER SPECIMENS PLACED IN THE MICHIGAN STATE UNIVERSITY ENTOMOLOGICAL MUSEUM

APPENDIX A

Record of Deposition of Voucher Specimens*

The specimens listed on the following sheet(s) have been deposited in the named museum(s) as samples of those species or other taxa which were used in this research. Voucher recognition labels bearing the Voucher No. have been attached or included in fluid-preserved specimens.

Voucher No.: 1987-02

Title of thesis or dissertation (or other research projects):

Temporal and Spacial Distribution and Dispersal Patterns of *Paraphlepsius irroratus* (Say)(Homoptera: Cicadellidae), a major vector of X-disease in Michigan

Museum(s) where deposited and abbreviations for table on following sheets:

Entomology Museum, Michigan State University (MSU)

Other Museums:

none

Investigator's Name (s) (typed)
Kirk J. Larsen

Date 23 April 1987

*Reference: Yoshimoto, C. M. 1978. Voucher Specimens for Entomology in North America. Bull. Entomol. Soc. Amer. 24:141-42.

Deposit as follows:

Original: Include as Appendix 1 in ribbon copy of thesis or dissertation.
Copies: Included as Appendix 1 in copies of thesis or dissertation.
Museum(s) files.
Research project files.

This form is available from and the Voucher No. is assigned by the Curator, Michigan State University Entomology Museum.

APPENDIX A

Voucher Specimen Data

Page 1 of 1 Pages

Species or other taxon	Label data for specimens collected or used and deposited	Number of: Eggs	Larvae	Nymphs	Pupae	Adults ♀	Adults ♂	Other	Museum where deposited
Paraphlepsius irroratus (Say)	Ingham Co. MI: East Lansing 16 July 1986					4	3		M.S.U.
	VanBuren Co. MI: Lawrence Twp. 22 May 1985						1		M.S.U.
	5 June 1985						1		M.S.U.
	Allegan Co. MI: Fennville 22 May 1985					1			M.S.U.

(Use additional sheets if necessary)

Investigator's Name(s) (typed)

Kirk J. Larsen

Date 23 April 1987

Voucher No. 1987-02

Received the above listed specimens for deposit in the Michigan State University Entomology Museum

[signature] 23 Apr 1987

Curator Date

APPENDIX B

FIELD MONITORING, CREPUSCULAR MOVEMENT, AND LEAFHOPPER DISPERSAL DATA

Table 1. List of X-disease vector leafhopper species and number captured by site and date during the 1985 and 1986 field seasons. Leafhopper species coded as follows: Pi = *Paraphlepsius irroratus*, Sa = *Scaphytopius acutus*, Cc = *Collodonus clitellarius*, Ns = *Norvellina seminuda*, Oi = *Orientus ishidae*, Ff = *Fieberiella florii*, Ss = *Scaphoideus* spp., Gl = *Gyponana lamina*. Page 1 of 4

Site			Species - Number Captured								Total
Date	JDate	DD50	Pi	Sa	Cc	Ns	Oi	Ff	Ss	Gl	
Bainbridge Center Site											
06/24/86	175	736	1								1
07/07/86	188	955	3	3							6
08/04/86	216	1565	1								1
09/03/86	246	1986	1								1
09/16/86	259	2083	1	1							2
10/01/86	274	2349	8	12		2					22
10/17/86	290	2391	15	1							16
10/31/86	304	2441	5	4						1	10
1986 totals			40	21		2				1	64
Clarksville Site											
06/13/85	162	588	1	6							7
06/26/85	176	750	7	13		1					21
07/10/85	190	1012	4	3	1					1	9
08/07/85	217	1539	2						2		4
08/20/85	230	1757	2	3					1		6
09/04/85	245	1996	3	7	1						11
09/18/85	259	2186	12	7		1			1		21
10/03/85	274	2308	17	2							19
10/17/85	288	2353	33	3							36
10/31/85	302	2370	17	1		1					19
11/14/85	316	2379	3		1						4
1985 totals			101	45	3	3			4	1	157
East Lansing Site											
07/23/85	203	1326	4							3	7
08/07/85	217	1598	18	4		1			2	2	27
08/20/85	230	1823	22	3		6				2	33
09/04/85	245	2090	35	2		14		1	1		53
09/18/85	259	2288	57	6		8					71
10/03/85	274	2414	124	1	1						126
10/17/85	288	2453	266	2	3	2					273
10/31/85	302	2470	113	1		14					128
11/14/85	316	2475	2								2
1985 totals			641	19	4	45		1	3	7	720

Table 1. (cont'd.). **Page 2 of 4**

Site Date	JDate	DD50	Species - Number Captured Pi	Sa	Cc	Ns	Oi	Ff	Ss	Gl	Total
Fennville Site											
05/29/85	148	385	6	1							7
06/13/85	163	534	22	4							26
06/26/85	176	700	16	17							33
07/10/85	190	947	6	4	1						11
07/23/85	203	1192	7	4					3	1	15
08/07/85	217	1451	6	8					4	2	20
08/20/85	230	1665	11	10		3	1		4		29
09/04/85	245	1911	17	12	2	3					34
09/18/85	259	2114	46	41	1	2					90
10/03/85	274	2247	59	26		1					86
10/17/85	288	2314	116	18		13					147
10/31/85	302	2336	59	2	2	3					66
11/14/85	316	2345				1					1
1985 totals			373	147	6	26	1		11	3	567
05/28/86	148	318	2								2
06/09/86	160	427		1			3				4
06/24/86	175	708	6	1							7
07/07/86	188	918	5	2							7
07/21/86	202	1256	1					2			3
08/04/86	216	1530	3	1				1			5
09/03/86	246	1968		5					1		6
09/16/86	259	2061	4	5							9
10/01/86	274	2301	22	23	1						46
10/17/86	290	2317	13	3							16
10/31/86	304	2343	6	1		1					8
1986 totals			62	42	1	1	3	3	1		113
Hartford Site											
05/29/85	148	475	4	2	1						7
06/12/85	162	651	4	22							26
06/26/85	176	845	6	20							26
07/10/85	190	1111	1	3						1	5
07/23/85	203	1365	1	2						1	4
08/07/85	217	1640		1					1		2
08/20/85	230	1863	4								4
09/04/85	245	2123	7	12					1		20
09/18/85	259	2325	33	41	2	2			1		79
10/03/85	274	2455	42	33							75
10/17/85	288	2518	134	7	1	1					143
10/31/85	302	2550	39	2	1						42
11/14/85	316	2557	1								1
1985 totals			276	145	5	3			3	2	434

Table 1. (cont'd.).

Site Date	JDate	DD50	Pi	Sa	Cc	Ns	Oi	Ff	Ss	Gl	Total
			Species - Number Captured								
Lawrence Site											
05/29/85	148	491	5	1							6
06/12/85	162	669	11	12							23
06/26/85	176	842	58	27							85
07/10/85	190	1120	8	1				1			10
07/23/85	203	1370	4	5							9
08/20/85	230	1866	1								1
09/04/85	245	2133	3	4					1		8
09/18/85	259	2336	56	65		8			1		130
10/03/85	274	2470	60	39		3					102
10/17/85	288	2535	141	15	1	3					160
10/31/85	302	2562	50	4	1	1					56
11/14/85	316	2571	2								2
1985 totals			399	173	2	15		1	2		592
06/09/86	160	507	1								1
06/24/86	175	757	5	1							6
07/07/86	188	988	13	5							18
07/21/86	202	1337	2								2
09/03/86	246	2119								1	1
09/16/86	259	2251	3	1							4
10/01/86	274	2500	22	8		1					31
10/17/86	290	2539	25	4	1						30
10/31/86	304	2585	18			1					19
1986 totals			89	19	1	2				1	112
Manistee Site											
06/10/86	161	407			1						1
06/26/86	177	576	1								1
07/09/86	190	772	1		2						3
07/22/86	203	1079	3		1						4
08/05/86	217	1350	1		1						2
08/21/86	233	1615		2	1				2		5
09/04/86	247	1785	1	4							5
09/17/86	260	1835	1		2						3
10/03/86	276	1973	18	6	3						27
10/18/86	291	1981	12	5	2						19
11/01/86	305	1989	1								1
1986 totals			39	17	13				2		71
Northport Site											
06/10/86	161	327					1				1
06/26/86	177	483								2	2
08/05/86	217	1189		3							3
08/21/86	233	1438		4							4
09/04/86	247	1589		3							3
09/17/86	260	1650		2							2
10/03/86	276	1800	1	8							9
10/18/86	291	1804		3							3
11/01/86	305	1819	1								1
1986 totals			2	23			1			2	28

Table 1. (cont'd.). **Page 4 of 4**

Site / Date	JDate	DD50	Pi	Sa	Cc	Ns	Oi	Ff	Ss	Gl	Total
Walkerville Site											
07/09/86	190	807	1								1
07/22/86	203	1119	1	1							2
08/05/86	217	1390	2	1							3
08/21/86	233	1647	1						1		2
09/04/86	247	1820	2	1							3
09/17/86	260	1886	6	2							8
10/03/86	276	2089	20	10	1						31
10/18/86	291	2100	11	7	1						19
11/01/86	305	2133	2								2
1986 totals			46	22	2				1		71

Species - Number Captured: Pi, Sa, Cc, Ns, Oi, Ff, Ss, Gl

Table 2. Number of X-disease symptomatic chokecherry observed/5 miles by site and date during the 1986 field season. Southwestern Lower Michigan. Page 1 of 2

Site	Date	Count
Bainbridge Center	05/14/86	0
	05/28/86	1
	06/09/86	1
	06/24/86	2
	07/07/86	2
	07/21/86	13
	08/04/86	13
	08/20/86	29
	09/03/86	27
	09/16/86	49
	10/01/86	34
	10/17/86	35
	10/31/86	39
Lawrence	05/14/86	0
	05/28/86	3
	06/09/86	1
	06/24/86	1
	07/07/86	9
	07/21/86	18
	08/04/86	20
	08/20/86	47
	09/03/86	52
	09/16/86	59
	10/01/86	50
	10/17/86	46
	10/31/86	47
Fennville	05/14/86	0
	05/28/86	2
	06/09/86	2
	06/24/86	1
	07/07/86	2
	07/21/86	9
	08/04/86	7
	08/20/86	35
	09/03/86	43
	09/16/86	55
	10/01/86	49
	10/17/86	53
	10/31/86	52

Table 2. (cont'd.).
Northwestern Lower Michigan. Page 2 of 2

Site	Date	Count
Walkerville	05/16/86	0
	05/30/86	0
	06/10/86	0
	06/26/86	0
	07/09/86	1
	07/22/86	1
	08/05/86	11
	08/21/86	13
	09/04/86	24
	09/17/86	37
	10/03/86	33
	10/18/86	36
Manistee	05/16/86	0
	05/30/86	1
	06/10/86	1
	06/26/86	0
	07/09/86	0
	07/22/86	1
	08/05/86	8
	08/21/86	17
	09/04/86	23
	09/17/86	27
	10/03/86	28
	10/18/86	42
Northport	05/16/86	0
	05/30/86	0
	06/10/86	0
	06/26/86	0
	07/09/86	0
	07/22/86	1
	08/05/86	11
	08/21/86	12
	09/04/86	32
	09/17/86	36
	10/03/86	43
	10/18/86	49

Table 3. Crepuscular Movement Data. Number of *P. irroratus* leafhoppers captured by subhabitat and time.
Generation: 1 Replicate: 1 = July 3-4, 1985 Page 1 of 6

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
1 1 1 0000 0	1 1 2 0000 34	1 1 3 0000 6	1 1 4 0000 0	1 1 0000 0
1 1 1 0030 0	1 1 2 0030 28	1 1 3 0030 7	1 1 4 0030 0	1 1 0030 0
1 1 1 0100 0	1 1 2 0100 33	1 1 3 0100 6	1 1 4 0100 0	1 1 0100 0
1 1 1 0130 0	1 1 2 0130 32	1 1 3 0130 3	1 1 4 0130 0	1 1 0130 0
1 1 1 0200 0	1 1 2 0200 30	1 1 3 0200 9	1 1 4 0200 0	1 1 0200 0
1 1 1 0230 0	1 1 2 0230 35	1 1 3 0230 8	1 1 4 0230 0	1 1 0230 0
1 1 1 0300 0	1 1 2 0300 33	1 1 3 0300 7	1 1 4 0300 0	1 1 0300 0
1 1 1 0330 0	1 1 2 0330 29	1 1 3 0330 5	1 1 4 0330 0	1 1 0330 0
1 1 1 0400 0	1 1 2 0400 30	1 1 3 0400 1	1 1 4 0400 0	1 1 0400 0
1 1 1 0430 0	1 1 2 0430 24	1 1 3 0430 4	1 1 4 0430 0	1 1 0430 0
1 1 1 0500 0	1 1 2 0500 27	1 1 3 0500 3	1 1 4 0500 0	1 1 0500 0
1 1 1 0530 0	1 1 2 0530 29	1 1 3 0530 1	1 1 4 0530 0	1 1 0530 0
1 1 1 0600 1	1 1 2 0600 21	1 1 3 0600 4	1 1 4 0600 0	1 1 0600 0
1 1 1 0630 0	1 1 2 0630 6	1 1 3 0630 2	1 1 4 0630 0	1 1 0630 0
1 1 1 0700 0	1 1 2 0700 2	1 1 3 0700 0	1 1 4 0700 0	1 1 0700 0
1 1 1 0730 3	1 1 2 0730 1	1 1 3 0730 0	1 1 4 0730 0	1 1 0730 0
1 1 1 0800 1	1 1 2 0800 0	1 1 3 0800 1	1 1 4 0800 0	1 1 0800 0
1 1 1 0830 2	1 1 2 0830 1	1 1 3 0830 0	1 1 4 0830 0	1 1 0830 0
1 1 1 0900 4	1 1 2 0900 0	1 1 3 0900 2	1 1 4 0900 0	1 1 0900 0
1 1 1 0930 3	1 1 2 0930 2	1 1 3 0930 0	1 1 4 0930 0	1 1 0930 0
1 1 1 1000 4	1 1 2 1000 0	1 1 3 1000 0	1 1 4 1000 0	1 1 1000 0
1 1 1 1030 5	1 1 2 1030 0	1 1 3 1030 1	1 1 4 1030 0	1 1 1030 0
1 1 1 1100 3	1 1 2 1100 0	1 1 3 1100 0	1 1 4 1100 0	1 1 1100 0
1 1 1 1130 6	1 1 2 1130 0	1 1 3 1130 0	1 1 4 1130 0	1 1 1130 0
1 1 1 1200 7	1 1 2 1200 0	1 1 3 1200 0	1 1 4 1200 0	1 1 1200 0
1 1 1 1230 7	1 1 2 1230 0	1 1 3 1230 0	1 1 4 1230 0	1 1 1230 0
1 1 1 1300 9	1 1 2 1300 0	1 1 3 1300 0	1 1 4 1300 0	1 1 1300 0
1 1 1 1330 8	1 1 2 1330 0	1 1 3 1330 0	1 1 4 1330 0	1 1 1330 0
1 1 1 1400 11	1 1 2 1400 1	1 1 3 1400 0	1 1 4 1400 0	1 1 1400 0
1 1 1 1430 9	1 1 2 1430 0	1 1 3 1430 0	1 1 4 1430 0	1 1 1430 0
1 1 1 1500 10	1 1 2 1500 0	1 1 3 1500 0	1 1 4 1500 0	1 1 1500 0
1 1 1 1530 8	1 1 2 1530 1	1 1 3 1530 0	1 1 4 1530 0	1 1 1530 0
1 1 1 1600 10	1 1 2 1600 0	1 1 3 1600 0	1 1 4 1600 0	1 1 1600 0
1 1 1 1630 10	1 1 2 1630 0	1 1 3 1630 0	1 1 4 1630 0	1 1 1630 0
1 1 1 1700 9	1 1 2 1700 0	1 1 3 1700 0	1 1 4 1700 0	1 1 1700 0
1 1 1 1730 10	1 1 2 1730 0	1 1 3 1730 0	1 1 4 1730 0	1 1 1730 0
1 1 1 1800 11	1 1 2 1800 1	1 1 3 1800 0	1 1 4 1800 1	1 1 1800 0
1 1 1 1830 8	1 1 2 1830 0	1 1 3 1830 2	1 1 4 1830 0	1 1 1830 0
1 1 1 1900 9	1 1 2 1900 0	1 1 3 1900 0	1 1 4 1900 0	1 1 1900 0
1 1 1 1930 10	1 1 2 1930 0	1 1 3 1930 0	1 1 4 1930 0	1 1 1930 0
1 1 1 2000 9	1 1 2 2000 0	1 1 3 2000 0	1 1 4 2000 0	1 1 2000 0
1 1 1 2030 10	1 1 2 2030 1	1 1 3 2030 0	1 1 4 2030 0	1 1 2030 0
1 1 1 2100 10	1 1 2 2100 1	1 1 3 2100 0	1 1 4 2100 0	1 1 2100 0
1 1 1 2130 7	1 1 2 2130 2	1 1 3 2130 1	1 1 4 2130 0	1 1 2130 5
1 1 1 2200 6	1 1 2 2200 28	1 1 3 2200 7	1 1 4 2200 1	1 1 2200 168
1 1 1 2230 2	1 1 2 2230 36	1 1 3 2230 3	1 1 4 2230 0	1 1 2230 5
1 1 1 2300 1	1 1 2 2300 38	1 1 3 2300 5	1 1 4 2300 3	1 1 2300 2
1 1 1 2330 0	1 1 2 2330 31	1 1 3 2330 8	1 1 4 2330 0	1 1 2330 0

Table 3 (cont'd.).
Generation: 1 Replicate: 2 = July 8-9, 1985

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
1 2 1 0000 0	1 2 2 0000 23	1 2 3 0000 13	1 2 4 0000 0	1 2 0000 1
1 2 1 0030 0	1 2 2 0030 21	1 2 3 0030 10	1 2 4 0030 0	1 2 0030 0
1 2 1 0100 0	1 2 2 0100 20	1 2 3 0100 12	1 2 4 0100 0	1 2 0100 1
1 2 1 0130 0	1 2 2 0130 22	1 2 3 0130 17	1 2 4 0130 0	1 2 0130 0
1 2 1 0200 1	1 2 2 0200 19	1 2 3 0200 18	1 2 4 0200 0	1 2 0200 0
1 2 1 0230 0	1 2 2 0230 18	1 2 3 0230 15	1 2 4 0230 0	1 2 0230 0
1 2 1 0300 0	1 2 2 0300 23	1 2 3 0300 14	1 2 4 0300 0	1 2 0300 0
1 2 1 0330 0	1 2 2 0330 20	1 2 3 0330 16	1 2 4 0330 0	1 2 0330 0
1 2 1 0400 0	1 2 2 0400 19	1 2 3 0400 18	1 2 4 0400 0	1 2 0400 0
1 2 1 0430 0	1 2 2 0430 21	1 2 3 0430 19	1 2 4 0430 0	1 2 0430 1
1 2 1 0500 0	1 2 2 0500 18	1 2 3 0500 17	1 2 4 0500 0	1 2 0500 0
1 2 1 0530 1	1 2 2 0530 13	1 2 3 0530 15	1 2 4 0530 0	1 2 0530 0
1 2 1 0600 0	1 2 2 0600 18	1 2 3 0600 4	1 2 4 0600 0	1 2 0600 0
1 2 1 0630 3	1 2 2 0630 8	1 2 3 0630 4	1 2 4 0630 0	1 2 0630 0
1 2 1 0700 5	1 2 2 0700 2	1 2 3 0700 1	1 2 4 0700 1	1 2 0700 0
1 2 1 0730 2	1 2 2 0730 2	1 2 3 0730 1	1 2 4 0730 0	1 2 0730 0
1 2 1 0800 1	1 2 2 0800 1	1 2 3 0800 0	1 2 4 0800 0	1 2 0800 0
1 2 1 0830 3	1 2 2 0830 0	1 2 3 0830 1	1 2 4 0830 0	1 2 0830 0
1 2 1 0900 2	1 2 2 0900 0	1 2 3 0900 0	1 2 4 0900 0	1 2 0900 0
1 2 1 0930 4	1 2 2 0930 1	1 2 3 0930 0	1 2 4 0930 0	1 2 0930 0
1 2 1 1000 3	1 2 2 1000 0	1 2 3 1000 0	1 2 4 1000 0	1 2 1000 0
1 2 1 1030 2	1 2 2 1030 0	1 2 3 1030 0	1 2 4 1030 0	1 2 1030 0
1 2 1 1100 5	1 2 2 1100 0	1 2 3 1100 0	1 2 4 1100 0	1 2 1100 0
1 2 1 1130 4	1 2 2 1130 0	1 2 3 1130 1	1 2 4 1130 1	1 2 1130 0
1 2 1 1200 6	1 2 2 1200 0	1 2 3 1200 0	1 2 4 1200 0	1 2 1200 0
1 2 1 1230 7	1 2 2 1230 0	1 2 3 1230 0	1 2 4 1230 0	1 2 1230 0
1 2 1 1300 4	1 2 2 1300 0	1 2 3 1300 0	1 2 4 1300 0	1 2 1300 0
1 2 1 1330 6	1 2 2 1330 1	1 2 3 1330 0	1 2 4 1330 0	1 2 1330 0
1 2 1 1400 5	1 2 2 1400 0	1 2 3 1400 0	1 2 4 1400 0	1 2 1400 0
1 2 1 1430 8	1 2 2 1430 0	1 2 3 1430 0	1 2 4 1430 0	1 2 1430 0
1 2 1 1500 9	1 2 2 1500 0	1 2 3 1500 0	1 2 4 1500 0	1 2 1500 0
1 2 1 1530 8	1 2 2 1530 0	1 2 3 1530 0	1 2 4 1530 0	1 2 1530 0
1 2 1 1600 4	1 2 2 1600 2	1 2 3 1600 0	1 2 4 1600 0	1 2 1600 0
1 2 1 1630 5	1 2 2 1630 0	1 2 3 1630 0	1 2 4 1630 0	1 2 1630 0
1 2 1 1700 3	1 2 2 1700 0	1 2 3 1700 0	1 2 4 1700 0	1 2 1700 0
1 2 1 1730 8	1 2 2 1730 0	1 2 3 1730 0	1 2 4 1730 0	1 2 1730 0
1 2 1 1800 5	1 2 2 1800 1	1 2 3 1800 0	1 2 4 1800 0	1 2 1800 0
1 2 1 1830 4	1 2 2 1830 0	1 2 3 1830 0	1 2 4 1830 0	1 2 1830 0
1 2 1 1900 6	1 2 2 1900 0	1 2 3 1900 1	1 2 4 1900 0	1 2 1900 0
1 2 1 1930 7	1 2 2 1930 0	1 2 3 1930 0	1 2 4 1930 0	1 2 1930 0
1 2 1 2000 5	1 2 2 2000 0	1 2 3 2000 0	1 2 4 2000 1	1 2 2000 0
1 2 1 2030 7	1 2 2 2030 0	1 2 3 2030 0	1 2 4 2030 0	1 2 2030 0
1 2 1 2100 6	1 2 2 2100 1	1 2 3 2100 0	1 2 4 2100 0	1 2 2100 0
1 2 1 2130 2	1 2 2 2130 6	1 2 3 2130 3	1 2 4 2130 0	1 2 2130 1
1 2 1 2200 1	1 2 2 2200 18	1 2 3 2200 6	1 2 4 2200 0	1 2 2200 225
1 2 1 2230 2	1 2 2 2230 19	1 2 3 2230 7	1 2 4 2230 0	1 2 2230 32
1 2 1 2300 1	1 2 2 2300 14	1 2 3 2300 10	1 2 4 2300 0	1 2 2300 17
1 2 1 2330 0	1 2 2 2330 11	1 2 3 2330 11	1 2 4 2330 0	1 2 2330 3

Table 3 (cont'd.).
Generation: 1 Replicate: 3 = July 17-18, 1985 Page 3 of 6

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
1 3 1 0000 0	1 3 2 0000 25	1 3 3 0000 6	1 3 4 0000 0	1 3 0000 1
1 3 1 0030 0	1 3 2 0030 24	1 3 3 0030 7	1 3 4 0030 0	1 3 0030 0
1 3 1 0100 0	1 3 2 0100 26	1 3 3 0100 7	1 3 4 0100 0	1 3 0100 0
1 3 1 0130 0	1 3 2 0130 23	1 3 3 0130 4	1 3 4 0130 0	1 3 0130 1
1 3 1 0200 1	1 3 2 0200 22	1 3 3 0200 0	1 3 4 0200 0	1 3 0200 0
1 3 1 0230 0	1 3 2 0230 23	1 3 3 0230 5	1 3 4 0230 0	1 3 0230 0
1 3 1 0300 0	1 3 2 0300 19	1 3 3 0300 3	1 3 4 0300 0	1 3 0300 0
1 3 1 0330 0	1 3 2 0330 20	1 3 3 0330 4	1 3 4 0330 0	1 3 0330 0
1 3 1 0400 0	1 3 2 0400 17	1 3 3 0400 1	1 3 4 0400 0	1 3 0400 0
1 3 1 0430 0	1 3 2 0430 9	1 3 3 0430 6	1 3 4 0430 0	1 3 0430 1
1 3 1 0500 1	1 3 2 0500 4	1 3 3 0500 0	1 3 4 0500 0	1 3 0500 0
1 3 1 0530 0	1 3 2 0530 7	1 3 3 0530 3	1 3 4 0530 0	1 3 0530 0
1 3 1 0600 1	1 3 2 0600 2	1 3 3 0600 1	1 3 4 0600 0	1 3 0600 0
1 3 1 0630 0	1 3 2 0630 3	1 3 3 0630 1	1 3 4 0630 0	1 3 0630 0
1 3 1 0700 3	1 3 2 0700 2	1 3 3 0700 0	1 3 4 0700 0	1 3 0700 0
1 3 1 0730 2	1 3 2 0730 4	1 3 3 0730 1	1 3 4 0730 0	1 3 0730 0
1 3 1 0800 2	1 3 2 0800 0	1 3 3 0800 0	1 3 4 0800 0	1 3 0800 0
1 3 1 0830 3	1 3 2 0830 1	1 3 3 0830 1	1 3 4 0830 0	1 3 0830 0
1 3 1 0900 2	1 3 2 0900 0	1 3 3 0900 0	1 3 4 0900 0	1 3 0900 0
1 3 1 0930 3	1 3 2 0930 1	1 3 3 0930 0	1 3 4 0930 0	1 3 0930 0
1 3 1 1000 4	1 3 2 1000 0	1 3 3 1000 0	1 3 4 1000 0	1 3 1000 0
1 3 1 1030 4	1 3 2 1030 0	1 3 3 1030 0	1 3 4 1030 0	1 3 1030 0
1 3 1 1100 3	1 3 2 1100 0	1 3 3 1100 0	1 3 4 1100 0	1 3 1100 0
1 3 1 1130 4	1 3 2 1130 1	1 3 3 1130 0	1 3 4 1130 0	1 3 1130 0
1 3 1 1200 5	1 3 2 1200 0	1 3 3 1200 0	1 3 4 1200 0	1 3 1200 0
1 3 1 1230 6	1 3 2 1230 0	1 3 3 1230 0	1 3 4 1230 0	1 3 1230 0
1 3 1 1300 4	1 3 2 1300 0	1 3 3 1300 1	1 3 4 1300 0	1 3 1300 0
1 3 1 1330 6	1 3 2 1330 1	1 3 3 1330 0	1 3 4 1330 0	1 3 1330 0
1 3 1 1400 5	1 3 2 1400 0	1 3 3 1400 0	1 3 4 1400 0	1 3 1400 0
1 3 1 1430 7	1 3 2 1430 0	1 3 3 1430 0	1 3 4 1430 0	1 3 1430 0
1 3 1 1500 8	1 3 2 1500 0	1 3 3 1500 0	1 3 4 1500 0	1 3 1500 0
1 3 1 1530 3	1 3 2 1530 1	1 3 3 1530 0	1 3 4 1530 0	1 3 1530 0
1 3 1 1600 4	1 3 2 1600 0	1 3 3 1600 0	1 3 4 1600 0	1 3 1600 0
1 3 1 1630 2	1 3 2 1630 0	1 3 3 1630 0	1 3 4 1630 0	1 3 1630 0
1 3 1 1700 6	1 3 2 1700 0	1 3 3 1700 0	1 3 4 1700 0	1 3 1700 0
1 3 1 1730 3	1 3 2 1730 0	1 3 3 1730 0	1 3 4 1730 0	1 3 1730 0
1 3 1 1800 7	1 3 2 1800 0	1 3 3 1800 0	1 3 4 1800 0	1 3 1800 0
1 3 1 1830 5	1 3 2 1830 0	1 3 3 1830 0	1 3 4 1830 0	1 3 1830 0
1 3 1 1900 6	1 3 2 1900 1	1 3 3 1900 0	1 3 4 1900 1	1 3 1900 0
1 3 1 1930 5	1 3 2 1930 0	1 3 3 1930 0	1 3 4 1930 0	1 3 1930 0
1 3 1 2000 4	1 3 2 2000 0	1 3 3 2000 1	1 3 4 2000 1	1 3 2000 0
1 3 1 2030 5	1 3 2 2030 1	1 3 3 2030 0	1 3 4 2030 0	1 3 2030 0
1 3 1 2100 3	1 3 2 2100 1	1 3 3 2100 0	1 3 4 2100 0	1 3 2100 0
1 3 1 2130 2	1 3 2 2130 2	1 3 3 2130 0	1 3 4 2130 0	1 3 2130 2
1 3 1 2200 2	1 3 2 2200 4	1 3 3 2200 1	1 3 4 2200 0	1 3 2200 119
1 3 1 2230 1	1 3 2 2230 13	1 3 3 2230 5	1 3 4 2230 0	1 3 2230 20
1 3 1 2300 1	1 3 2 2300 19	1 3 3 2300 3	1 3 4 2300 0	1 3 2300 3
1 3 1 2330 0	1 3 2 2330 23	1 3 3 2330 7	1 3 4 2330 0	1 3 2330 2

Table 3 (cont'd.).
Generation: 2   Replicate:1 = Sept. 16-17, 1985   Page 4 of 6

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
2 1 1 0000 0	2 1 2 0000 6	2 1 3 0000 14	2 1 4 0000 0	2 1 0000 0
2 1 1 0030 0	2 1 2 0030 15	2 1 3 0030 15	2 1 4 0030 0	2 1 0030 0
2 1 1 0100 0	2 1 2 0100 11	2 1 3 0100 18	2 1 4 0100 0	2 1 0100 0
2 1 1 0130 0	2 1 2 0130 13	2 1 3 0130 16	2 1 4 0130 0	2 1 0130 0
2 1 1 0200 0	2 1 2 0200 17	2 1 3 0200 14	2 1 4 0200 0	2 1 0200 0
2 1 1 0230 0	2 1 2 0230 12	2 1 3 0230 16	2 1 4 0230 0	2 1 0230 0
2 1 1 0300 0	2 1 2 0300 14	2 1 3 0300 15	2 1 4 0300 0	2 1 0300 0
2 1 1 0330 0	2 1 2 0330 13	2 1 3 0330 16	2 1 4 0330 0	2 1 0330 0
2 1 1 0400 0	2 1 2 0400 14	2 1 3 0400 16	2 1 4 0400 0	2 1 0400 0
2 1 1 0430 0	2 1 2 0430 13	2 1 3 0430 16	2 1 4 0430 0	2 1 0430 0
2 1 1 0500 0	2 1 2 0500 14	2 1 3 0500 16	2 1 4 0500 0	2 1 0500 0
2 1 1 0530 1	2 1 2 0530 13	2 1 3 0530 15	2 1 4 0530 0	2 1 0530 0
2 1 1 0600 0	2 1 2 0600 13	2 1 3 0600 14	2 1 4 0600 0	2 1 0600 0
2 1 1 0630 0	2 1 2 0630 13	2 1 3 0630 12	2 1 4 0630 0	2 1 0630 0
2 1 1 0700 0	2 1 2 0700 9	2 1 3 0700 11	2 1 4 0700 0	2 1 0700 0
2 1 1 0730 2	2 1 2 0730 5	2 1 3 0730 8	2 1 4 0730 0	2 1 0730 0
2 1 1 0800 1	2 1 2 0800 1	2 1 3 0800 2	2 1 4 0800 0	2 1 0800 0
2 1 1 0830 4	2 1 2 0830 2	2 1 3 0830 0	2 1 4 0830 0	2 1 0830 0
2 1 1 0900 5	2 1 2 0900 0	2 1 3 0900 0	2 1 4 0900 0	2 1 0900 0
2 1 1 0930 2	2 1 2 0930 0	2 1 3 0930 0	2 1 4 0930 0	2 1 0930 0
2 1 1 1000 1	2 1 2 1000 0	2 1 3 1000 0	2 1 4 1000 0	2 1 1000 0
2 1 1 1030 3	2 1 2 1030 0	2 1 3 1030 0	2 1 4 1030 0	2 1 1030 0
2 1 1 1100 4	2 1 2 1100 0	2 1 3 1100 0	2 1 4 1100 0	2 1 1100 0
2 1 1 1130 6	2 1 2 1130 0	2 1 3 1130 0	2 1 4 1130 0	2 1 1130 0
2 1 1 1200 5	2 1 2 1200 0	2 1 3 1200 0	2 1 4 1200 0	2 1 1200 0
2 1 1 1230 4	2 1 2 1230 0	2 1 3 1230 0	2 1 4 1230 0	2 1 1230 0
2 1 1 1300 5	2 1 2 1300 0	2 1 3 1300 0	2 1 4 1300 0	2 1 1300 0
2 1 1 1330 4	2 1 2 1330 0	2 1 3 1330 0	2 1 4 1330 0	2 1 1330 0
2 1 1 1400 1	2 1 2 1400 0	2 1 3 1400 1	2 1 4 1400 0	2 1 1400 0
2 1 1 1430 6	2 1 2 1430 0	2 1 3 1430 0	2 1 4 1430 0	2 1 1430 0
2 1 1 1500 5	2 1 2 1500 0	2 1 3 1500 0	2 1 4 1500 0	2 1 1500 0
2 1 1 1530 7	2 1 2 1530 1	2 1 3 1530 0	2 1 4 1530 0	2 1 1530 0
2 1 1 1600 1	2 1 2 1600 0	2 1 3 1600 0	2 1 4 1600 0	2 1 1600 0
2 1 1 1630 5	2 1 2 1630 0	2 1 3 1630 0	2 1 4 1630 2	2 1 1630 0
2 1 1 1700 5	2 1 2 1700 0	2 1 3 1700 0	2 1 4 1700 0	2 1 1700 0
2 1 1 1730 6	2 1 2 1730 0	2 1 3 1730 0	2 1 4 1730 0	2 1 1730 0
2 1 1 1800 4	2 1 2 1800 0	2 1 3 1800 0	2 1 4 1800 1	2 1 1800 0
2 1 1 1830 3	2 1 2 1830 0	2 1 3 1830 0	2 1 4 1830 0	2 1 1830 0
2 1 1 1900 5	2 1 2 1900 1	2 1 3 1900 2	2 1 4 1900 0	2 1 1900 0
2 1 1 1930 2	2 1 2 1930 7	2 1 3 1930 8	2 1 4 1930 1	2 1 1930 0
2 1 1 2000 1	2 1 2 2000 9	2 1 3 2000 15	2 1 4 2000 0	2 1 2000 2
2 1 1 2030 2	2 1 2 2030 10	2 1 3 2030 17	2 1 4 2030 0	2 1 2030 132
2 1 1 2100 1	2 1 2 2100 8	2 1 3 2100 18	2 1 4 2100 0	2 1 2100 11
2 1 1 2130 0	2 1 2 2130 13	2 1 3 2130 15	2 1 4 2130 0	2 1 2130 6
2 1 1 2200 1	2 1 2 2200 12	2 1 3 2200 16	2 1 4 2200 0	2 1 2200 0
2 1 1 2230 0	2 1 2 2230 13	2 1 3 2230 15	2 1 4 2230 0	2 1 2230 1
2 1 1 2300 1	2 1 2 2300 11	2 1 3 2300 15	2 1 4 2300 0	2 1 2300 0
2 1 1 2330 0	2 1 2 2330 14	2 1 3 2330 15	2 1 4 2330 0	2 1 2330 0

Table 3 (cont'd.).

Generation: 2 Replicate:2 = Sept. 17-18, 1985 Page 5 of 6

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
2 2 1 0000 0	2 2 2 0000 5	2 2 3 0000 6	2 2 4 0000 0	2 2 0000 0
2 2 1 0030 1	2 2 2 0030 4	2 2 3 0030 7	2 2 4 0030 0	2 2 0030 0
2 2 1 0100 0	2 2 2 0100 4	2 2 3 0100 8	2 2 4 0100 0	2 2 0100 0
2 2 1 0130 0	2 2 2 0130 3	2 2 3 0130 7	2 2 4 0130 0	2 2 0130 0
2 2 1 0200 0	2 2 2 0200 2	2 2 3 0200 7	2 2 4 0200 0	2 2 0200 0
2 2 1 0230 0	2 2 2 0230 3	2 2 3 0230 6	2 2 4 0230 0	2 2 0230 0
2 2 1 0300 0	2 2 2 0300 5	2 2 3 0300 7	2 2 4 0300 0	2 2 0300 0
2 2 1 0330 0	2 2 2 0330 4	2 2 3 0330 6	2 2 4 0330 0	2 2 0330 0
2 2 1 0400 0	2 2 2 0400 4	2 2 3 0400 6	2 2 4 0400 0	2 2 0400 0
2 2 1 0430 0	2 2 2 0430 3	2 2 3 0430 5	2 2 4 0430 0	2 2 0430 0
2 2 1 0500 0	2 2 2 0500 6	2 2 3 0500 7	2 2 4 0500 0	2 2 0500 0
2 2 1 0530 0	2 2 2 0530 5	2 2 3 0530 6	2 2 4 0530 0	2 2 0530 0
2 2 1 0600 0	2 2 2 0600 5	2 2 3 0600 4	2 2 4 0600 0	2 2 0600 0
2 2 1 0630 0	2 2 2 0630 5	2 2 3 0630 3	2 2 4 0630 0	2 2 0630 0
2 2 1 0700 0	2 2 2 0700 2	2 2 3 0700 2	2 2 4 0700 0	2 2 0700 0
2 2 1 0730 1	2 2 2 0730 0	2 2 3 0730 1	2 2 4 0730 0	2 2 0730 0
2 2 1 0800 2	2 2 2 0800 1	2 2 3 0800 0	2 2 4 0800 0	2 2 0800 0
2 2 1 0830 3	2 2 2 0830 1	2 2 3 0830 0	2 2 4 0830 0	2 2 0830 0
2 2 1 0900 4	2 2 2 0900 0	2 2 3 0900 0	2 2 4 0900 0	2 2 0900 0
2 2 1 0930 4	2 2 2 0930 1	2 2 3 0930 0	2 2 4 0930 0	2 2 0930 0
2 2 1 1000 4	2 2 2 1000 0	2 2 3 1000 0	2 2 4 1000 0	2 2 1000 0
2 2 1 1030 5	2 2 2 1030 0	2 2 3 1030 0	2 2 4 1030 0	2 2 1030 0
2 2 1 1100 6	2 2 2 1100 0	2 2 3 1100 0	2 2 4 1100 0	2 2 1100 0
2 2 1 1130 5	2 2 2 1130 0	2 2 3 1130 0	2 2 4 1130 0	2 2 1130 0
2 2 1 1200 5	2 2 2 1200 0	2 2 3 1200 0	2 2 4 1200 0	2 2 1200 0
2 2 1 1230 5	2 2 2 1230 0	2 2 3 1230 0	2 2 4 1230 0	2 2 1230 0
2 2 1 1300 4	2 2 2 1300 0	2 2 3 1300 0	2 2 4 1300 0	2 2 1300 0
2 2 1 1330 6	2 2 2 1330 0	2 2 3 1330 1	2 2 4 1330 0	2 2 1330 0
2 2 1 1400 3	2 2 2 1400 0	2 2 3 1400 0	2 2 4 1400 0	2 2 1400 0
2 2 1 1430 5	2 2 2 1430 0	2 2 3 1430 0	2 2 4 1430 0	2 2 1430 0
2 2 1 1500 5	2 2 2 1500 1	2 2 3 1500 0	2 2 4 1500 0	2 2 1500 0
2 2 1 1530 7	2 2 2 1530 0	2 2 3 1530 0	2 2 4 1530 0	2 2 1530 0
2 2 1 1600 4	2 2 2 1600 0	2 2 3 1600 0	2 2 4 1600 0	2 2 1600 0
2 2 1 1630 8	2 2 2 1630 0	2 2 3 1630 0	2 2 4 1630 0	2 2 1630 0
2 2 1 1700 7	2 2 2 1700 1	2 2 3 1700 0	2 2 4 1700 0	2 2 1700 0
2 2 1 1730 5	2 2 2 1730 0	2 2 3 1730 1	2 2 4 1730 0	2 2 1730 0
2 2 1 1800 4	2 2 2 1800 0	2 2 3 1800 0	2 2 4 1800 0	2 2 1800 0
2 2 1 1830 6	2 2 2 1830 0	2 2 3 1830 0	2 2 4 1830 0	2 2 1830 0
2 2 1 1900 6	2 2 2 1900 0	2 2 3 1900 0	2 2 4 1900 0	2 2 1900 0
2 2 1 1930 5	2 2 2 1930 0	2 2 3 1930 0	2 2 4 1930 0	2 2 1930 0
2 2 1 2000 4	2 2 2 2000 2	2 2 3 2000 1	2 2 4 2000 0	2 2 2000 10
2 2 1 2030 2	2 2 2 2030 3	2 2 3 2030 1	2 2 4 2030 0	2 2 2030 249
2 2 1 2100 0	2 2 2 2100 3	2 2 3 2100 2	2 2 4 2100 0	2 2 2100 27
2 2 1 2130 1	2 2 2 2130 4	2 2 3 2130 3	2 2 4 2130 0	2 2 2130 12
2 2 1 2200 0	2 2 2 2200 3	2 2 3 2200 5	2 2 4 2200 0	2 2 2200 0
2 2 1 2230 1	2 2 2 2230 5	2 2 3 2230 6	2 2 4 2230 0	2 2 2230 0
2 2 1 2300 0	2 2 2 2300 5	2 2 3 2300 7	2 2 4 2300 0	2 2 2300 0
2 2 1 2330 0	2 2 2 2330 4	2 2 3 2330 7	2 2 4 2330 0	2 2 2330 0

Table 3 (cont'd.).

Generation: 2   Replicate:3 = Sept. 19-20, 1985   Page 6 of 6

Groundcover	Sour Cherry	Sweet Cherry	Apple	Light Trap
2 3 1 0000 1	2 3 2 0000 21	2 3 3 0000 28	2 3 4 0000 0	2 3 0000 0
2 3 1 0030 0	2 3 2 0030 19	2 3 3 0030 32	2 3 4 0030 0	2 3 0030 0
2 3 1 0100 0	2 3 2 0100 20	2 3 3 0100 29	2 3 4 0100 0	2 3 0100 0
2 3 1 0130 0	2 3 2 0130 18	2 3 3 0130 26	2 3 4 0130 0	2 3 0130 0
2 3 1 0200 0	2 3 2 0200 19	2 3 3 0200 24	2 3 4 0200 0	2 3 0200 0
2 3 1 0230 0	2 3 2 0230 18	2 3 3 0230 30	2 3 4 0230 0	2 3 0230 0
2 3 1 0300 0	2 3 2 0300 17	2 3 3 0300 28	2 3 4 0300 0	2 3 0300 0
2 3 1 0330 0	2 3 2 0330 16	2 3 3 0330 23	2 3 4 0330 0	2 3 0330 0
2 3 1 0400 0	2 3 2 0400 17	2 3 3 0400 21	2 3 4 0400 0	2 3 0400 0
2 3 1 0430 0	2 3 2 0430 15	2 3 3 0430 20	2 3 4 0430 0	2 3 0430 0
2 3 1 0500 0	2 3 2 0500 16	2 3 3 0500 19	2 3 4 0500 0	2 3 0500 0
2 3 1 0530 0	2 3 2 0530 14	2 3 3 0530 24	2 3 4 0530 0	2 3 0530 0
2 3 1 0600 0	2 3 2 0600 15	2 3 3 0600 23	2 3 4 0600 0	2 3 0600 0
2 3 1 0630 1	2 3 2 0630 13	2 3 3 0630 21	2 3 4 0630 0	2 3 0630 0
2 3 1 0700 1	2 3 2 0700 14	2 3 3 0700 6	2 3 4 0700 0	2 3 0700 0
2 3 1 0730 2	2 3 2 0730 11	2 3 3 0730 7	2 3 4 0730 0	2 3 0730 0
2 3 1 0800 3	2 3 2 0800 2	2 3 3 0800 1	2 3 4 0800 0	2 3 0800 0
2 3 1 0830 4	2 3 2 0830 1	2 3 3 0830 2	2 3 4 0830 0	2 3 0830 0
2 3 1 0900 4	2 3 2 0900 1	2 3 3 0900 0	2 3 4 0900 0	2 3 0900 0
2 3 1 0930 5	2 3 2 0930 0	2 3 3 0930 0	2 3 4 0930 0	2 3 0930 0
2 3 1 1000 3	2 3 2 1000 0	2 3 3 1000 0	2 3 4 1000 0	2 3 1000 0
2 3 1 1030 4	2 3 2 1030 0	2 3 3 1030 0	2 3 4 1030 1	2 3 1030 0
2 3 1 1100 5	2 3 2 1100 0	2 3 3 1100 0	2 3 4 1100 0	2 3 1100 0
2 3 1 1130 6	2 3 2 1130 0	2 3 3 1130 0	2 3 4 1130 0	2 3 1130 0
2 3 1 1200 7	2 3 2 1200 0	2 3 3 1200 0	2 3 4 1200 0	2 3 1200 0
2 3 1 1230 8	2 3 2 1230 0	2 3 3 1230 0	2 3 4 1230 0	2 3 1230 0
2 3 1 1300 6	2 3 2 1300 0	2 3 3 1300 0	2 3 4 1300 0	2 3 1300 0
2 3 1 1330 7	2 3 2 1330 1	2 3 3 1330 0	2 3 4 1330 0	2 3 1330 0
2 3 1 1400 8	2 3 2 1400 0	2 3 3 1400 0	2 3 4 1400 0	2 3 1400 0
2 3 1 1430 6	2 3 2 1430 0	2 3 3 1430 1	2 3 4 1430 0	2 3 1430 0
2 3 1 1500 7	2 3 2 1500 0	2 3 3 1500 0	2 3 4 1500 0	2 3 1500 0
2 3 1 1530 6	2 3 2 1530 0	2 3 3 1530 0	2 3 4 1530 0	2 3 1530 0
2 3 1 1600 7	2 3 2 1600 0	2 3 3 1600 0	2 3 4 1600 0	2 3 1600 0
2 3 1 1630 7	2 3 2 1630 0	2 3 3 1630 1	2 3 4 1630 0	2 3 1630 0
2 3 1 1700 8	2 3 2 1700 0	2 3 3 1700 0	2 3 4 1700 0	2 3 1700 0
2 3 1 1730 6	2 3 2 1730 0	2 3 3 1730 0	2 3 4 1730 0	2 3 1730 0
2 3 1 1800 7	2 3 2 1800 0	2 3 3 1800 0	2 3 4 1800 0	2 3 1800 0
2 3 1 1830 6	2 3 2 1830 0	2 3 3 1830 0	2 3 4 1830 0	2 3 1830 0
2 3 1 1900 7	2 3 2 1900 1	2 3 3 1900 1	2 3 4 1900 0	2 3 1900 0
2 3 1 1930 5	2 3 2 1930 3	2 3 3 1930 2	2 3 4 1930 0	2 3 1930 0
2 3 1 2000 3	2 3 2 2000 4	2 3 3 2000 3	2 3 4 2000 0	2 3 2000 2
2 3 1 2030 3	2 3 2 2030 7	2 3 3 2030 29	2 3 4 2030 0	2 3 2030 383
2 3 1 2100 1	2 3 2 2100 19	2 3 3 2100 26	2 3 4 2100 0	2 3 2100 29
2 3 1 2130 0	2 3 2 2130 18	2 3 3 2130 33	2 3 4 2130 0	2 3 2130 18
2 3 1 2200 1	2 3 2 2200 21	2 3 3 2200 37	2 3 4 2200 0	2 3 2200 2
2 3 1 2230 0	2 3 2 2230 23	2 3 3 2230 35	2 3 4 2230 0	2 3 2230 0
2 3 1 2300 0	2 3 2 2300 22	2 3 3 2300 34	2 3 4 2300 0	2 3 2300 0
2 3 1 2330 0	2 3 2 2330 20	2 3 3 2330 30	2 3 4 2330 0	2 3 2330 0

Table 4. Leafhopper dispersal survival data. Count is the mean number of days until captured. Page 1 of 1

Generation 1				Generation 2			
Gen	Cage	Color	Count	Gen	Cage	Color	Count
1	1	1	12.33	2	1	1	12.8
1	1	2	13.5	2	1	2	15.3
1	1	3	11.33	2	1	3	10.2
1	1	4	10.67	2	1	4	15.5
1	1	5	15.17	2	1	5	17.67
1	1	6	9.5	2	1	6	21
1	1	7	13.17	2	1	7	18.67
1	2	1	13.83	2	2	1	18.5
1	2	2	9.33	2	2	2	21
1	2	3	11.67	2	2	3	13
1	2	4	13.67	2	2	4	15.6
1	2	5	12.33	2	2	5	15.5
1	2	6	7.67	2	2	6	19.67
1	2	7	13.67	2	2	7	17.5
1	3	1	8.33	2	3	1	15.67
1	3	2	10.17	2	3	2	15.5
1	3	3	6.67	2	3	3	16
1	3	4	12.83	2	3	4	10
1	3	5	10.17	2	3	5	15.5
1	3	6	10.33	2	3	6	15
1	3	7	6.17	2	3	7	10.17
1	4	1	10.83	2	4	1	17.17
1	4	2	14	2	4	2	12.17
1	4	3	11.17	2	4	3	11.17
1	4	4	14.33	2	4	4	11.33
1	4	5	7.17	2	4	5	15.5
1	4	6	6.83	2	4	6	14.17
1	4	7	9.83	2	4	7	16.5
1	5	1	8.67	2	5	1	15.83
1	5	2	12.83	2	5	2	3.33
1	5	3	13.5	2	5	3	18
1	5	4	14.83	2	5	4	10.33
1	5	5	13.5	2	5	5	11.83
1	5	6	7.33	2	5	6	16.17
1	5	7	13.17	2	5	7	13
1	6	1	10.33	2	6	1	10.17
1	6	2	11.5	2	6	2	13.83
1	6	3	14.17	2	6	3	13.66
1	6	4	10.83	2	6	4	13.33
1	6	5	14.33	2	6	5	16.17
1	6	6	14	2	6	6	13.17
1	6	7	13.5	2	6	7	16.83

Table 5. Leafhopper dispersal flight to yellow sticky board trap data. Count is the mean number of days until captured.

Generation 1				Generation 2			
Gen	Trap	Color	Count	Gen	Trap	Color	Count
1	1	1	2.78	2	1	1	4.46
1	1	2	2.95	2	1	2	2.75
1	1	3	1.71	2	1	3	2.64
1	1	4	2.25	2	1	4	3.5
1	1	5	2.71	2	1	5	3.62
1	1	6	4	2	1	6	2.31
1	1	7	3.91	2	1	7	3
1	2	1	1.8	2	2	1	3.6
1	2	2	1.67	2	2	2	4
1	2	3	2.67	2	2	3	3.67
1	2	4	2.31	2	2	4	1.78
1	2	5	4	2	2	5	1.94
1	2	6	2.29	2	2	6	2.08
1	2	7	3.1	2	2	7	2.67
1	3	1	1.91	2	3	1	3.89
1	3	2	2.36	2	3	2	2.82
1	3	3	1.7	2	3	3	2.91
1	3	4	2.23	2	3	4	1.54
1	3	5	3.75	2	3	5	2.1
1	3	6	2	2	3	6	2.36
1	3	7	7.25	2	3	7	2.62
1	4	1	2.47	2	4	1	2.31
1	4	2	2.5	2	4	2	2.64
1	4	3	2.3	2	4	3	3.38
1	4	4	2.64	2	4	4	3.31
1	4	5	3	2	4	5	2.2
1	4	6	2.8	2	4	6	2.23
1	4	7	2.67	2	4	7	2.67

Marking treatment colors:

- 1 = unmarked
- 2 = magenta
- 3 = creme
- 4 = blue
- 5 = green
- 6 = red
- 7 = yellow

Table 6. Leafhopper field recapture data.

	Release			Capture			Distance
Site	Date	Point	Duration	Dist	Direc	#	Per Day
East Lansing	06/23/86	e	4	10	60	1	2.5
East Lansing	07/05/86	e	1	10	60	1	10.0
East Lansing	07/05/86	e	1	5	240	1	5.0
East Lansing	07/05/86	e	1	5	0	1	5.0
East Lansing	07/05/86	e	2	5	120	1	2.5
East Lansing	07/05/86	e	2	5	120	1	2.5
East Lansing	07/05/86	e	2	5	60	1	2.5
East Lansing	07/05/86	e	2	10	180	1	5.0
East Lansing	07/05/86	e	2	5	180	1	2.5
East Lansing	07/05/86	e	2	10	240	1	5.0
East Lansing	07/05/86	e	3	5	120	1	1.7
East Lansing	06/23/86	e	15	40	240	1	2.7
East Lansing	07/05/86	e	3	10	120	1	3.3
East Lansing	07/05/86	e	4	10	180	1	2.5
East Lansing	07/05/86	e	4	10	0	1	2.5
East Lansing	07/05/86	e	5	5	180	1	1.0
East Lansing	07/05/86	e	5	40	60	1	8.0
East Lansing	07/05/86	e	7	10	60	1	1.4
East Lansing	07/05/86	e	8	20	0	1	2.5
East Lansing	07/05/86	e	8	10	180	1	1.3
East Lansing	07/12/86	e	1	5	120	1	5.0
East Lansing	07/05/86	e	9	20	180	1	2.2
East Lansing	06/23/86	e	21	20	60	1	0.0
East Lansing	07/05/86	e	10	60	120	1	6.0
East Lansing	07/05/86	e	10	20	60	1	2.0
East Lansing	07/05/86	e	11	40	120	1	3.6
East Lansing	07/12/86	e	5	5	180	1	1.0
East Lansing	07/12/86	e	5	5	0	1	1.0
East Lansing	07/05/86	e	12	20	180	1	1.7
East Lansing	07/12/86	e	5	5	300	1	1.0
East Lansing	07/12/86	e	5	5	60	1	1.0
East Lansing	07/05/86	e	13	20	120	1	1.5
East Lansing	07/05/86	e	14	60	180	1	4.3
East Lansing	07/12/86	e	7	20	300	1	2.9
East Lansing	07/05/86	e	14	20	300	1	1.4
East Lansing	07/05/86	e	14	40	180	1	2.9
East Lansing	07/05/86	e	17	60	60	1	3.5
East Lansing	07/05/86	e	17	20	60	1	1.2
East Lansing	07/05/86	e	17	40	120	1	2.4
East Lansing	07/12/86	e	10	5	180	1	0.5
East Lansing	07/12/86	e	11	20	180	1	1.8
East Lansing	07/12/86	e	12	20	180	1	1.7
East Lansing	07/05/86	e	19	5	60	1	0.3
East Lansing	07/05/86	e	21	20	180	1	0.0
East Lansing	07/12/86	e	14	5	180	1	0.4
East Lansing	07/12/86	e	14	5	120	1	0.4
East Lansing	07/12/86	e	14	20	180	1	1.4
East Lansing	06/23/86	o	2	5	180	1	2.5
East Lansing	07/05/86	o	1	5	240	1	5.0
East Lansing	07/05/86	o	1	5	120	1	5.0
East Lansing	07/05/86	o	2	10	180	1	5.0
East Lansing	07/05/86	o	2	10	120	1	5.0
East Lansing	07/05/86	o	2	5	0	1	2.5
East Lansing	07/05/86	o	2	10	60	1	5.0
East Lansing	07/05/86	o	2	5	240	1	2.5
East Lansing	07/05/86	o	2	5	120	1	2.5

Table 6. (cont'd.). **Page 2 of 7**

	Release			Capture			Distance
Site	Date	Point	Duration	Dist	Direc	#	Per Day
East Lansing	07/05/86	o	3	5	0	1	1.7
East Lansing	07/05/86	o	3	20	180	1	6.7
East Lansing	07/05/86	o	3	10	180	1	3.3
East Lansing	07/05/86	o	4	10	60	1	2.5
East Lansing	07/05/86	o	4	5	180	1	1.3
East Lansing	07/05/86	o	4	5	120	1	1.3
East Lansing	06/23/86	o	17	60	180	1	3.5
East Lansing	07/05/86	o	5	20	300	1	4.0
East Lansing	07/05/86	o	5	10	300	1	2.0
East Lansing	07/05/86	o	5	10	300	1	2.0
East Lansing	07/05/86	o	5	5	60	1	1.0
East Lansing	07/05/86	o	5	5	0	1	1.0
East Lansing	07/05/86	o	6	10	60	1	1.7
East Lansing	07/05/86	o	7	10	240	1	1.4
East Lansing	07/05/86	o	7	20	120	1	2.9
East Lansing	07/12/86	o	1	5	180	1	5.0
East Lansing	07/05/86	o	8	10	120	1	1.3
East Lansing	06/23/86	o	21	60	180	1	2.9
East Lansing	06/23/86	o	21	40	300	1	1.9
East Lansing	06/23/86	o	21	60	240	1	2.9
East Lansing	07/05/86	o	9	20	180	1	2.2
East Lansing	07/05/86	o	10	40	60	1	4.0
East Lansing	07/05/86	o	10	40	120	1	4.0
East Lansing	07/05/86	o	10	20	240	1	2.0
East Lansing	07/12/86	o	3	10	60	1	3.3
East Lansing	07/05/86	o	11	40	180	1	3.6
East Lansing	07/12/86	o	4	10	240	1	2.5
East Lansing	07/12/86	o	5	5	60	1	1.0
East Lansing	07/12/86	o	6	60	120	1	10.0
East Lansing	07/05/86	o	13	20	180	1	1.5
East Lansing	07/05/86	o	13	20	120	1	1.5
East Lansing	07/12/86	o	7	5	60	1	0.7
East Lansing	07/05/86	o	14	40	120	1	2.9
East Lansing	07/12/86	o	8	40	120	1	5.0
East Lansing	07/05/86	o	16	40	120	1	2.5
East Lansing	07/05/86	o	16	5	300	1	0.3
East Lansing	07/05/86	o	17	20	60	1	1.2
East Lansing	07/05/86	o	17	60	60	1	3.5
East Lansing	07/12/86	o	10	10	0	1	1.0
East Lansing	07/12/86	o	10	10	120	1	1.0
East Lansing	07/12/86	o	11	10	120	1	0.9
East Lansing	07/12/86	o	12	20	60	1	1.7
East Lansing	07/05/86	o	20	20	0	1	1.0
East Lansing	07/12/86	o	14	20	180	1	1.4
Lawrence	07/17/86	e	2	5	120	1	2.5
Lawrence	07/17/86	e	3	10	60	1	3.3
Lawrence	07/17/86	e	3	5	0	1	1.7
Lawrence	07/20/86	e	2	5	60	1	2.5
Lawrence	07/20/86	e	2	5	180	1	2.5
Lawrence	07/20/86	e	2	5	300	1	2.5
Lawrence	07/20/86	e	3	5	0	1	1.7
Lawrence	07/17/86	e	6	20	60	1	3.3
Lawrence	07/20/86	e	3	10	60	1	3.3
Lawrence	07/20/86	e	4	5	120	1	1.3
Lawrence	07/20/86	e	4	10	180	1	2.5
Lawrence	07/20/86	e	4	40	120	1	10.0

Table 6. (cont'd.). **Page 3 of 7**

Site	Release Date	Release Point	Release Duration	Capture Dist	Capture Direc	Capture #	Distance Per Day
Lawrence	07/20/86	e	4	5	240	1	1.3
Lawrence	07/19/86	e	5	20	0	1	4.0
Lawrence	07/20/86	e	4	20	60	1	5.0
Lawrence	07/20/86	e	4	10	120	1	2.5
Lawrence	07/17/86	e	7	10	60	1	1.4
Lawrence	07/20/86	e	5	10	60	1	2.0
Lawrence	07/20/86	e	5	5	120	1	1.0
Lawrence	07/20/86	e	5	10	120	1	2.0
Lawrence	07/20/86	e	6	20	60	1	3.3
Lawrence	07/20/86	e	7	10	0	1	1.4
Lawrence	07/20/86	e	7	20	120	1	2.9
Lawrence	07/20/86	e	7	40	60	1	5.7
Lawrence	07/17/86	e	11	60	60	1	5.5
Lawrence	07/20/86	e	8	40	60	1	5.0
Lawrence	07/19/86	e	11	40	300	1	3.6
Lawrence	07/19/86	e	11	40	300	1	3.6
Lawrence	07/20/86	e	12	40	120	1	3.3
Lawrence	07/20/86	e	14	20	60	1	1.4
Lawrence	07/20/86	e	15	60	120	1	4.0
Lawrence	07/20/86	e	15	60	120	1	4.0
Lawrence	07/17/86	o	2	10	180	1	5.0
Lawrence	07/17/86	o	2	10	120	1	5.0
Lawrence	07/19/86	o	1	5	180	1	5.0
Lawrence	07/19/86	o	1	5	60	1	5.0
Lawrence	07/17/86	o	3	10	60	1	3.3
Lawrence	07/19/86	o	1	10	120	1	10.0
Lawrence	07/17/86	o	4	10	120	1	2.5
Lawrence	07/20/86	o	1	5	120	1	5.0
Lawrence	07/20/86	o	2	5	120	1	2.5
Lawrence	07/20/86	o	2	5	0	1	2.5
Lawrence	07/20/86	o	3	5	180	1	1.7
Lawrence	07/20/86	o	3	10	180	1	3.3
Lawrence	07/20/86	o	4	5	120	1	1.3
Lawrence	07/20/86	o	4	20	0	1	5.0
Lawrence	07/20/86	o	4	10	300	1	2.5
Lawrence	07/20/86	o	5	20	60	1	4.0
Lawrence	07/20/86	o	5	10	120	1	2.0
Lawrence	07/20/86	o	7	20	120	1	2.9
Lawrence	07/20/86	o	7	40	180	1	5.7
Lawrence	07/20/86	o	7	5	0	1	0.7
Lawrence	07/20/86	o	9	20	240	1	2.2
Lawrence	07/20/86	o	9	60	120	1	6.7
Lawrence	07/17/86	o	13	40	300	1	3.1
Lawrence	07/19/86	o	11	20	0	1	1.8
Lawrence	07/20/86	o	13	40	120	1	3.1
Lawrence	07/20/86	o	16	40	240	1	2.5
Lawrence	07/20/86	o	17	60	120	1	3.5
east lansing	10/07/86	e	1	20	180	1	20.0
east lansing	10/07/86	e	1	10	120	1	10.0
east lansing	10/07/86	e	1	5	300	1	5.0
east lansing	10/07/86	e	1	5	180	1	5.0
east lansing	10/07/86	e	2	5	120	1	2.5
east lansing	10/07/86	e	2	5	240	1	2.5
east lansing	10/07/86	e	2	10	180	1	5.0
east lansing	10/09/86	e	1	5	180	1	5.0
east lansing	10/09/86	e	1	5	120	1	5.0

Table 6. (cont'd.). **Page 4 of 7**

	Release			Capture			Distance
Site	Date	Point	Duration	Dist	Direc	#	Per Day
east lansing	10/09/86	e	1	5	0	1	5.0
east lansing	10/07/86	e	3	20	180	1	6.7
east lansing	10/09/86	e	1	5	60	1	5.0
east lansing	10/07/86	e	3	5	300	1	1.7
east lansing	10/07/86	e	3	10	240	1	3.3
east lansing	10/07/86	e	3	10	0	1	3.3
east lansing	10/07/86	e	4	20	120	1	5.0
east lansing	10/09/86	e	2	10	120	1	5.0
east lansing	10/09/86	e	2	10	240	1	5.0
east lansing	10/07/86	e	4	20	180	1	5.0
east lansing	10/09/86	e	2	5	120	1	2.5
east lansing	10/07/86	e	4	20	180	1	5.0
east lansing	10/07/86	e	4	5	180	1	1.3
east lansing	10/07/86	e	4	20	60	1	5.0
east lansing	10/11/86	e	1	5	180	1	5.0
east lansing	10/11/86	e	1	5	180	1	5.0
east lansing	10/09/86	e	3	20	180	1	6.7
east lansing	10/09/86	e	3	5	240	1	1.7
east lansing	10/11/86	e	1	5	120	1	5.0
east lansing	10/07/86	e	6	20	180	1	3.3
east lansing	10/11/86	e	3	5	120	1	1.7
east lansing	10/07/86	e	8	20	180	1	2.5
East Lansing	10/11/86	e	5	40	240	1	8.0
East Lansing	10/07/86	e	9	5	180	1	0.6
East Lansing	10/11/86	e	5	10	0	1	2.0
East Lansing	10/07/86	e	10	40	120	1	4.0
East Lansing	10/11/86	e	6	20	180	1	3.3
East Lansing	10/09/86	e	8	20	0	1	2.5
East Lansing	10/07/86	e	11	40	180	1	3.6
East Lansing	10/09/86	e	9	20	300	1	2.2
East Lansing	10/09/86	e	10	20	120	1	2.0
East Lansing	10/11/86	e	10	10	120	1	1.0
East Lansing	10/07/86	e	14	20	300	1	1.4
east lansing	10/11/86	e	11	10	120	1	0.9
east lansing	10/09/86	e	13	20	120	1	1.5
east lansing	10/09/86	e	13	40	240	1	3.1
east lansing	10/09/86	e	13	40	180	1	3.1
east lansing	10/07/86	e	16	20	300	1	1.3
east lansing	10/09/86	e	14	40	120	1	2.9
east lansing	10/07/86	e	16	40	180	1	2.5
east lansing	10/11/86	e	12	10	0	1	0.8
east lansing	10/11/86	e	13	5	0	1	0.4
east lansing	10/07/86	e	19	40	240	1	2.1
east lansing	10/09/86	e	17	20	180	1	1.2
east lansing	10/11/86	e	16	40	120	1	2.5
east lansing	10/11/86	e	16	40	120	1	2.5
east lansing	10/11/86	e	17	60	120	1	3.5
east lansing	10/07/86	e	21	40	180	1	1.9
east lansing	10/11/86	e	18	40	180	1	2.2
east lansing	10/09/86	e	20	60	120	1	3.0
east lansing	10/07/86	o	1	5	180	1	5.0
east lansing	10/07/86	o	1	5	0	1	5.0
east lansing	10/07/86	o	1	10	60	1	10.0
east lansing	10/07/86	o	2	5	180	1	2.5
east lansing	10/07/86	o	2	5	120	1	2.5
east lansing	10/07/86	o	2	20	120	1	10.0

Table 6. (cont'd.). **Page 5 of 7**

Site	Release Date	Release Point	Release Duration	Capture Dist	Capture Direc	Capture #	Distance Per Day
east lansing	10/07/86	o	3	5	300	1	1.7
east lansing	10/09/86	o	1	5	120	1	5.0
east lansing	10/07/86	o	3	10	240	1	3.3
east lansing	10/09/86	o	1	5	0	1	5.0
east lansing	10/09/86	o	1	5	120	1	5.0
east lansing	10/07/86	o	3	40	120	1	13.3
east lansing	10/09/86	o	1	10	60	1	10.0
east lansing	10/09/86	o	1	5	180	1	5.0
east lansing	10/07/86	o	4	5	180	1	1.3
east lansing	10/09/86	o	2	20	0	1	10.0
east lansing	10/09/86	o	2	20	180	1	10.0
east lansing	10/09/86	o	2	5	120	1	2.5
east lansing	10/07/86	o	4	10	60	1	2.5
east lansing	10/07/86	o	4	40	180	1	10.0
east lansing	10/07/86	o	4	20	120	1	5.0
east lansing	10/09/86	o	2	5	0	1	2.5
east lansing	10/09/86	o	2	5	300	1	2.5
east lansing	10/09/86	o	3	10	180	1	3.3
east lansing	10/09/86	o	3	10	0	1	3.3
east lansing	10/11/86	o	1	5	120	1	5.0
east lansing	10/11/86	o	1	5	60	1	5.0
east lansing	10/11/86	o	1	5	180	1	5.0
east lansing	10/11/86	o	2	5	120	1	2.5
east lansing	10/11/86	o	3	10	60	1	3.3
East Lansing	10/09/86	o	7	20	120	1	2.9
East Lansing	10/11/86	o	5	5	60	1	1.0
East Lansing	10/09/86	o	8	20	180	1	2.5
East Lansing	10/09/86	o	8	20	180	1	2.5
East Lansing	10/07/86	o	10	10	240	1	1.0
East Lansing	10/09/86	o	8	10	0	1	1.3
East Lansing	10/09/86	o	8	20	60	1	2.5
East Lansing	10/07/86	o	10	40	120	1	4.0
East Lansing	10/09/86	o	9	40	120	1	4.4
East Lansing	10/09/86	o	9	20	180	1	2.2
East Lansing	10/07/86	o	12	10	180	1	0.8
East Lansing	10/11/86	o	8	20	120	1	2.5
East Lansing	10/07/86	o	13	20	180	1	1.5
East Lansing	10/11/86	o	10	20	0	1	2.0
East Lansing	10/09/86	o	12	20	240	1	1.7
East Lansing	10/07/86	o	14	40	120	1	2.9
East Lansing	10/07/86	o	14	20	120	1	1.4
east lansing	10/09/86	o	13	20	60	1	1.5
east lansing	10/09/86	o	13	10	180	1	0.8
east lansing	10/11/86	o	11	40	180	1	3.6
east lansing	10/11/86	o	11	10	0	1	0.9
east lansing	10/07/86	o	15	40	240	1	2.7
east lansing	10/07/86	o	15	20	120	1	1.3
east lansing	10/09/86	o	14	20	300	1	1.4
east lansing	10/09/86	o	14	40	120	1	2.9
east lansing	10/09/86	o	14	10	120	1	0.7
east lansing	10/11/86	o	12	40	60	1	3.3
east lansing	10/07/86	o	16	40	180	1	2.5
east lansing	10/09/86	o	17	10	120	1	0.6
east lansing	10/07/86	o	19	20	0	1	1.1
east lansing	10/11/86	o	16	40	60	1	2.5
east lansing	10/11/86	o	16	20	180	1	1.3

Table 6. (cont'd.). **Page 6 of 7**

Site	Release Date	Release Point	Release Duration	Capture Dist	Capture Direc	Capture #	Distance Per Day
east lansing	10/11/86	o	18	20	60	1	1.1
east lansing	10/09/86	o	21	40	120	1	1.9
east lansing	10/11/86	o	20	60	120	1	3.0
east lansing	10/11/86	o	20	60	120	1	3.0
Lawrence	10/09/86	e	1	5	300	1	5.0
Lawrence	10/09/86	e	1	5	60	1	5.0
Lawrence	10/09/86	e	1	10	180	1	10.0
Lawrence	10/10/86	e	1	20	0	1	20.0
Lawrence	10/09/86	e	2	10	240	1	5.0
Lawrence	10/09/86	e	2	10	300	1	5.0
Lawrence	10/09/86	e	2	10	60	1	5.0
Lawrence	10/09/86	e	2	60	120	1	30.0
Lawrence	10/10/86	e	1	5	120	1	5.0
Lawrence	10/11/86	e	1	5	0	1	5.0
Lawrence	10/09/86	e	3	20	120	1	6.7
Lawrence	10/10/86	e	2	10	60	1	5.0
Lawrence	10/11/86	e	1	5	180	1	5.0
Lawrence	10/10/86	e	3	10	120	1	3.3
Lawrence	10/11/86	e	3	5	240	1	1.7
Lawrence	10/09/86	e	7	20	240	1	2.9
Lawrence	10/09/86	e	7	20	240	1	2.9
LAWRENCE	10/10/86	e	7	10	60	1	1.4
LAWRENCE	10/11/86	e	6	10	300	1	1.7
LAWRENCE	10/09/86	e	8	40	120	1	5.0
LAWRENCE	10/09/86	e	9	40	180	1	4.4
LAWRENCE	10/10/86	e	9	20	60	1	2.2
LAWRENCE	10/09/86	e	10	5	180	1	0.5
LAWRENCE	10/09/86	e	11	20	60	1	1.8
LAWRENCE	10/10/86	e	11	40	120	1	3.6
LAWRENCE	10/10/86	e	11	20	60	1	1.8
LAWRENCE	10/10/86	e	11	10	60	1	0.9
LAWRENCE	10/10/86	e	11	20	60	1	1.8
LAWRENCE	10/10/86	e	12	10	0	1	0.8
LAWRENCE	10/11/86	e	11	40	60	1	3.6
LAWRENCE	10/11/86	e	11	5	60	1	0.5
LAWRENCE	10/09/86	e	13	10	60	1	0.8
LAWRENCE	10/10/86	e	12	40	120	1	3.3
LAWRENCE	10/09/86	e	13	20	240	1	1.5
LAWRENCE	10/11/86	e	11	20	120	1	1.8
LAWRENCE	10/10/86	e	13	40	180	1	3.1
LAWRENCE	10/09/86	e	14	20	120	1	1.4
LAWRENCE	10/10/86	e	15	20	120	1	1.3
LAWRENCE	10/09/86	e	16	40	120	1	2.5
LAWRENCE	10/09/86	e	17	40	120	1	2.4
LAWRENCE	10/10/86	e	17	60	120	1	3.5
LAWRENCE	10/10/86	e	18	20	240	1	1.1
LAWRENCE	10/09/86	e	20	60	120	1	3.0
LAWRENCE	10/11/86	e	19	40	180	1	2.1
LAWRENCE	10/11/86	e	21	60	120	1	2.9
Lawrence	10/09/86	o	1	5	60	1	5.0
Lawrence	10/09/86	o	1	5	120	1	5.0
Lawrence	10/09/86	o	1	5	60	1	5.0
Lawrence	10/09/86	o	1	5	240	1	5.0
Lawrence	10/09/86	o	1	5	0	1	5.0
Lawrence	10/10/86	o	1	20	60	1	20.0
Lawrence	10/10/86	o	1	5	300	1	5.0

Table 6. (cont'd.).

Site	Release Date	Release Point	Release Duration	Capture Dist	Capture Direc	#	Distance Per Day
Lawrence	10/09/86	o	2	20	180	1	10.0
Lawrence	10/10/86	o	1	40	120	1	40.0
Lawrence	10/09/86	o	2	10	240	1	5.0
Lawrence	10/09/86	o	2	10	0	1	5.0
Lawrence	10/10/86	o	2	5	120	1	2.5
Lawrence	10/09/86	o	3	10	240	1	3.3
Lawrence	10/11/86	o	1	5	180	1	5.0
Lawrence	10/11/86	o	1	5	300	1	5.0
Lawrence	10/09/86	o	4	10	180	1	2.5
Lawrence	10/11/86	o	3	10	180	1	3.3
Lawrence	10/09/86	o	6	20	120	1	3.3
Lawrence	10/09/86	o	7	20	120	1	2.9
Lawrence	10/10/86	o	6	5	0	1	0.8
LAWRENCE	10/11/86	o	6	10	300	1	1.7
LAWRENCE	10/10/86	o	7	20	240	1	2.9
LAWRENCE	10/09/86	o	8	40	120	1	5.0
LAWRENCE	10/10/86	o	7	40	180	1	5.7
LAWRENCE	10/09/86	o	9	60	180	1	6.7
LAWRENCE	10/10/86	o	8	40	120	1	5.0
LAWRENCE	10/09/86	o	10	20	0	1	2.0
LAWRENCE	10/11/86	o	8	10	240	1	1.3
LAWRENCE	10/10/86	o	9	5	120	1	0.6
LAWRENCE	10/09/86	o	11	20	240	1	1.8
LAWRENCE	10/10/86	o	10	10	0	1	1.0
LAWRENCE	10/09/86	o	12	20	180	1	1.7
LAWRENCE	10/11/86	o	10	20	240	1	2.0
LAWRENCE	10/11/86	o	10	10	60	1	1.0
LAWRENCE	10/11/86	o	10	20	180	1	2.0
LAWRENCE	10/09/86	o	13	10	240	1	0.8
LAWRENCE	10/11/86	o	11	20	60	1	1.8
LAWRENCE	10/10/86	o	12	20	0	1	1.7
LAWRENCE	10/11/86	o	11	40	60	1	3.6
LAWRENCE	10/10/86	o	12	40	120	1	3.3
LAWRENCE	10/10/86	o	13	40	60	1	3.1
LAWRENCE	10/11/86	o	12	10	180	1	0.8
LAWRENCE	10/09/86	o	14	5	120	1	0.4
LAWRENCE	10/09/86	o	15	20	180	1	1.3
LAWRENCE	10/09/86	o	16	60	60	1	3.8
LAWRENCE	10/10/86	o	16	40	120	1	2.5
LAWRENCE	10/09/86	o	17	60	60	1	3.5
LAWRENCE	10/10/86	o	17	20	300	1	1.2
LAWRENCE	10/11/86	o	17	60	120	1	3.5
LAWRENCE	10/09/86	o	20	40	240	1	2.0
LAWRENCE	10/11/86	o	19	20	240	1	1.1
LAWRENCE	10/10/86	o	21	60	120	1	2.9

Table 7. Number of male and female *P. irroratus* captured by method, site and date during 1985 and 1986. Page 1 of 4

Site Date	Yellow Board Male	 Female	Sweep Net Male	 Female	Total
Bainbridge Center Site					
06/24/86	1				1
07/07/86		1	1	1	3
08/04/86	1				1
09/03/86	1				1
09/16/86	1				1
10/01/86	2	3	1	2	8
10/17/86	3	7	2	3	15
10/31/86	1	4			5
1986 Totals	10	15	4	6	35
Clarksville Site					
06/13/85		1			1
06/26/85	3	1	1	2	7
07/10/85	2	1		1	4
08/07/85		2			2
08/20/85		1	1		2
09/04/85	1	2			3
09/18/85	5	3	1	3	12
10/03/85	3	8	3	3	17
10/17/85	10	17	4	2	33
10/31/85	14	2		1	17
11/14/85	2	1			3
1985 Totals	40	39	10	12	101
East Lansing Site					
07/23/85	3	1			4
08/07/85	12	5		1	18
08/20/85	7	7	3	5	22
09/04/85	19	10	2	4	35
09/18/85	27	23	3	4	57
10/03/85	84	27	5	8	124
10/17/85	207	55		4	266
10/31/85	66	47			113
11/14/85	1	1			2
1985 Totals	426	176	13	26	641

Table 7. (cont'd.). Page 2 of 4

Site Date	Yellow Board Male	Yellow Board Female	Sweep Net Male	Sweep Net Female	Total
Fennville Site					
05/29/85			2	4	6
06/13/85	2	1	11	8	22
06/26/85	3	6	1	6	16
07/10/85	4	1		1	6
07/23/85	1	4	1	1	7
08/07/85	3	3			6
08/20/85	2	5	2	2	11
09/04/85	9	6		2	17
09/18/85	18	28			46
10/03/85	40	16	3		59
10/17/85	81	34		1	116
10/31/85	31	26		2	59
1985 Totals	194	130	20	27	371
05/28/86	1	1			2
06/24/86	2	1	1	2	6
07/07/86	2	2		1	5
07/21/86	1				1
08/04/86	1	1	1		3
09/16/86	1	1	1	1	4
10/01/86	9	11	1	1	22
10/17/86	5	5	2	1	13
10/31/86	5	1			6
1986 Totals	27	23	6	6	62
Hartford Site					
05/29/85	2	1	1		4
06/12/85	1	2		1	4
06/26/85	3	3			6
07/10/85		1			1
07/23/85		1			1
08/20/85	1	1	1	1	4
09/04/85	1	3	2	1	7
09/18/85	16	4	6	7	33
10/03/85	30	7	2	3	42
10/17/85	99	35			134
10/31/85	26	12		1	39
11/14/85	1				1
1985 Totals	180	70	12	14	276

Table 7. (cont'd.). Page 3 of 4

Site Date	Yellow Board Male	Yellow Board Female	Sweep Net Male	Sweep Net Female	Total
Lawrence Site					
05/29/85	1		1	3	5
06/12/85		3	4	4	11
06/26/85	24	26	2	6	58
07/10/85	3	4		1	8
07/23/85	1	3			4
08/20/85				1	1
09/04/85	2			1	3
09/18/85	38	15	2	1	56
10/03/85	29	27	1	3	60
10/17/85	97	43		1	141
10/31/85	33	17			50
11/14/85	2				2
1985 Totals	230	138	10	21	399
06/09/86	1				1
06/24/86	3	2			5
07/07/86	5	3	2	3	13
07/21/86	2				2
09/16/86	2		1		3
10/01/86	10	9	1	2	22
10/17/86	10	9	3	3	25
10/31/86	13	5			18
1986 Totals	46	28	7	8	89
Manistee Site					
06/26/86	1				1
07/09/86			1		1
07/22/86	2	1			3
08/05/86			1		1
09/04/86				1	1
09/17/86	1				1
10/03/86	12	4	2		18
10/18/86	4	3	3	2	12
11/01/86	1				1
1986 Totals	21	8	7	3	39

Table 7. (cont'd.). **Page 4 of 4**

Site Date	Yellow Board Male	 Female	Sweep Net Male	 Female	Total
<u>Northport Site</u>					
10/03/86	1				1
11/01/86	1				1
1986 Totals	2				2
<u>Walkerville Site</u>					
07/09/86				1	1
07/22/86	1				1
08/05/86	1	1			2
08/21/86			1		1
09/04/86	1	1			2
09/17/86	4	1	1		6
10/03/86	11	7	2		20
10/18/86	6	2	1	2	11
11/01/86	1			1	2
1986 Totals	25	12	5	4	46