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Spruce Budworms Handbook

Techniques for Measuring Early-Larval Dispersal of Spruce and Jack Pine Budworms

In 1977, the United States Department of Agriculture and the Canada Department of the Environment agreed to cooperate in an expanded and accelerated research and development effort, the Canada/United States Spruce Budworms Program (CANUSA), aimed at the spruce budworm in the East and the western spruce budworm in the West. The objective of CANUSA was to design and evaluate strategies for controlling the spruce budworms and managing budworm-susceptible forests, to help forest managers attain their objectives in an economically and environmentally acceptable manner. The work reported in this publication was wholly or partially funded by the Program. This manual is one in a series on the spruce budworm.

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Contents

Techniques for Measuring Early-Larval Dispersal of Spruce and Jack Pine Budworms

by

Daniel T. Jennings, David G. Fellin, Harold O. Batzer, Mark W. Houseweart, and Roy C. Beckwith[1]

Introduction

Early-instar larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.); the western spruce budworm, *C. occidentalis* Freeman; and the jack pine budworm, *C. pinus pinus* Freeman, disperse periodically within and from their host trees. Some larvae disperse by crawling, but most dispersal occurs when the small larvae "spin down" from trees on silken threads. The larvae spin silk from glands located near their mouthparts. The silk threads are anchored to branches or other attachment sites and the larvae continue to spin silk as they descend from the tree. Frequently, the threads break at their points of attachment and larvae are carried by winds, sometimes for great distances.

Small larvae disperse primarily after egg hatch in midsummer, when first-instar larvae seek overwintering shelters, and the following spring, when second-instar larvae leave their overwintering hibernacula and seek feeding sites in needles and buds. First-instar larvae disperse in search of overwintering sites under bark flakes, moss, lichens, flower bracts, and branch debris, and in previously mined buds (Batzer 1960) on host trees. Once suitable shelter is found, the larva spins a hibernaculum, molts to the second instar, and overwinters in a physiological state of inactivity. The following spring these second-instar larvae leave their overwintering sites and disperse in search of food. Spring-dispersing larvae usually mine old needles, current buds, and male cones before feeding on new foliage.

Dispersal of young larvae generally is downward rather than lateral. The position and density of host trees within a forest stand are significant factors in "larval dispersal dynamics." Previous infestation and defoliation histories can influence dispersal patterns. For example, during early phases of budworm outbreaks, the majority of eggs are laid on foliage in the upper crowns of dominant trees; hence, most dispersing first-instar larvae originate from upper crowns. Lower crowns of dominant trees, crowns of codominant and suppressed trees, nonhost understory vegetation, and forest floor litter are substrates where dispersing larvae may land. Subsequently, spring-dispersing larvae may originate from lower crown levels, including tree boles and lower

[1]Daniel T. Jennings: USDA Forest Service (FS), Northeastern Forest Experiment Station, Orono, Maine; Fellin: USDA FS, Intermountain Forest and Range Experiment Station, Missoula, Mont.; Batzer: recently retired, USDA FS, North Central Forest Experiment Station, St. Paul, Minn.; Houseweart: Cooperative Forestry Research Unit, University of Maine, Orono; Beckwith: USDA FS, Pacific Northwest Forest and Range Experiment Station, LaGrande, Oreg.

limbs where the larvae have overwintered. During later phases of budworm outbreaks, upper crowns become progressively thinner due to defoliation, shifting suitable egg-laying sites to lower and lower levels. Because dispersing larvae originating from these lower levels have less substrate for interception, a large portion drops to the forest floor.

Larval mortality is high during both dispersal periods. Summer-dispersing larvae that encounter inhospitable or unsatisfactory overwintering sites are forced to continue searching for suitable sites to spin hibernacula. Spring-dispersing larvae often impinge on nonhost vegetation (Miller 1958), where they die or continue to search for suitable host foliage. Dispersal losses are considerably greater during spring dispersal than during summer dispersal (Mott 1963, Foltz and others 1972, Batzer and Jennings 1980). Because spring weather frequently contains turbulent air, larvae are more likely to be dispersed by wind at this time of year (Henson 1950). During both dispersal periods, larvae are exposed to a variety of predators, including ants, spiders, beetles, and birds. They also are susceptible to adverse abiotic factors such as wind, rain, and changes in temperature.

Over the past several years we studied early-larval dispersal of conifero-phagous budworms as part of more comprehensive population dynamics research or to determine the relationships between stand conditions or silvicultural practices and their effects on larval dispersal behavior. Species, study areas, and forest types included

Species	State	Forest Type
C. pinus pinus Freeman	Minnesota	Jack pine
C. fumiferana (Clem.)	Maine	Northeastern spruce – fir
C. occidentalis Freeman	Oregon and Washington	Northwestern Douglas-fir
C. occidentalis Freeman	Montana	Mixed conifer, northern Rocky Mountain

The purpose of this paper is to (1) describe four trap designs developed independently and used in recent years to measure early-larval dispersal of budworms, (2) present information on sticky materials that are available and the tools needed to apply these materials to traps, (3) describe how to place traps in the forest and how to time larval emergence so that deployed traps will capture dispersing larvae, (4) describe transport-storage box designs for transporting sticky traps to and from the forest and for storing traps in the laboratory, (5) describe methods for examining sticky traps in the forest and laboratory, and (6) provide information on cleaning and preserving specimens for further study.

The techniques developed for measuring early-larval dispersal of spruce and jack pine budworms are applicable to other species of forest defoliators with similar dispersal habits, e.g., gypsy moth, *Lymantria dispar* (Linnaeus); and Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough).

We thank the following for their critical review comments and suggestions: Paul E. Buffam, Director, Forest Pest Management, USDA Forest Service, Pacific Northwest Region (R-6); John L. Foltz, Assistant Professor of Entomology, University of Florida; Daniel M. Schmitt, Program Manager, CANUSA-East; and Ronald W. Stark, Program Manager, CANUSA-West.

Traps

The four study traps were named for the States in which they were used: Minnesota, Maine, Montana, and Oregon. All four traps have (1) a support mechanism, (2) a trapping or collecting surface, and (3) sticky materials or adhesives to ensnare insects falling or alighting on the trap surface. The Maine and Montana traps also have a wire screen that excludes birds and small mammals that might be attracted to the traps.

Minnesota Trap

This trap (figs. 1 and 2) was designed for trapping jack pine budworm larvae. It has the simplest design of the four traps. It consists of a 6- by 6- by 1/8-inch[2] piece of tempered hardboard (Masonite)[3] mounted on a 2- by 2- by 24-inch stake with a 4-dwt duplex staging nail. Stakes are presharpened at one end and driven 1 foot into the ground with a hammer or mallet. To achieve uniform height of the trapping surface, stakes are premarked before they are driven.

Tempered hardboard is preferred over untempered hardboard and should be

[2] To convert English units to metric units, use these equivalents:
1 inch = 2.54 cm
1 ft = 0.3048 m
1 acre = 0.4047 ha
1 inch^2 = 6.452 cm^2

[3] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

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Figure 1—Field placement of Minnesota trap for measuring early-larval dispersal of jack pine budworm.

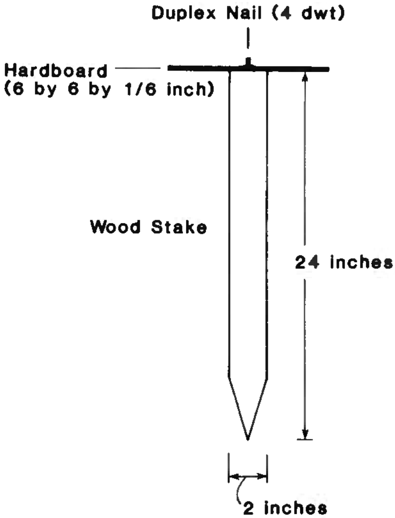

Figure 2—Schematic of Minnesota trap with components.

painted before applying the sticky materials; otherwise, the sticky material is absorbed into the board, leaving a dry, untacky surface. We used fast-drying white enamel spray paint and applied one or two coats. Sticky materials are applied **after** the hardboards have been fastened to stakes in the field.

The duplex nail fastens the board to the stake and provides a means for retrieving the boards after they are coated with sticky materials. An easy way to avoid touching the sticky surfaces is to pull the duplex nail with slip-joint pliers. Board and nail usually separate (together) from the stake; the duplex nail is then used to handle both. Before the board is placed in a box or carrying case for transport and storage, the nail is snipped just beneath the board with wire cutters or diagonal-cutting pliers.

Advantages of the Minnesota trap are that it is small, light, and simple to construct. The trap has less surface area than larger board traps; less paint and sticky material are required.

Disadvantages of the Minnesota trap are that the trapping surface is unprotected and that the trap board is white. Birds and small mammals may be attracted to dead insects ensnared on the sticky boards and in turn, may become trapped. Also, flying beetles, flies, wasps, and aphids are attracted to light-colored surfaces, and their presence on sticky boards makes it difficult to distinguish and accurately count budworm larvae. This problem can be eliminated by painting the boards a color that is less attractive to insects, such as red. In addition, the small size of the Minnesota trap means that the probability of ensnaring dispersing larvae is diminished, so a number of traps may be needed to obtain an adequate sample.

Maine Trap

This trap (figs. 3 and 4) has four times the trapping surface area of the Minnesota trap, and has a protective screen that excludes birds and small mammals. The Maine trap consists of a 12- by 12- by 1/4-inch piece of tempered hardboard that is fastened to a 2- by 2- by 32-inch presharpened

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Figure 3—Field placement of Maine trap for measuring early-larval dispersal of spruce budworm.

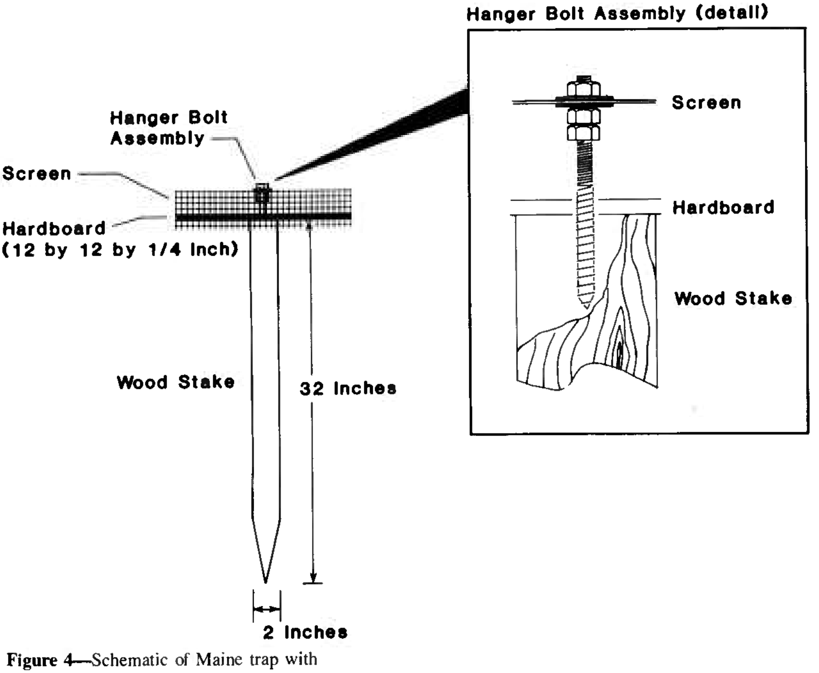

Figure 4—Schematic of Maine trap with components.

stake with a hanger bolt assembly. The hanger bolt (fig. 4) has both machine and wood threads. Two 1/4-inch nuts one-half inch in diameter are locked together about three-quarters of an inch below the top of the bolt.

Before installation, the hardboard is primed with white enamel primer followed by one coat of red latex exterior paint (Jennings and Houseweart 1983). A 3/16-inch hole is drilled in the center of the board for mounting on the stake.

For installation, the stake is first driven 1 foot into the ground with a hammer or mallet. As with the Minnesota trap, premarking the stakes achieves uniform height of the trapping surface. A wrench is used to mount the hardboard on the stake by means of the hanger bolt. Once the hardboard is in place, sticky material is applied to the hardboard with a spreader.

The protective screen is constructed from an 18- by 18-inch piece of galvanized hardware cloth (1/2-inch mesh). The screen is cut with metal-cutting snips and folded into an "open-sided box" about 12 by 12 by 3 inches (fig. 5). Needle-nose pliers are

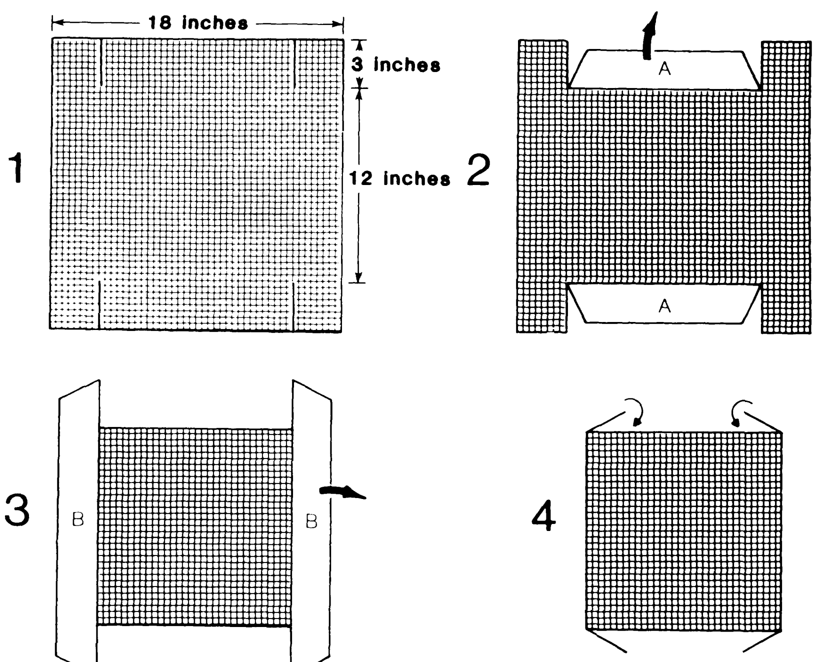

Figure 5—Procedure for cutting and folding protective screening, Maine trap.

used for handling screen corners and hooking loose wire ends. Two 5/16-inch washers (3/4 inch in diameter) and a third 1/4-inch nut support and fasten the protective screen above the sticky board.

To disassemble the Maine trap, the top nut, two washers, and screen are removed. The hanger bolt is unscrewed from the stake by means of the locked nuts, releasing the board. The hanger bolt also provides a means for handling the trap and avoiding contact with the sticky surface. Once removed from the stake, the board is held by the lower uncoated surface while the hanger bolt is removed. The sticky board is then placed in a transport-storage box for transport to the laboratory.

Adding a protective screen to the Maine trap requires a special mounting support. Tests indicated that more spruce budworm larvae were trapped on screened than unscreened traps (Jennings and Houseweart 1983). We found no evidence that screening interfered with trapping efficiency. Moreover, screened traps generally had fewer nontarget insects and less debris, making them easier to examine. One possible disadvantage is that the screens are bulky and are difficult to store and transport.

Montana Trap

This trap (figs. 6–8) consists of plywood covered with coated paper to which sticky material is applied. The trap is covered with a protective screen and supported by three stakes.

The trap board is an 18- by 24-inch piece of 3/8-inch grade A-C exterior plywood with three 1-inch holes

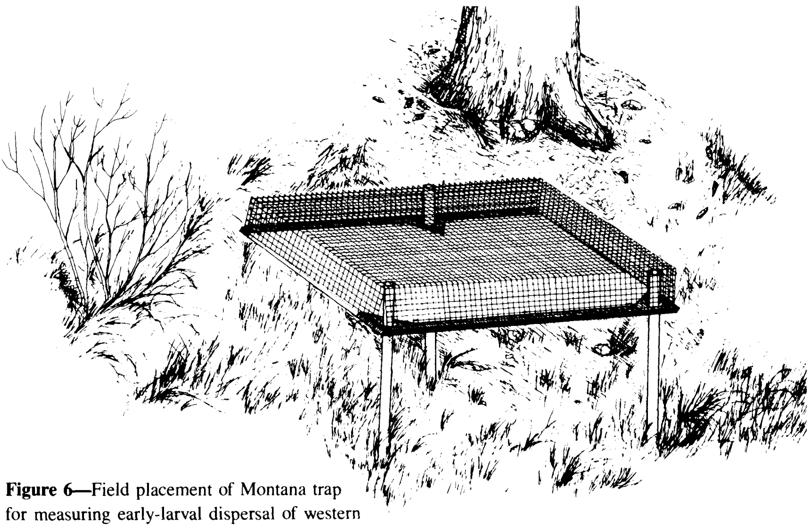

Figure 6—Field placement of Montana trap for measuring early-larval dispersal of western spruce budworm.

drilled approximately 1/2 inch from the trap edge. Two holes are drilled near two corners of the board and a third hole drilled midway along the length of the board near the opposite edge (fig. 7). We cut trap boards from 4- by 8-foot sheets of plywood so that the outer grain of the ply was parallel to the long dimension of the board. If cut with the grain at right angles to the long dimension, trap boards tend to curl, making it difficult to place traps in and remove them from storage-transport boxes.

We painted our traps dark green, light green, or off-white. Dark green (a lead-based exterior enamel) appeared to absorb more heat than the other colors and caused the sticky material to permeate the coated paper. The paper would then stick to the trap board, making it difficult to remove the paper and examine the sample. We now use an off-white (latex-base exterior) paint for trap boards.

Trap boards are covered on one side with polyethylene-coated freezer wrapping paper. Stock rolls of paper are 20 inches wide, so, before use, the entire roll is cut to a width of 17 inches with a bandsaw. The paper is then cut into 3-foot lengths, notched midway along one side, and the opposite corners are trimmed so that the paper does not cover the holes in the trap boards. The paper is placed on the board coated side up and stapled along the edges with 1/2-inch staples. Ends of the paper are turned under and stapled to the bottom of the board (fig. 8). Staples are inserted with the stapler tilted slightly sideways; this makes the staples easier to pull when dismantling the traps.

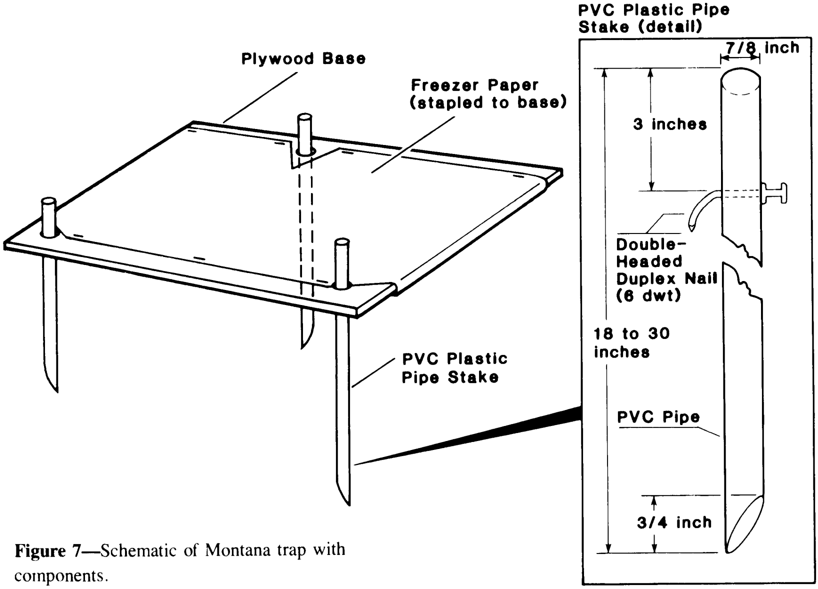

Figure 7—Schematic of Montana trap with components.

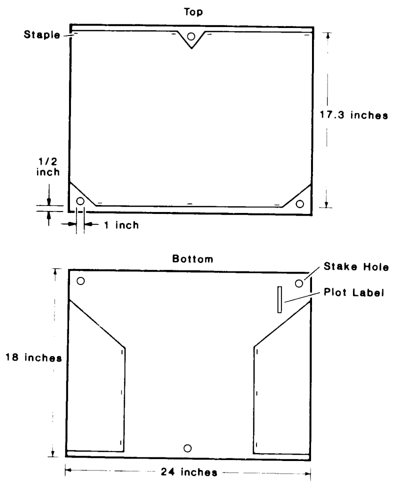

Figure 8—Top and bottom view of Montana trap.

The sticky material is applied to the coated paper about 2 weeks **before** the traps are deployed. During that period, traps are held in storage-transport boxes in the laboratory.

Stakes used to support Montana traps are cut from 20-foot lengths of 7/8-inch o.d. PVC pipe. Stakes are cut to lengths ranging from 18 to 30 inches, and beveled on one end for driving into the soil. A hole is drilled 3 inches from the top of the stake and a 3-inch, 6-dwt duplex nail is inserted and bent slightly to support the trap. Stakes are cut on a table saw with a fine-tooth blade; coarser blades cause the pipe to shatter.

All traps are covered with a 1/2-inch mesh hardware cloth screen similar to that used with the Maine trap. Each piece of screen is cut to 24 by 30 inches with metal-cutting snips, and a 3-inch square is cut from each corner (fig. 9). Each side is then folded to form an 18- by 24-inch "open-sided box." For ease in handling, screens are transported flat and are folded immediately before being placed over the trap board.

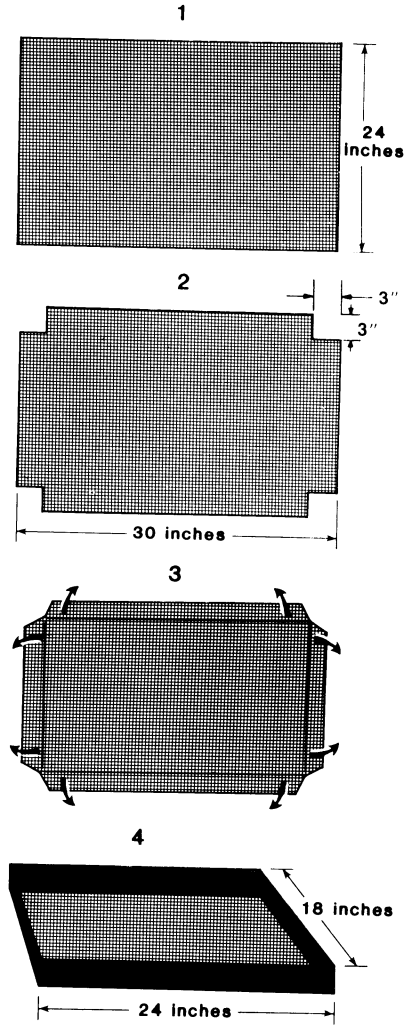

Figure 9—Procedure for cutting and folding protective screening, Montana trap.

For installation, three stakes are driven about 6 inches into the ground. Tops of the stakes are slipped through the holes in the board until the board rests on the duplex nails in the stake. The screen is placed over the trap, supported by the stakes.

On steep slopes, traps are installed with the long axis of the trap on the contour and with the single stake uphill. Traps so positioned have the trapping surface somewhat parallel to the slope, allowing rainwater to run off. However, the trap board should be at least 1 foot from the ground (fig. 6).

An important advantage of the Montana trap is its large size, which allows at least six subsamples to be taken; the resulting data can be used to test trapping efficiency and larval distributions per unit area. Covering the boards with freezer paper allows them to be used for several years. The PVC pipe stakes are light and can be installed easily.

Oregon Trap

This trap (figs. 10 and 11) was designed for trapping larvae of the Douglas-fir tussock moth (Mitchell 1979) and larvae of western spruce budworm in the Pacific Northwest. The Oregon trap is constructed from a 2-qt (Seal Right) ice-cream carton 6-1/2 inches high and 5 inches in diameter. The outside surface of the carton is covered with a plasticized laminated paper (Tyrek), allowing about five-eighths of an inch overlap, and fastened with a pushpin at the top and bottom. Tyrek paper resists moisture, oil penetration, and tearing. The paper is coated with a sticky material, either by spreader or aerosol application. We prefer aerosol application because it is cleaner, provides a more uniform coating, and is easier to do, especially under field conditions. The paper is changed periodically, depending on the trapping objective. The paper can be examined in the field with a hand lens or returned to a laboratory for microscopic examination.

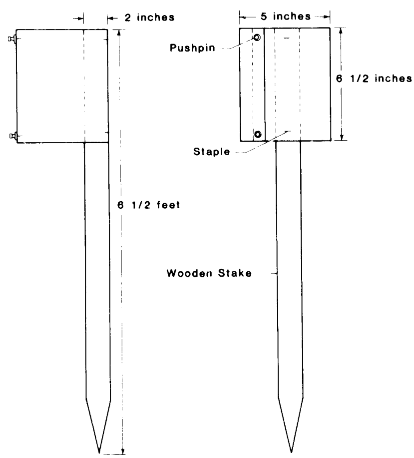

Figure 10—Schematic of stake-mounted Oregon trap with components.

In field use, the trap is supported in a vertical position by one of two methods, depending on study objectives. For studying periodicity, individual traps are supported on a 2- by 2-inch by 6-1/2-foot wooden stake that has been presharpened and marked at groundline for driving. The carton cover is discarded and the ice-cream carton is inverted over the stake and attached to the stake opposite the pushpins with a staple gun and two 3/4-inch staples (fig. 10). For stability, the bottom of the carton should rest on the top of the stake.

For studying periodicity and vertical distributions, traps are suspended at various sample heights on a 1/8-inch nylon rope attached to a pulley that is anchored by another rope to a nearby tree (fig. 11). The rope should be three times the total height from pulley to ground so that the top trap can be lowered for servicing. With this system, traps can be raised and lowered for periodic examination and collecting. The cover remains on the carton and provides an anchoring surface to keep each carton in a vertical position. Small holes are bored through the cover and bottom of the carton with a knife or screwdriver. The rope passes through these holes and an overhand knot is tied just above and below the carton. Flat steel washers with 1/4-inch holes provide strength and keep the carton from slipping over the knot (fig. 11).

Advantages of the Oregon trap are that it is small, light, and easily constructed, and that the collecting surface is disposable. Ice-cream

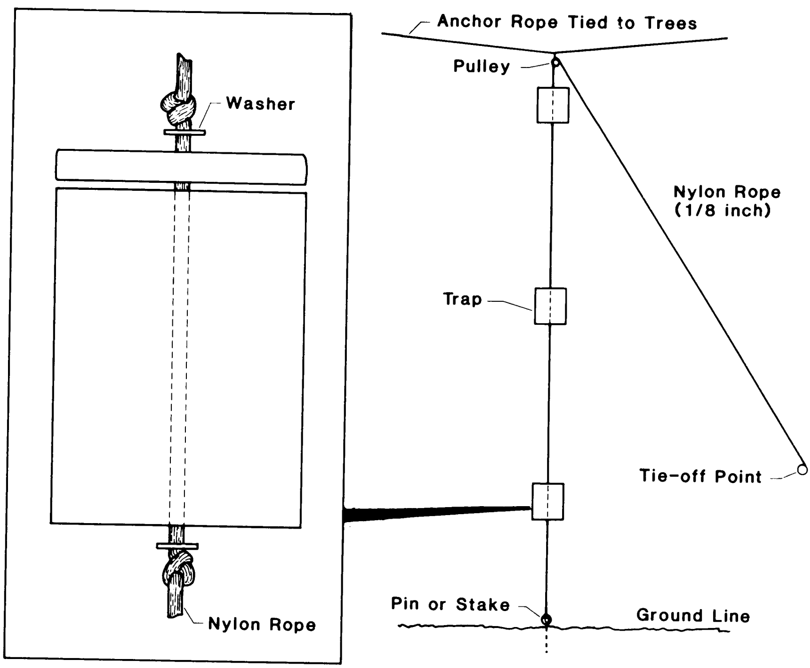

Figure 11—Schematic of rope-mounted Oregon traps for sampling larvae at different heights.

cartons last for about 4 months unless damaged during servicing or ruined by long rainy periods. In north-central Washington, only 5 percent of 90 traps were damaged during 1980, an excessively wet year in that region. The suspended trap position keeps the collecting surface relatively clean and reduces interference from birds. The rope-pulley system allows trapping at different crown levels (Beckwith and Burnell 1982). Because the removable collecting surface allows sampling without removing the entire trap, the Oregon trap can be used to determine dispersal periodicity (Mitchell 1979).

The cylindrical traps are bulkier and more difficult to transport than most flat traps; we used a large nylon laundry bag to carry traps into the woods. The small collecting surface—96.5 in^2 stake mounted; 103 in^2 rope mounted—may be a disadvantage, but size did not hinder our trapping objectives. Also, a larger cylindrical container can be used.

Materials
A variety of sticky materials (adhesives) and greases are available for trapping insects (Southwood 1978). The following materials generally are effective for trapping and holding early-stage larvae of spruce and jack pine budworms: Tree Tanglefoot, Bird Tanglefoot, Stikem Special, Tack Trap, and Tangle Trap. Although we have not tested and compared their trapping effectiveness, some general information is available (Kaloostian 1961). Tack Trap and Stikem Special are colorless while Tree Tanglefoot is light amber. Budworm larvae are distinguishable in all of these adhesives, but larvae are easier to recognize in the two relatively clear, colorless materials. Tree Tanglefoot has a tendency to form a surface film or glaze after prolonged exposure, but we did not detect a deficiency in trapping and holding jack pine budworm larvae. Tack Trap is viscous and will not flow off vertical surfaces even at temperatures of 125° F (52° C). This is an important feature when traps are placed on steep slopes as in Montana, or on vertical rope mounts as in Oregon.

Tree Tanglefoot, Bird Tanglefoot, and Tangle Trap are available in aerosol cans that are easy to use, especially when traps are serviced periodically in the field as in the Pacific Northwest. Bird Tanglefoot is the more viscous and must be sprayed with the can held in an inverted position. Tangle Trap applies a thinner coat, but it is still sticky enough to capture budworm larvae. More frequent spraying of the trap surface may be necessary with Tangle Trap than with the other products.

The trapping efficiency of all adhesive materials is impaired by the accumulation of debris, including conifer needles, deciduous tree leaves, pollen, dust, and flying insects. In 1980, the Montana traps were covered with volcanic ash from the May 18 eruption of Mount St. Helens in Washington (Theroux and Fellin 1982). Resurfacing or recoating traps with fresh sticky material is virtually impossible except with aerosol sprays. To avoid excessive accumulation of debris, traps should be retrieved from the field as soon as possible after larval dispersal ceases.

Spreaders

A variety of tools are available for applying and spreading sticky materials to traps, including joint knives, wall scrapers, taping knives, linoleum spreaders, grout spreaders, and putty knives. Various wall scrapers, linoleum spreaders (metal trowel) and grout spreaders are shown in fig. 12. One adhesive manufacturer recommends a short, medium-stiff, nylon paintbrush for applying sticky materials; however, the materials must be soft and pliable, i.e., at temperatures above 75° F (24° C).

Although we have not tested all spreading tools, we have found that wall scrapers work well. Scrapers with a medium-stiff flexible blade, about 3 to 3-1/2 inches wide, allow uniform spreading of adhesive over a wide area. Putty knives with narrow blades are unsatisfactory, particularly for larger traps. Wall scrapers with 3- to 5-inch handles allow easy removal of sticky materials from gallon cans; removal may be difficult with larger linoleum spreaders or metal trowels. Removal of adhesives from containers was not difficult in Montana because adhesives were purchased in 5-gallon buckets.

Figure 12—Tools for applying and spreading sticky materials to traps.

Grout spreaders work well on most flat traps, but should not be used with the Montana trap because the serrated teeth cut the paper. Commercial grout spreaders are relatively inexpensive compared with the other spreading tools and can be discarded after use.

Two other tools are used for applying and spreading adhesives to Montana traps. The sticky material is spread liberally over the trap paper with a cake-decorating spatula with a 12- by 1/4-inch blade and 5-1/2-inch handle. Final spreading is done with a spreader made from a piece of 0.05-inch-thick 4- by 6-inch aluminum inserted into a grooved 6- by 1-1/2- by 3/4-inch wooden handle. The bottom portion of the aluminum is bent about 45 degrees (fig. 13) and the leading edge is V-notched with a triangular file to a depth of 0.10 inch. The points are rounded with an 8-inch flat mill bastard. This spreader resembles the commercial grout spreader shown in figure 12 except for the pointed teeth.

Regardless of the compound, spreader, or trap used, sticky materials should be applied and spread evenly over the trap; bubbles, skips, and thick concentrations of the material should be avoided. Similar precautions are needed with aerosol applications; a 1/16- to 1/32-inch coating is recommended. At this thickness, 1 gallon of Tack Trap covers about 23 to 25 boards (12 by 12 inches). Care should also be taken to cover all trapping surfaces, including areas around supporting bolts or nails. However, with the Montana trap, Tack Trap is not applied within 1/2 inch of the edge of the coated paper to keep the board free of sticky material.

Ideally, sticky materials should be applied at a temperature of about 75° F (24° C). At lower temperatures these materials are less pliable and more difficult to spread. Preheating may be required. **Caution:** Because many sticky materials contain volatile petroleum solvents, they should **not** be heated directly over an open flame or electric heating element. A hot-water bath with a double pan or double boiler arrangement is safer and recommended by manufacturers of these materials.

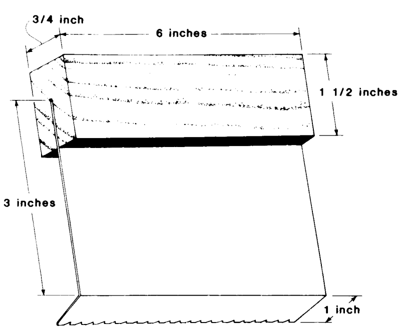

Figure 13—Spreader used for spreading sticky materials on Montana traps.

Trap Deployment

Depending on the study objectives, traps can be deployed in the forest in a variety of ways, including placement along line transects; in pairs or singly; in a randomized block design for testing two or more variables; or in a grid throughout a study area where both treatment and edge effects are variables in the design. Traps can be placed under individual tree crowns and at various distances from individual, isolated trees.

Sampling Designs

In Minnesota we used a systematic randomized scheme for locating traps within circular 1/10-acre plots in a jack pine forest (Batzer and Jennings 1980). A map of each circular plot was divided into pie-shaped fifths, and by superimposing graph paper on the pies, we numbered all potential 6-inch squares. One trap was randomly located per fifth by drawing numbers from a table of random numbers. Compass bearings and distances from plot center were determined within each fifth for ease in locating the trap.

To sample dispersing western spruce budworm larvae in north-central Washington, we used a randomized trap placement based on a 100-point grid covering 12.5 acres. Thirty traps (two traps at each of 15 points) were used for general dispersal sampling. Traps were spaced about 33 feet apart at each sample point.

A similar grid system was used in Montana. Traps were positioned in cutting units so as to grid the entire area. Initially, second-instar dispersal was measured in four 15-acre cutting units. We positioned traps arbitrarily at approximately 100-foot centers throughout each unit for a distribution of 2.7 traps per acre (fig. 14). In later research, sampling intensities ranged from 0.3 to 2.2 traps per acre. The proportional allocation of traps usually was based not so much on a statistical apportionment but on the number of traps that could be handled logistically, in both field and laboratory.

We have little information on the **optimum** spacing of traps within forest stands or between trees. Unlike the spacing of pheromone traps used to study adult dispersal, spacing of sticky traps is not hampered by possible interference from surrounding nearby traps. Larvae have little or no control over the pattern of dispersal; they are not "lured" to a particular trap. Dispersal is influenced by a variety of physical and biotic factors, such as density and composition of the forest and weather during the dispersal period. In New Brunswick, Shaw and Little (1973) found that about two-thirds of the spring-dispersing (May) larvae were trapped during the hottest part of the day. They concluded that rainfall markedly inhibited dispersal but found no association between larval dispersal and winds. Effects were similar for the western spruce budworm in Washington (Beckwith and Burnell 1982).

Timing Trap Deployment

Regardless of the larval instar (first or second) being sampled, traps should

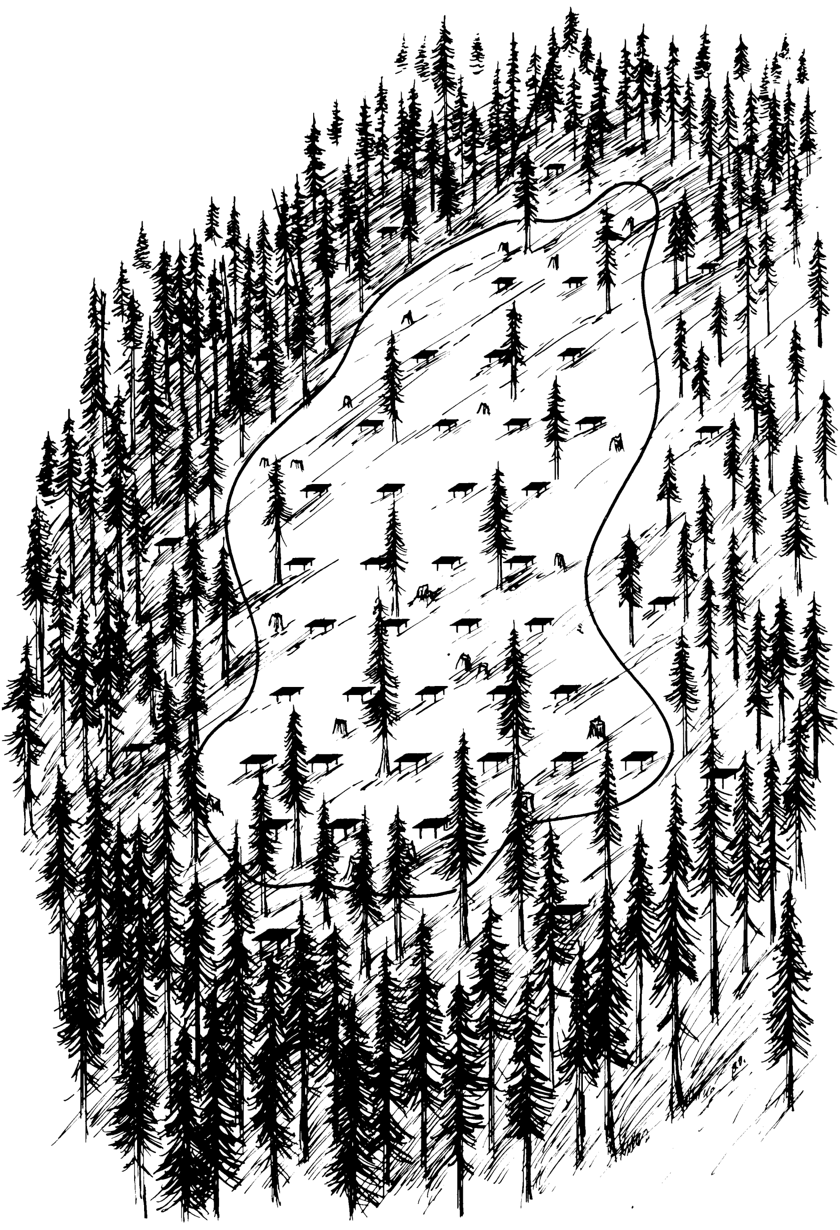

Figure 14—Grid system used for field placement of Montana traps.

be deployed **before** dispersal begins and left in the field until dispersal ends. Both trapping periods may be prolonged, and local weather and climate play an important role in determining the initiation and duration of dispersal. Periods of dispersal vary by geographic region.

Summer Dispersal—To bracket summer dispersal, traps are deployed in the forest **before** egg deposition and eclosion, and are left in the field until all larvae have emerged from egg masses, dispersed, and spun hibernacula. Because budworm eggs are deposited over an extended period of time (20 to 30 days) and embryonic development varies, the period of first-instar emergence and subsequent dispersal may span several weeks. In Maine, this dispersal period can begin as early as mid-June and may continue through August. Variations in summer dispersal are influenced by local weather conditions and seasonal development of the budworm.

In Montana, Fellin and Theroux (unpublished) monitored dispersal of first-instar larvae for 3 consecutive years. They found that the dispersal period in 1978 was twice as long as in 1979 and 1980:

Year	Dispersal began	Dispersal ended	Dispersal peaked	Length of dispersal period
1978	August 4	October 13	August 6–13	70 days
1979	August 13	September 17	August 20	35 days
1980	July 29	September 8	August 17	41 days

In addition to a longer period in 1978, larval dispersal peaked earlier that year. This prolonged dispersal of first-instar larvae, though unexplained, indicates the variability encountered in measuring dispersal.

Sampling pupae or adults can be helpful for timing the deployment of summer-dispersal traps. In the Pacific Northwest and in Minnesota, traps are placed in the forest when 50 percent of the budworm population pupates, or when the first emerged pupal cases are found, whichever occurs first. Elsewhere, we have used catches of male moths in pheromone-baited traps to aid in timing trap deployment. Because male moths generally emerge several days before female moths, first pheromone-trap catches of males are good indicators that female emergence and egg laying are imminent.

Spring Dispersal—To bracket spring dispersal, traps are deployed **before** larvae emerge from overwintering hibernacula and are left in the forest until dispersal is complete and the larvae have established feeding sites in needles or buds. In the Northeast, spring dispersal is apt to commence in late March to mid-April (or even May) and span a full month. Peak emergence of larvae generally occurs within a few days (Shaw and Little 1973), but Rose and Blais (1954) reported two peaks in spring emergence occurring 3 weeks apart in northwestern Ontario during the spring of 1952.

In Montana, the second-instar larvae begin dispersing about mid- to late April, but the period of emergence characteristically extends beyond a month. Fellin and Theroux (unpublished) monitored spring dispersal in Montana at weekly intervals for 4 years and found that the dispersal period ranged from more than 29 to 60 days, but with only one peak. Spring dispersal began in mid- to late April, peaked in mid- to late May, and ended in early to late June.

Larval emergence from the hibernaculum is related to accumulated heat units above a certain threshold temperature (Bean 1961, Cameron and others 1968, Miller and others 1971); thus, the date of spring emergence often can be predicted within a few days. Two threshold temperatures have been used: Bean (1961) used 37° F (2.8° C) in Minnesota, and Miller and others (1971) used 42° F (5.6° C) in New Brunswick. Degree-days generally are calculated from mean daily temperatures **above** the base threshold temperature. Calculation begins on the first day in spring when the maximum temperature reaches or exceeds the threshold temperature. More precise methods for calculating degree-days are given by Baskerville and Emin (1969) and Allen (1976).

The number of degree-days that accumulate before larvae begin emerging varies by region; an average is 75 degree-days above 42° F (5.6° C). In New Brunswick, Miller and others (1971) found that spring emergence of overwintering spruce budworm larvae ranged from 69 accumulated degree-days above 42° F (5.6° C) at Green River to 84 degree-days at Fredericton. Shaw and Little (1973) determined that only 1.7 percent of all captured larvae had dispersed when 75 degree-days had accumulated; but to avoid missing any early emerging larvae, they initiated trapping once 67 degree-days had accumulated. They caught 77.4 percent of all larvae during a 4-day period when degree-days were consistently high, ranging from 101 to 168.

In Montana, Fellin and Theroux used a threshold temperature of 37° F (2.8° C), based on Bean's (1961) research. Over a 3-year period they found that spring larval emergence began after about 3,900 degree-hours (162.5 degree-days) had accumulated, and ranged from 3,933 degree-hours in 1977 to 4,368 in 1978:

Year	**Dispersal began**	**Accumulated degree-hours (37° F)**	**Accumulated degree-days (37° F)**
1977	April 26	3,933	163.9
1978	April 15	4,368	182.0
1979	April 30	3,971	165.5

Transport-Storage Boxes

Specially designed boxes are needed to retrieve and store sticky traps so that the traps can be handled and stacked conveniently without damaging specimens. Transport-storage boxes must have dividers to separate the boards, be light for ease in transporting, and be able to accommodate the size of the trap board. Trap-board size also dictates the overall dimensions of the transport-storage box. The following boxes were used in our studies.

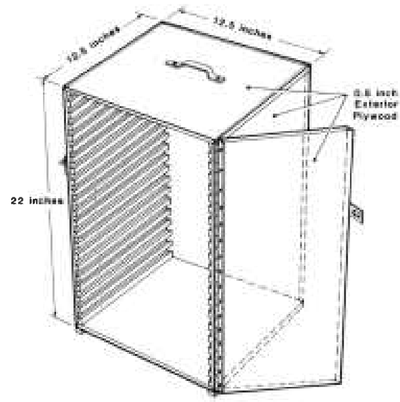

Figure 15—Schematic of Maine transport-storage box.

Maine Box

The Maine box is designed to transport and store 20 Maine traps. The box is 22 by 12-1/2 by 12-1/2 inches, and is constructed from 1/2-inch exterior plywood (fig. 15). The box is equipped with a piano-hinged door, a handle for carrying, and a hasp for locking. Traps are inserted horizontally between cleat runners (dividers) that prevent the traps from contacting one another (fig. 16). The box weighs 13 lb 7 oz empty and 40 lb 9 oz full (20 coated boards).

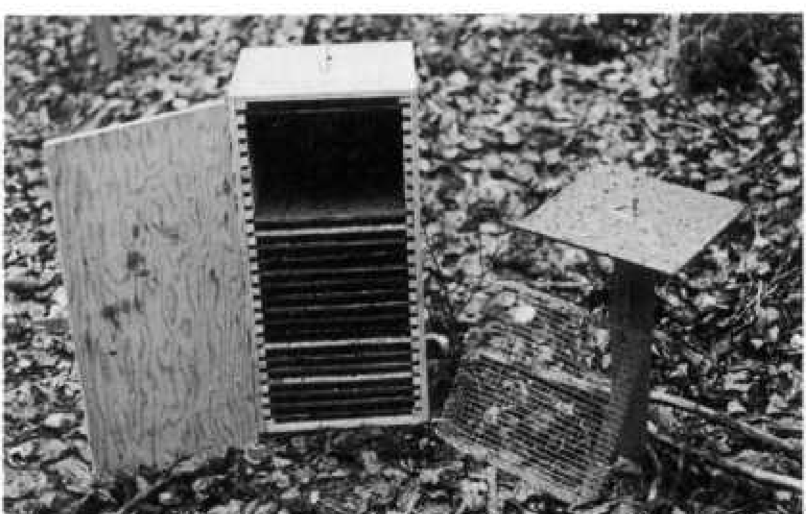

Figure 16—Retrieval of Maine trap (screen removed) and trap boards in Maine transport-storage box.

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Minnesota Box

The Minnesota box is similar to the Maine box in design and construction; however, its overall dimensions are reduced to accommodate the smaller trap size. Twenty-five of the smaller traps can be stored in the Minnesota box. Double-column boxes also are feasible.

Montana Box

Two types of transport-storage boxes have been used in Montana. One box was designed and used from 1973 to 1978, the other designed and used since 1978. Both Montana boxes are larger and heavier than the other boxes described, mainly because the Montana traps are larger. Each can transport and store eight Montana traps.

The initial Montana box was constructed of 3/8-inch and 1/2-inch exterior grade A-C plywood (fig. 17).

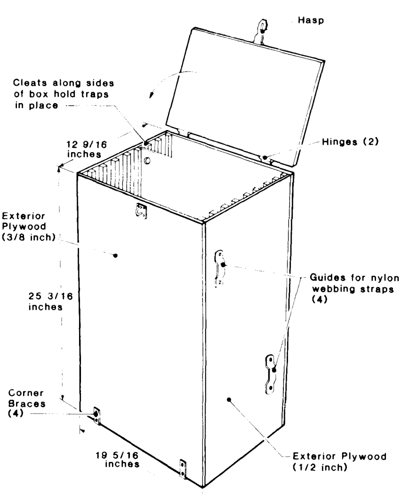

Figure 17—Schematic of Montana transport-storage box.

It is 25-3/16 by 19-5/16 by 12-9/16 inches. The two sides are 1/2-inch plywood, and the back, front, bottom, and top are 3/8-inch plywood. The cover is attached at the rear with two 4-inch strap hinges, and fastened in front with a hasp. Two strap guides are screwed to each side of the box, 5 inches from the top and bottom, to hold the carrying straps. The bottom is reinforced on the outside with four 4-inch corner braces.

The inside of the Montana box is equipped on both sides with nine 1/2- by 5/8-inch cleats, spaced 1 inch apart, vertically along the sides of the box (fig. 17). On each side, two cleats are flush, with the front and back of the box. With this cleat arrangement, traps can slide in or out of the box with their sticky surface facing either the front or back of the box. Boxes can be stored on any side.

For transport, the box is strapped to a packboard frame and carried in backpack fashion (fig. 18). Two 8-foot pieces of 1-inch nylon web strapping are threaded through the two guides on each side of the box and across the back of the packboard, and held by a spring-loaded buckle. The front of the packboard is made from a 20-inch-long and 12-inch-wide piece of heavy canvas, equipped with eight grommets along each side. The canvas is held to the front of the packboard with nylon cord laced through the grommets and to the sides of the packboard. This transport box with packframe weighs 22 lb; loaded with eight traps, it weighs 47.5 lb.

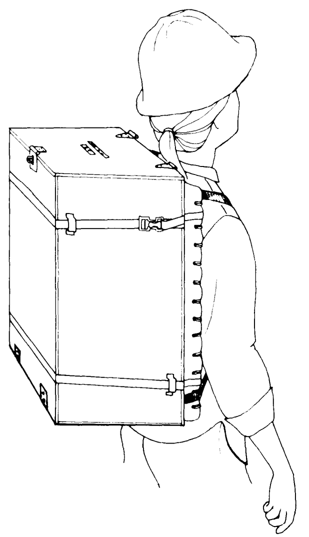

Figure 18—Packboard frame and Montana transport-storage box for deploying traps in the field.

After the last trap has been placed in the forest, the box is removed from the packboard and left at the trap site. The technician then loads another full box of traps on the packboard and deploys them. The reverse procedure is followed for trap retrieval.

In 1978, Leon Theroux, a biological technician assigned to the Montana studies, designed a new transport box. This box is fabricated from 0.05-inch-thick aluminum sheets (3 by 8 feet) (fig. 19). The box is 24-3/4 by 18 by 13 inches and has several features that make it more desirable than the plywood box:

1. The cleat arrangement is the same except that the cleats are U-shaped and the bottom of the cleat is riveted to the sides of the box.

2. The aluminum box is equipped to transport trap stakes. Two 19-5/8- by 2-inch aluminum strips are bent at right angles 3-1/8 inches from each end of the strip and then riveted to the front and back of the box so that the strip is 3-3/16 inches from the side of the box. The bottom of the box is constructed so that it protrudes 3-3/16 inches from the side of the box and 3-3/16 inches upward on each side. This arrangement holds 52 trap stakes, 26 on each side of the box (fig. 20).

3. This box also can transport trap screens. Approximately 5-1/8 inches down and in the center of the back of the box, a 1/4- by 3-inch carriage bolt is bolted to the back; the bolt protrudes to the outside. Screens are slipped over the bolt and held in place with a wing nut.

4. The new transport box is designed to fit a Kelty pack frame. Four metal brackets (fig. 19) are bolted in each corner of the back side of the box. The pack frame is, in turn, bolted to the mounts.

In the current deployment system, plywood boxes are used for storage and the newer aluminum boxes are used for transportation. Traps are first taken to the forest in plywood boxes (fig. 18), then transferred, eight at a time, into the new aluminum transport box (fig. 20), and carried to the sampling locations. For retrieval, traps are placed in the aluminum box and transported to a vehicle, where they are transferred to a plywood box for transport to the laboratory and storage until examined. This aluminum transport box weighs 18 lb; loaded with eight traps, eight screens, and 24 stakes it weighs 60.1 lb.

During the Minnesota, Maine, and Montana research we occasionally had trouble with mold developing on the samples, especially if the traps were wet when retrieved from the forest. We now take three steps to prevent or retard development of mold: (1) prop open the doors of the boxes to allow the traps to dry, (2) spray the traps with a common household disinfectant, (3) store the boxes in walk-in coolers held at 34° F (1° C) until the traps are examined.

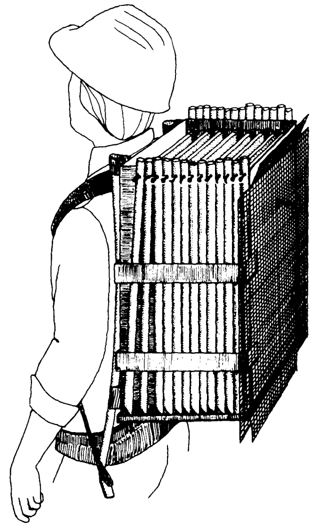

Figure 20—Montana transport-storage box loaded with eight trap boards, PVC stakes, and protective screens.

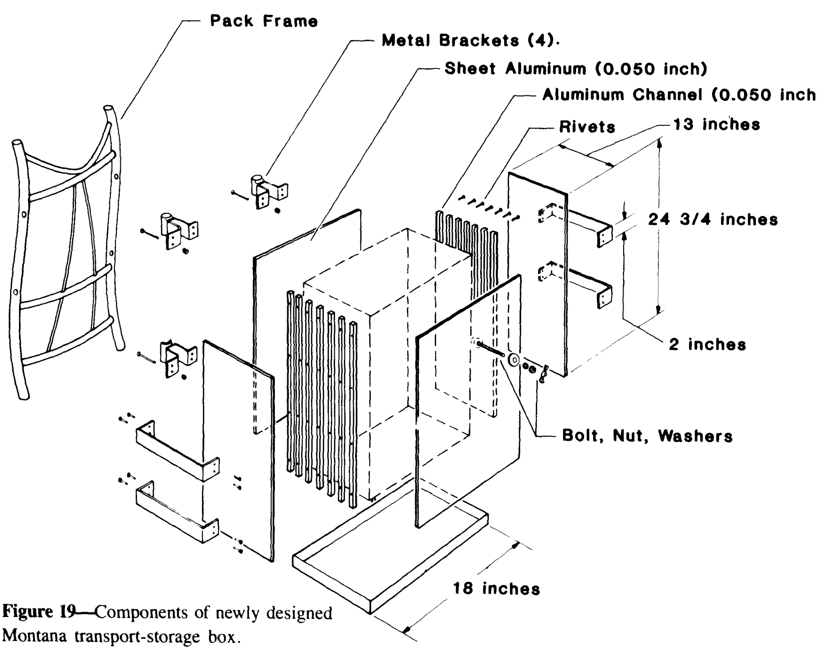

Figure 19—Components of newly designed Montana transport-storage box.

Examination of Sticky Traps

Oregon Sandwich
For transporting and storing Oregon trap papers, a simple transportation "sandwich" is used. The papers are removed from the traps, carefully covered with Saran Wrap, and placed between two pieces of exterior plywood 17 by 6-1/2 inches by 1/2 inch. A large rubberband or heavy string is used to hold the samples between the boards. Thirty samples can easily be held and transported in one sandwich. This system works well if one does not wish to remove and preserve the budworm larvae on the traps.

The Minnesota, Maine, and Montana traps are returned to the laboratory for examination. The smaller cylindrical Oregon traps are examined in the forest or returned to the laboratory. The following items are useful in examining trap boards: (1) sewing thread or a counting board, (2) a microscope or lamp magnifier, and (3) a counter or tally meter.

Minnesota Traps
Minnesota traps are examined in the laboratory with a counting board similar to that used with Montana traps. However, overall dimensions of the counting board are smaller to accommodate the smaller trap size. Parallel rows of sewing thread are strung between evenly spaced nails to delineate the area to be searched. The trap board is slipped beneath these thread rows and searched systematically.

Maine Traps
Before examining Maine traps, we placed pieces of white sewing thread in nearly parallel rows directly in the sticky material (fig. 21). The threads are spaced about 1 inch apart but no wider than the microscope's field of view. The threads delineate the sample area and allow the examiner to search the trap systematically so that no portion is missed or counted twice.

Montana Traps
For the Montana traps, the counting board consists of a 7-1/2- by 13-1/2-inch piece of 1/2-inch plywood with two pieces of 3/4- by 3/4- by 7-1/2-inch soft pine attached to the top at

Figure 21—Sewing threads placed in sticky material of Maine trap to mark off areas for searching.

either end, and a 1/4- by 3/4-inch piece of molding attached to the top along the back (fig. 22). Twelve 1/2-inch brads are nailed five-eighths of an inch apart into the top of the 3/4-inch square pine, and black thread is strung between the brads.

A carrier board for the samples is then made from a 6-1/2- by 11-3/4-inch piece of 1/4-inch plywood with two 3/4-inch brads driven into one edge of a long side 1-1/2 inches from each end (fig. 22). Once a Montana trap is ready to be examined, the coated paper is cut into six equal-sized rectangles and, one at a time, the pieces are placed on the carrier board and slipped onto the counting board under the threads. This prevents the samples from being moved, which often causes the examiner to lose track

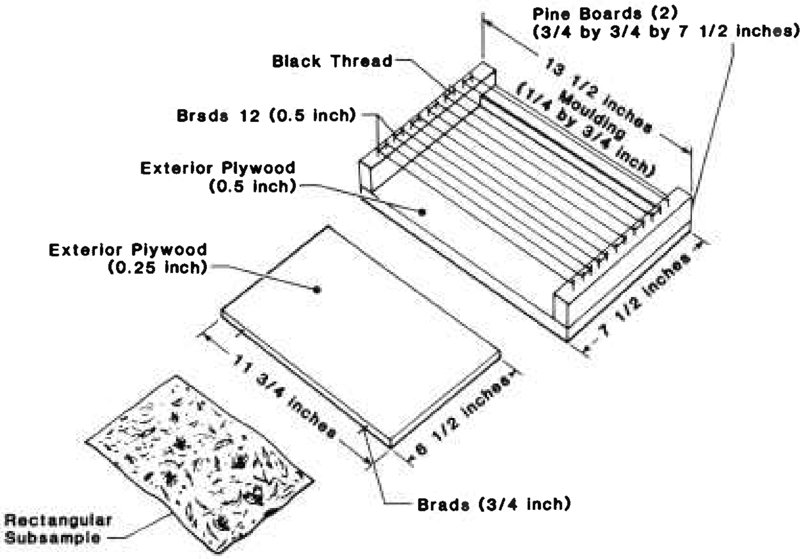

Figure 22—Counting board for examining and counting Montana trap subsamples.

of the portion of the sample that has been examined.

For the Minnesota, Maine, and Montana traps, the usual examination procedure is to search across on one row and back along the next adjacent row. Technicians are trained to begin their search in one of the four trap corners and to continue this back-and-forth process until the trap or sample has been examined fully. Budworm larvae and other arthropods of interest are counted and tallied as they are seen on the trap. Each field of view is searched thoroughly before the technician moves to the next adjacent field. Care is taken to examine only one field-of-view width at a time; otherwise, some surface areas will be missed between fields.

Oregon Traps
For Oregon traps, experienced observers examine traps and count budworm larvae in the field. Field examination saves time and supplies without reducing accuracy; it also provides a cumulative record of catches so that peaks in dispersal activity can be determined. Larvae are identified with the aid of a 10× hand lens, and picked off the paper with forceps. Counts are then recorded. If needed, the paper is resprayed with sticky adhesive. This process is repeated at 2-day intervals until debris and miscellaneous insects interfere with finding the small larvae. When this occurs, the trapping paper is replaced and the original paper returned to the laboratory for final checking. The frequency with which paper is changed depends on a number of factors such as weather, stand density, trap position, and the abundance of trapped nontarget insects.

Microscope and Magnifiers
For examining sticky boards in the laboratory we recommend a stereozoom or fixed-magnification dissecting microscope mounted on an adjustable arm stand (fig. 23). The adjustable arm stand allows free movement of the sticky board beneath the microscope. Magnifications of 10× and 20× are sufficient to identify most insects and spiders. With our microscope set at 10× magnification and a 4-1/8-inch board-to-objective distance, the field of view is 1 inch in diameter. At 20× magnification this area is reduced to a diameter of three-eighths of an inch. The 10× magnification is sufficient for recognizing first- and second-instar budworm larvae; higher magnifications are used to examine smaller questionable specimens and for verification.

Desk lamps with circular fluorescent lights and built-in magnifiers (fig. 23) can also be used for examination. However, the field of view is greatly enlarged, making it difficult to conduct a systematic search and increasing the possibility of overlooking small larvae. If lamp magnifiers are used, small areas (about 4/5 by 4/5 inch) should be delineated with string or thread and searched systematically. Fluorescent lamps with built-in, 3-diopter (1.75×) lenses are adequate for gross examinations.

Figure 23—Left: Dissecting microscope mounted on an adjustable arm stand. Right: Circular fluorescent light with built-in magnifier.

Counters

We have used two types of counter in our research, depending on the number of groups or categories of arthropods being tallied. When counting only budworm larvae, a 4- digit tally meter with a positive reset knob is useful (fig. 24). Examiners are trained to **record** the registered counts **immediately** after completing a row or unit area searched.

Figure 24—Multiregister counter and tally meter used in registering counts of budworm larvae and other arthropods.

When more than one arthropod taxon is being counted, we use a multiregister counter with three to nine registers (fig. 24). Individual keys record counts from 0 to 999 in each register. The multiregister counter has eight keys, controlling eight separate counting registers, plus a totalizing register which records the total of all eight counting registers. Reset knobs at one or both ends of these counters reset all register keys to zero in one operation. Removable tabs are inserted in slots along the top of the counter to indicate the arthropod group that is being tallied in each register.

Cleaning and Preserving Specimens

Sometimes we remove budworm larvae, other insects, and spiders from sticky traps for further examination and study. Specimens are removed from the traps with a laboratory dissecting needle; a scooping motion is used to minimize the possibility of damaging the specimen. It is best to remove some sticky material along with the specimen. The specimen and sticky material are then placed in a watchglass or similar container and the excess sticky material dissolved with solvents (e.g., paint thinner, acetone, hexane). Solvents are used only in a well-ventilated room or outdoors, and while observing all fire precautions. Some solvents act as clearing agents, so soft-bodied insects and spiders are observed carefully to avoid excessive treatment and clearing of body parts.

After being cleaned, specimens are stored in vials containing 70- to 80-percent ethanol. Patent-lipped vials with neoprene stoppers are used for semipermanent storage. For prolonged storage, shell vials are stoppered with cotton and inverted in jars of alcohol with metal screw-cap lids. Jars are checked every 6 months to replenish evaporated alcohol. Labels are inserted **inside** each vial and a group label inserted **inside** each jar. All labeling is done in pencil or waterproof ink.

Summary

We **do not** recommend one trap design or transport-storage box design over another. Rather, all designs are presented so that investigators can choose the design that is most appropriate for their individual needs and objectives. Our basic designs can be modified, and more than one design can be used to meet specific requirements. For example, traps for measuring the vertical distribution of dispersing larvae should follow the Oregon trap design; traps for measuring larvae dispersing to the forest floor should resemble one of our flat trap designs—the Minnesota, Maine, or Montana trap.

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