Forest insect surveys within specified areas. Number 21 1960

Shenefelt, R. D.; Jones, P. A.
Madison, Wisconsin: Wisconsin Conservation Department, 1960

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FOREST INSECT SURVEYS WITHIN SPECIFIED AREAS

TECHNICAL BULLETIN NUMBER 21

WISCONSIN CONSERVATION DEPARTMENT
Madison 1, Wisconsin
1960

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FOREST INSECT SURVEYS WITHIN SPECIFIED AREAS

by

R. D. Shenefelt
(Professor, Department of Entomology
University of Wisconsin)

P. A. Jones
(Research Assistant, Department of Entomology
University of Wisconsin)

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Acknowledgments

The authors wish to express their appreciation to the numerous individuals who have given so freely of their time and ideas during the development of the experimental survey and for many personal favors and much help. Special recognition is due to the forestry personnel on the state forests and particularly to L. H. Mirkes and S. E. Banish during the formative stages of the survey, and to Dr. J. H. Torrie of the University of Wisconsin for statistical help.

Reported here are the results of a cooperative project supported jointly by the Wisconsin Conservation Department and the Agricultural Experiment Station, College of Agriculture, University of Wisconsin. Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

Edited by Ruth L. Hine

Contents

Introduction

Forest insect surveys are important factors in the economy of managed forests. The emphasis which sampling of forest insects has been receiving lately is shown by the papers being published dealing with techniques. The more intensively a forest is managed the greater the need for surveys which will reveal or help to anticipate insect outbreaks. The losses caused from insect epidemics can be enormous and have been calculated in particular instances. As management costs increase and are added to the total investment in each acre of forest, the challenge to the forest entomologist becomes greater to develop survey techniques which will yield the greatest returns for the minimum expenditure of time and money. In this paper, concepts and methods utilized in a preliminary survey are discussed. It is hoped that this will lead thoughts of others toward the bases for establishing a forest-insect-detection survey within a limited area.

Although surveys, per se, have no effect in preventing outbreaks (Orr, 1954), a basic survey might be established to provide more adequate knowledge of the trends in populations and the reasons for them. To quote Orr, ". . . more emphasis in our forest insect program should be placed upon research that will develop information regarding the basic reasons for changes in insect populations, more complete knowledge of the biologies and habits of the various insect pests and their natural enemies . . .".

One of the purposes of most survey programs is that of detection of incipient outbreaks of injurious insects. In the past "detection" has implied primarily only the chance observation and reporting of insect populations, usually shortly before or after they reached outbreak proportions. In many instances the primary objective has not been met—rather the "detection" has occurred after the populations have already caused extensive damage. Detection at an early stage of population build-up is desirable in order to institute biological and silvicultural control programs and avoid reliance upon chemicals. Since there are many injurious insects in any forest, such surveys necessarily must be conducted upon an over-all basis, involving all tree types and age classes and all nooks and crannies where insects live.

Examination of the literature and discussion with numerous individuals revealed that our present published survey techniques deal with single insect species and that directions for the conduct of general forest insect surveys for an area are non-existent.

The topic under review is the result of a request made by a forest manager in Wisconsin. He said essentially, "We would like to make our own annual survey of insects in the forests under our control. Will you please furnish us with the exact directions so that we can do it? Of course, we must keep the time involved to a practical basis—say 200 man hours of actual time spent in collecting samples. The directions should be such that any one of us could stop as we passed by a plot and collect whatever is needed. You tell us where to stop and when to stop and what to do. We will give you the material for analysis. Through this we want to be able to obtain information as to what insects are present and know when they start to build up in numbers so we can do something about them before they have caused the kind of damage we have been having in the past."

Our objective, therefore, was obviously that of a program of detection, either of an outbreak or of new immigrants into the region, and our sampling universe was defined by the geographical limit.

The difficulties inherent in the problem are evidenced by the absence of literature upon the subject and also by statements such as one made by Graham and Stark in 1954, "The most fundamental requirement is that the sampling of a particular insect population must be resolved about the distribution and life-cycle of the insect involved. There is no 'universal' sampling method." This subject of over-all forest insect surveys has been avoided for very good reasons.

Though the development of steps for making such a detection survey is in its early stages in Wisconsin, it seems desirable to report our thoughts and progress to date so that we may obtain the advantages of the counsel and experience of others in meeting such a forest-insect-survey problem.

Let us first try to analyze some of the factors involved.

1. There is a limited area in which the survey is to be conducted.

(a) Within the area there is an established population of forest trees. These are of particular species, age classes and forest types. The population of each species has a limited genetic variability as compared to the variability in the entire population of the species over its range, i.e., the trees are characteristic and their behavior patterns can be determined in due course of time. We should not expect radical changes to occur in the forest composition from year to year—but the entire picture should gradually become modified as the years pass.

(b) There is also present an insect population composed of many species. Since the area is limited we are dealing with a limited population of any particular insect. As with the trees, the genetic constitution and variability of each species are both limited—there is a given population which has its local and characteristic genetic make-up, habit range, food plant preferences, etc. Over the entire range of the species these may be quite different than they are within the area.

It should be remembered that insects have been on the earth for a long time. They have been able to spread out into various kinds of micro-environments and have become firmly established in their particular abodes. One of the most striking features of modern insects is their amazing specificity. For example, it makes little difference to man whether he looks at the bottom or the top of a leaf—but it may make a great deal of difference to an insect. Associated with this specificity of choice of a "place to live" is a fixation of habit patterns which is so firm that predictions of behavior can be made.

Though the populations of the various species within the area will fluctuate drastically, we should not anticipate that there will be radical changes in the over-all composition of the species involved, nor that there would be many new introductions or exterminations from year to year. Furthermore, the insects inhabiting an area are present throughout the entire year, although their stages vary with the season.

2. The detection of the beginning of an outbreak implies that one knows what the "normal" numbers of any given insect are and that the population trend is being followed carefully. Usually this is not the case, as such information can be accumulated only after the surveys have been in existence for a long time—the longer the better. Populations must be studied whether high or low. The questions, "What is the normal population fluctuation within endemic populations?", and, "How do we recognize an incipient outbreak?", are not easily answered. The job of detection of forest insect outbreaks thus becomes one of continued population surveys.

3. While in any one year we need not be too concerned about the long-range aspects of population dynamics, levels of insect numbers and subsequent damage must be correlated. Not only the current populations but also those of the past must be considered in determining the point at which "outbreak" numbers occur, i.e., the point where the damage becomes more than the pocketbook desires or, as expressed by some, the point where the loss exceeds the annual increment. Ultimately it may be possible to set up a statistical description for expressing abundance. Perhaps within one standard deviation away from the mean we might have a "normal" population. If the population is greater than one standard deviation we might have an "outbreak", etc., but such work lies well in the future except for a few insects which have been studied intensively.

4. The detection of a new immigrant into the area also implies a rather profound knowledge of the species already present—and such knowledge is usually not an actuality. The taxonomic problem is further compounded by the fact that insects appear so differently in their various stages or instars. Furthermore, the micro-habitat in which a given species may be expected often varies with the developmental position which the insect has attained.

5. Since the survey is to be annual, one sampling must cover all tree species and all insects. It must be made at the same phenological period each year to make valid comparisons. If this is done, we will not be sampling the same stages of different insects. For some we might be collecting pupae, for others very young larvae, adults, or eggs. Some indices, such as the extent of damage, may have to be utilized to represent particular species.

6. As the insects usually occupy rather specific micro-niches the problem becomes one of trying to sample these areas. To do this the niches must be defined as to position and size. By "niche" we mean the place in which the animal lives, not the ecological role of the insect.

7. Methods must be evolved for objective measurement of the numbers of insects within the niche. The units by which numbers of insects are recorded will vary with the type of niche being sampled. Insect numbers may be determined per bud, per ten needles, per square foot, etc.

8. Sampling must be standardized and repeatable. It must be on a quantitative basis to avoid subjective interpretation to as great a degree as possible. It must be of such a nature that a man who has not majored in entomology can do the actual collecting of the samples.

9. What accuracy is desired in the survey and what will increase of accuracy involve from the monetary standpoint? Again the answers are not available and can be gained only through experience. Admittedly, the best of surveys is imperfect. The aim is to do the best one can with the time allotted after thorough analysis and planning. Obviously any survey technique must go through a process of development and refinement to become a better and sharper tool. And, just as obviously, the manpower and funds available will determine what can be accomplished. In our case the limiting factor is the time for field work—not more than 200 man hours. This makes the choice of number and allocation of sampling areas of prime importance.

The Area to be Surveyed

The Northern Highland State Forest and the adjoining American Legion State Forest in northern Wisconsin were chosen to serve as a pilot plant for development and testing of techniques. Together these two forests contain 162,699 acres, exclusive of water area, and this unit appears to be sufficiently large to represent the problem adequately. Commercial forest occupies 147,157 acres.

The major part of the forest lies in the pine subclimax of the northern hardwoods, the remainder in the maple subclimax (Curtis and McIntosh, 1951). The broad soil units associated with the former type are glacial and fluvial sands or sandy loams which may be melanized, mildly podzolized or strongly podzolized. This same type of modification may occur in the morainic and fluvio-glacial loams on which the maple climax types are located (Wilde, Wilson and White, 1949).

Type maps and figures regarding the forest composition were obtained from the Wisconsin Conservation Department. Twelve main timber types occur as shown in Table 1.

Type maps were arranged by townships and each type colored a particular hue. This gave information regarding the distribution and grouping of the types which provided a fairly comprehensive picture of the universe to be sampled.

Number and Location of Plots

Following these activities, difficulties were immediately encountered in answering the following questions: How should the number of plots necessary be determined? Where should samples be taken? How many plots could be handled? How should the plots be distributed among the tree types and age classes?

S. R. Gevorkiantz and W. A. Duerr (Region 9 Forest Survey Section of the Timber Management Handbook of the U. S. Forest Service, North Central Region) give the following formula for determining the number of random 1/5-acre sample plots required in estimating timber to the accuracy desired.

$$N = \frac{A\ (C)^2}{A\ (E)^2 + a\ (C)^2}$$

E = per cent of accuracy expressed as decimal
A = total area to be sampled in acres
N = number of 1/5-acre sample plots
a = area of sample plot in acres
C^2 = coefficient of variation squared

TABLE 1

Timber Types in the Northern Highland and American Legion Forests of Northern Wisconsin

Type*	Total Acreage	Per Cent Total Area	Large Saw Timber Acres	Large Saw Timber %	Small Saw Timber Acres	Small Saw Timber %	Poles Acres	Poles %	Seedlings and Saplings Acres	Seedlings and Saplings %
White pine	3,954	2.7	1,458	36.9	1,142	28.9	870	22.0	484	12.3
Red pine	8,116	5.5	485	6.0	2,400	29.6	1,686	20.8	3,545	43.7
Jack pine	10,344	7.0	-----	----	155	1.5	2,797	27.0	7,392	71.5
Fir–spruce	2,620	1.8	-----	----	-----	----	741	28.3	1,879	71.7
Black spruce	6,290	4.3	-----	----	-----	----	235	3.7	6,055	96.3
Tamarack	2,407	1.6	-----	----	-----	----	77	3.2	2,330	96.8
Swamp conifer	3,396	2.3	-----	----	68	0.2	821	24.2	2,507	74.0
Hemlocks–hardwoods	1,348	0.9	267	19.8	1,081	80.3	------	----	------	----
Mixed hardwoods	12,982	8.8	1,070	8.2	4,153	32.1	4,146	32.0	3,613	27.8
Swamp hardwoods	268	0.2	-----	----	14	5.2	234	87.3	20	7.5
Aspen	75,926	51.5	-----	----	100	0.1	53,139	70.0	22,687	30.0
Oak	3,138	2.1	-----	----	64	2.0	2,735	87.2	339	10.8
Totals		88.67	3,280	2.2	9,177	6.3	67,481	46.0	50,851	34.3
Grass	11,008									
Upland Brush	801									
Lowland Brush	4,559									
Total Forest Area	147,157	100.0								

*Forest types are defined in the Appendix of the U. S. Forest Service Timber Management Handbook for Region 9.

The coefficients of variation are given by size classes for poorly, medium and well-stocked stands. The allowable error (E) varies with the size of the area, its value per acre and the purpose for which the estimate is being taken.

With the numbers of timber types present and their variations in acreages, however, it was at once evident that we could not utilize pure random sampling of the entire area but that stratification would be necessary. The picture was additionally complicated by the desirability of including the different age classes for each type and it was evident that there would have to be stratification of plots within the major types.

The jack pine type was examined and broken down according to acreages of age classes (small saw-timber, poles, fifteen years plus and less than fifteen years) and the valuation and stocking for each determined. Then, using the formula, it was calculated that 176 plots would be needed. This process was followed for nine additional types, most of them treated as a unit instead of being separated into age classes. For the ten types, 872 plots were required, and these ten did not include red pine, one of the more valuable species. At this stage it became evident that over 1,000 plots would be necessary if the formula was followed—which was an obvious impossibility for 200 man hours.

Reconsideration of the bases for plot determination pointed out that (a) the formula, which has often been utilized as a basis for insect survey work in the region in the past, was not intended for insects but for trees; (b) insect sampling must be done on a point basis primarily, rather than upon an area basis; (c) insects are not respecters of values and perhaps timber value should be entirely ignored—although it was considered later to some extent.

The number of plots involved, when worked out as above, brought into very sharp focus the problem of manpower. Considering the number of plots which could be visited for short intervals once each year and what should be done at each plot, we set an arbitrary maximum of 300 plots.

Statistical design called for a minimum of 10 plots in each forest type. However, with the very low acreage and low value of swamp hardwood, it appeared undesirable to spend the same amount of money and time on it as upon the other types. We decided to place only two plots in swamp hardwoods even though it would not be possible to follow the results statistically. This then accounted for 112 of the 300 plots.

In considering during this period the nature of the plots to be established, we first assumed that there would be only permanent plots. But it became evident that this would not give the information desired, since the type might change in some instances during a relatively short interval (for example, due to removal of aspen overstory) and the age class also might be subject to rather rapid change (for example, from sapling into pole class). For this reason the 300 plots were divided into two categories, designated as permanent and roving plots. Permanent plots were to be followed indefinitely, regardless of what occurred within the plot. Roving plots were to remain only as long as they were useful in a particular situation or for a particular purpose. They could be used to:

a) increase the number of plots in high hazard areas;

b) gather additional information on one timber type as the need arises;

c) obtain additional information during an outbreak of a particular insect; or

d) gain further coverage of an area in a timber type if the permanent plots are found to give inadequate information for that type.

A two-to-one ratio of permanent to roving type was chosen, and it appeared that at least 10 plots in each type should be permanent.

There was tremendous variation in the acreages shown in Table 1, and ten plots per type would therefore provide relatively intense coverage in some of the smaller types and scanty coverage in others. Because white pine, red pine, jack pine, mixed hardwoods and aspen had the greater acreages and economic values, it appeared best to allocate the remaining 188 plots of the 300 maximum desired among them, using the percentages of total area and the relative susceptibilities to insect injury as a basis.

"Relative susceptibility" was determined in the following arbitrary manner:

(1) A list of the insects attacking the tree species in the state, and the age class attacked, was compiled from the literature and our Wisconsin forest insect records. (Admittedly, this list is far from complete).

(2) The insects were rated according to their seriousness in causing damage as: 1 = little damage; 2 = moderate damage; and 3 = severe damage. This subjective rating was based upon past history of infestations and subsequent damage.

(3) By totalling the insects for each tree species or age class, we obtained a *relative risk hazard* for the species or age class. As shown

TABLE 2

Risk Rating For Jack Pine and its Age Classes

Species	Rating*	Seedlings and Saplings	Pole	Small Saw-timber
Cinara spp.	1	1	--	--
Phyllophaga spp.	3	3	--	--
Neodiprion lecontei (Fitch)	3	3	--	--
Tetralopha robustella Zell.	2	2	--	--
Pissodes strobi Peck	3	3	--	--
Petrova albicapitana Busck	3	3	--	--
Eucosma sonomana Kft.	3	3	--	--
Aphrophora saratogensis Fitch	3	3	--	--
Hylobius radicis Buch.	1	--	1	--
Argyrotaenia pinatubana Kft.	1	1	1	--
Nepytia canosaria Wlk.	1	1	1	--
Parorgyia plagiata Wlk.	3	3	3	--
Neodiprion americanus banksiana Roh.	2	2	2	--
Choristoneura rosaceana Harr.	1	--	1	--
Adelges pinicorticis Fitch	1	--	1	--
Aphrophora parallela Say	2	--	2	--
Phenacaspis pinifoliae Fitch	1	1	1	--
Neodiprion dyari Roh.	1	--	1	--
Exotelia pinifoliella Cham.	1	--	--	--
Vespamia pini Kell.	1	--	1	--
Pinipestis zimmermani Grt.	2	2	2	--
Toumeyella numismaticum P. and McD.	3	3	3	3
Choristoneura pinus Freem.	3	3	3	3
Nuculaspis californica (Colm.)	1	--	1	1
Ips pini Say	3	--	--	3
Dendroctonus valens Lec.	3	--	--	3
Pityogenes sp.	1	--	--	1
Totals	53	37	24	14
Ratios		2.6	1.7	1

*Insects rated from most serious to less serious as
3—most serious
2—moderately serious
1—least serious

in Table 2, this was 53 for jack pine as a whole, 37 for jack pine seedlings and saplings, etc.

From the information available it appeared that jack pine was least subject to insect attack during the small saw-timber stage. Using this lowest figure as unity, a ratio of susceptibility was obtained for each age class. Such a procedure could be altered readily. For example, a rating system from one to ten could be used for the insects. Some system is desirable, however, rather than simply saying that jack pine was more susceptible to insect attack than red pine and therefore should be watched more closely.

The relative risks thus obtained for the tree types among which we wished to distribute the 188 plots are shown in Table 3.

TABLE 3

Relative Risk Ratings of Major Timber Types in Study Area

	No. Acres	Per Cent of Total	Risk Rating	Relative risk as compared to aspen
Jack pine	10,344	9.3	53	2.8
White pine	3,954	3.6	34	1.8
Red pine	8,116	7.3	36	1.9
Aspen	75,926	68.2	19	1
Mixed hardwoods	12,982	11.7	?	1 (assigned)
	111,322	100.1		

Estimated relative values were also considered at this point, involving both the type of timber and the acreage.

By now it was becoming clear that we were dealing with a very complex situation and that it would be extremely difficult to prepare a formula for use in allocation of the plots which would fit all factors. We were also aware of the fact that several of the factors which we were trying to use—such as the over-all average stocking for a type, the risk or susceptibility rating, and the values—were estimates only. And there seemed to be little point in trying to develop a tool more refined than our basic information.

Consequently, after re-examining the various factors involved, the following numbers of plots were assigned to those types in which we wished to place additional plots:

	Original	Additional Plots Assigned	Total Plots
Jack pine	10	45	55
White pine	10	20	30
Red pine	10	45	55
Aspen	10	40	50
Mixed hardwoods	10	38	48
		188	

To determine how the plots should be distributed within a type, we first considered when the trees were most apt to be severely damaged. It appeared that the trees fell into two categories: (a) the hardwoods and conifers, except pine, which did not appear to have any period of special risk except old age, and (b) the pines, which appeared to have periods in which they were most susceptible to injury by insects, especially if the trees were planted. These periods of danger, excluding over-maturity, seemed to be associated with trees less than 15 years of age (to closing of plantation in the forest area involved) and again at the time of pole competition.

For this reason an age-risk factor was developed in the same manner as the relative risks for the different tree species (See Table 2. The ratio is 1.0, 1.7, and 2.6 for small saw-timber, poles, and seedlings and saplings respectively). The number of plots to be placed in each age class of pines was determined in the manner shown in Table 4, using jack pine as an example.

The plots in the seedling (— 15 years, 0–1″ d.b.h.) and sapling (+ 15 years, 1–5″ d.b.h.) stages were further allocated on a 60:40 basis which was obtained from acreage figures for the forest.

This procedure (except the last mentioned step) can be placed in a formula as follows:

$$t = \frac{T \times A \times R}{Mf}, \text{ where}$$

T = total number of plots available for type

A = percentage of area covered by age class

R = risk factor

Mf = manpower factor

t = number of plots for the age class

TABLE 4

Distribution of Plots Within Different Age Classes of Jack Pine

	Small Saw-timber	Poles	Seedlings and Saplings	
Percentage of Area	1.5	27.0	71.5	
A. Total plots (55) x percentage area (= no. of plots based on area)	.8	14.9	39	
B. Relative risk of age class	1	1.7	2.6	
A x B (= no. of plots based on percentage area x risk)	1	25	101	Total = 127
Manpower factor = 127 ÷ 55 = 2.3				
$\frac{A \times B}{2.3}$ = no. of plots to establish	1*	11	43	Total = 55

(*Not possible to have less than one plot)

For types other than pine, where size class did not appear to be of great importance, the plots were placed within each type as a whole. Thus the number of plots to go into each tree type and age class was decided. Consecutive numbers were assigned to the plots within each tree type for identification and recording purposes.

The next problem was that of locating the plots within each type or age class. From the type maps all sections containing the desired tree type and age class were listed by township and range. Keeping in mind the advantages of having the plots as accessible as possible, i.e., near fire lanes or roads and of having as wide a dispersion of the plots as possible, we chose the plots more or less mechanically by dividing the number of plots for a tree class into the number of sections available. Then each "nth" section was chosen to receive a plot. (It appeared better to use a form of systematic allocation at this stage rather than to rely entirely upon the random approach because of the desirability of covering as wide an area as possible.) Each plot was then marked on the type map within the boundaries of the particular section as a place where a plot was to be located. Since only 200 were wanted as permanent plots, every third plot was dropped in those tree types having above ten. It did not appear desirable to establish the majority of the roving plots at the beginning of the survey.

The areas selected were visited, examined and the permanent plots put in. If, upon field examination, the original point on the type map was unsuitable, the plot was moved to the closest available satisfactory point. The plots, established as areas from which information is to be obtained and from which samples are to be drawn, were 1/10 acre in size (1 chain square). A recognition corner was marked and the plot set in by compass on a north-south basis—the boundary being marked with blue paint. After finishing at the plot, a paint trail was marked to the road.

Sampling Within Plots

Once the plots were established, the methods of sampling and the reliability of the procedures to be used became the main problems. Since the time available for field work would not allow sampling for each of the numerous insect species involved on the basis of its life history, the method chosen was that of sampling the probable sites of infestation. In other words, reliance was placed upon sampling of the habitat niches for populations rather than sampling for individual species. Such a procedure should help to correct any tendency to overlook one species in favor of another, either because of differences in size, coloration, stage of life cycle or habitat niche. Samples were taken during equal phenological periods, based upon indicator plant development, from year to year.

Within each plot, samples were taken from three trees of the species concerned. Thirty niches were sampled separately on each tree, including buds, new growth, two- to four-year old wood, new and old foliage, terminals, laterals, cones, flowers or seed, bark, cambium and wood of trunk (only if infested), the root collar, and roots (if found to be infested). A soil sample was taken, including duff. Alternate hosts were examined. The method of collecting each sample was recorded.

Directions were worked out for choosing the trees to be sampled within the plot and also for taking the samples from particular portions and aspects of each tree. These directions and the field record sheet used are included in Appendix A. Material collected was placed in numbered ice cream cartons.

Following the sampling, the material was taken into the laboratory for detailed study and analysis. Here the species of insects involved were identified (or reared, or the stage described so that it could be recognized when encountered again. Many specimens were also preserved for future reference.) Counts were made per unit chosen, e.g., per inch of new growth, per 10 needles, per bud, etc. and the data recorded under the proper niche. This was done separately for each tree sampled. Appendix B is the form used for the laboratory records. In addition, a separate record was kept of what was found in the soil.

Samples from the micro-niches were thus stratified by forest type, tree species, age class, height in relation to crown, and aspect in the tree sampled.

Records are kept under each plot number so that comparisons can be readily made of what is occurring in the plot from year to year. They are also kept by insect species.

Correlation of Insect Information with Plot and other Conditions

In order to correlate the insect populations with the conditions occurring a number of things were done.

(1) At the time of establishment of the plots, descriptive data for each were recorded on McBee Keysort cards which were then hand punched. This recorded information such as the history of the stand, windthrow, cutting, previous treatment with insecticides, closure of overstory, understory and comparable items.

(2) Later each plot was rated by a Vegetational Continuum Index number according to the method developed by J. T. Curtis and his associates. This index utilizes all of the tree species in a stand to express numerically the position of the stand on a gradient from pioneer to climax condition. At the same time, it provides knowledge of the vegetational aspect of the immediate environment. The following quotation from Curtis and McIntosh (1952) is regarded as being especially significant—"One of the difficulties heretofore encountered in studies of natural animal populations has been the lack of an adequate means of delimitation of the nature of the plant segment of the habitat complex. The vegetational continuum index affords a more accurate means of describing this habitat factor and in addition immediately places a stand in its proper relation to other stands."

(3) Weather records were obtained from a station within the Northern Highland State Forest and also from other nearby stations. These are being correlated with development of insects.

(4) Close watch was kept of the occurrence of phenological events in indicator plants, both near the laboratory and within the plots, and the sequences and dates recorded.

Records of climatic and vegetational changes should produce some very interesting information when correlated with insect populations. At the present time we know that certain types of forests are more susceptible to insect attack than are others, but we have had no accurate way of definitely describing or of setting the limits of these susceptible classes.

The matters of susceptibility of trees or cover types to insect attack, and changes in susceptibility which occur during the plant succession, bring up the problems of the ordination of insects which occurs, risk or hazard rating, and the levels at which insect populations may become critical. Insect populations must also be correlated with the extent of subsequent damage.

By utilizing the continuum index and following what is occurring in micro-niches, the conditions under which a particular insect becomes abundant should ultimately become known. Furthermore, study of the micro-niches should provide information regarding the relative frequency of occurrence of insects within the niches (either as individual species or *en masse*), the density or numbers in the niches, the extent of dominance or control of the niche by the insects and the consequences which result. These can be utilized to develop a formula to give an index value which can in turn be multiplied by the "importance value" or "seriousness factor" for the particular niche. Totalling these figures and averaging them for the specific type of niche should give figures which will be useful in comparing the insect populations and their importance within one stand as opposed to another, or from year to year within the single stand. The correlation of such figures with subsequent damage may be utilized to determine the point of "outbreak" and also to record the changes occurring in the forest as far as "area hazard" is concerned. This information should enable the discovery of a population rise before damaging epidemics are in progress and the application of corrective measures before it is too late.

We hope that discussion of this survey plan will serve to focus attention upon the bases for such surveys and for obtaining better information regarding population fluctuations of insect inhabitants of the forest.

Of course, it will require a long period of time to develop the information needed for accurate prediction and for association of the insects with the stages in forest succession. And the methods with which we are experimenting will undoubtedly be modified, improved and refined by many others before we really know how to make a meaningful annual detection survey within a defined area.

One of the difficulties of the sampling method described lies in its failure to follow winged, rapidly moving insects. Special collections are necessary to overcome this fault.

Due to the manpower factor no forest insect survey will ever be completely satisfactory. The difficulties are exemplified by the fact that in a jack pine stand being sampled quite intensively for pine tortoise scale during an appraisal survey, only one out of every 85,000 twigs was examined. It must be emphasized therefore that systematic sampling techniques will never replace the eyes of the foresters as they go about their work. A combination of sampling plus alert observation will give the best results. One of the problems encountered in all sampling of forest insects is that of obtaining sufficient data. However, comparative studies of fluctuations in numbers, carried out with stratified samples and associated with environmental factors, may help to give leads to the solution of the problem.

Summary

A preliminary and experimental forest-insect-detection survey for use within a specified area is outlined. The methods developed take into account the fact that the limiting factor in such a program is the number of man hours available for field work. The bases for establishment of field plots are discussed, together with procedures utilized within the plots. Emphasis is placed upon defining and examining the habitat niches in a forest and on measuring what insect activity is occurring within them. The correlation of the insect ordination with that of the plants and other environmental factors must be taken into consideration. After such factors are known it should be possible, through silvicultural or biological means, to avoid many of the losses now being encountered—which is the goal towards which the forest entomologist is striving.

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APPENDIX A

Northern Highland State Forest Insect Survey

General Methods and Instructions

1) Collect from living trees only, except in case of young plantation trees (0–1″ d.b.h.) where trees appear to have died in previous six months.

2) Samples are to be taken from trees which are representative of forest type for which survey plot was located. Sampling to be restricted to one host species per plot. Notes are to be taken on insect species observed on other host trees, indicating which niche on what tree is involved. In case of the following forest types, sample tree species which contribute the most to the forest type: Fir-spruce, hemlock-hardwood, mixed hardwood, swamp conifer, swamp hardwood.

3) Use three trees for sampling in any one plot. Sample the trees representative of the forest type at the following location—(1) near recognition corner, (2) at five paces, and (3) at ten paces along diagonal from recognition corner to opposite corner. Use appropriate tree closest to point of stopping and sample niches as indicated on collection sheet.

4) Make collections in order from lower, mid- and upper crown. Trees to be divided into 3 aspects 1 = NE to S, 2 = S to NW, 3 = NW to NE. Start sampling tree 1 in aspect 1, tree 2 in aspect 2, tree 3 in aspect 3.

5) Check off on collection sheet the niches sampled by writing number for method of collection in column under the tree number.

6) Since the maximum number of pole pruner lengths which any one person can handle at one time is limited, the higher trees will have to be examined by use of binoculars. Note off-color foliage, defoliation etc. in special remarks column of collection sheet.

7) At every fifth plot as indicated on the plot summary sheet—a replicate plot for sampling is offset 1 chain from the original plot. Replicate plot is offset from side of original plot which lies farthest from edge of forest type. Replicate plots to be indicated by collection sheet by prefix R in front of plot number. Replicate plot has no marked boundaries, but sampling procedure will follow procedure used on original plot. (Plots are one chain square).

8) Walk boundaries of plot noting insect conditions. Observations can be written in special remarks column of collection sheet.

9) Make notes on observations as to condition of trees on plot, management practices carried out on plot, whether forest type has been changed by management practices or not, etc.

10) All collection containers should be properly labeled. Plot number can be placed on tape on carton. Tree and niche number can be permanently marked on container; e.g. container labeled 3–8 would mean new growth on upper lateral (niche 8) on tree 3. Plot number is preceded by year, e.g. 58–23, would mean plot 23, sampled in 1958. Replicate plots are indicated by prefix R, e.g. R58–23 would mean replicate plot 23, collection made in 1958. On lab. sheet R should be made with red pencil.

11) Recognition corner of plot has tree with two bands of blue paint or 4′ stake (2″ x 2″ square) painted blue on top half. There is a metal tag on wire at base of the tree or stake.

Specific Directions

1) *Leaders and laterals*—These are to be separated into new growth and 2–4 year old wood. New growth is to include all growth of new terminal from base of bud present in spring of year. All leader and lateral samples are to include an accumulative total of 10″ of growth wherever possible. These samples can be fractioned into 2–3 inch lengths by use of hand clippers, in order to fit collections into containers. Wherever possible, leader and lateral collections should possess foliage. Prune laterals and tips at one time and place on mat on ground before sectioning to save time in handling pole pruner. Mat is to help locate insects which may drop off. With deciduous trees leader (terminal) samples will have to be taken from branches in upper-most part of crown.

2) *Buds*—Buds are sampled as such until bud breaks and candle formed, then growth is classified as new growth.

3) *Cones*—Cones can be left on branches and removed in lab.

4) *Trunk*—Trunk or bole of tree is to be examined up to breast height. This category is set up to include insects usually associated with bark and cambium on older trees. If evidence of insects is found, then sample, giving size of area examined and size of area sample is taken from. Sample to be taken only if damage is externally visible.

5) *Root collar*—Use three consecutive arcs around tree for sampling. These arcs are to correspond to those used for sampling lateral branches. Watch for pitch masses etc. Indicate size of arc from which sample taken.

6) *Roots*—Take sample from seedling tree only if visibly damaged and it does not appear tree will recover.

7) *Alternate host*—Make notes of species of host examined, e.g. spittlebug on sweetfern in Pn plantation.

Soil Sampling

1) Take four 3″ diameter soil samples, 3″ deep into soil, spaced at intervals around plot. Try to take samples from the four quarters (NW, NE, SE, SW) and these should be representative of the different conditions that are encountered on the plot. Keep these collections separated and in plastic bags in containers. If standing water in area note height above water level that soil sample was taken. Soil sample containers can be marked with date, plot number, niche number and quadrant section, e.g. 58–23–1 NW.

2) At least one sample should be taken from under crown of tree representative of the forest type on the plot.

3) If tree over 1″ d.b.h. then soil sample should be taken at least one foot from bole of tree and within radius or circumference of crown of tree.

4) If tree under 1″ d.b.h., particularly those up to about 4′ tall, and showing symptoms characteristic of root injury, sample soil directly under tree around roots, at the same time examining this area of the tree for insect damage.

Northern Highland Insect Survey

Date______ Plot #______
Forest Type______ Tree species sampled______ Collector______
Sampling started______ M. Finished______ M. Temp.______ °F. % Cloud______
Rain______ Wind______ m.p.h.______ Direction______
Phenological data______
*1. *Soil collection*—Distance from nearest tree______ Plot Quadrant______
Shaded or open—______

Niche #		Tree #1	Tree #2	Tree #3
	Height			
	Starting aspect			
	Shaded or open			
2	*Leaders* buds			
*3	new growth			
*4	2-4-yr.-old wood			
5	foliage new			
6	old			
7	*Laterals* buds			
*8	new growth lower			
*9	mid			
*10	upper			
*11	2-4-yr.-old wood lower			
*12	mid			
*13	upper			
14	foliage new lower			
15	mid			
16	upper			
17	old lower			
18	mid			
19	upper			
20	*Cones* ♂			
21	♀ 1st year			
22	♀ 2nd year			
23	Deciduous flowers flower			
24	fruit			
*25	*Trunk* bark			
26	cambium			
27	wood			
*28	Root collar			
29	Root			
30	*Alternate Host*			

Boundary Examination and Special Remarks —

Collection method: Picking = 1 Hand clip = 2 Pole pruner = 3
Examined with binocular = 4 Examined only = E
Tree Aspect: NE to S = 1 S to NW = 2 NW to NE = 3 Shaded = S Open = O
*Indicates those niches for which field collection containers will be necessary.

APPENDIX B

Northern Highland State Forest Insect Survey
Laboratory Record

Plot No.________

Date____________

Tree species____________

Tree No.____________

Measurements					Damage	Insect Species					
Niche	Unit	No. or size	Units Exam.		per cent damage (within niche sampled)		Stage	No. of insects	Ave. No./Unit	No. Rear	No. Preserved

Record total length of new growth and designate for other measurements.
Damage: visual estimate of percentage of structure destroyed.

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