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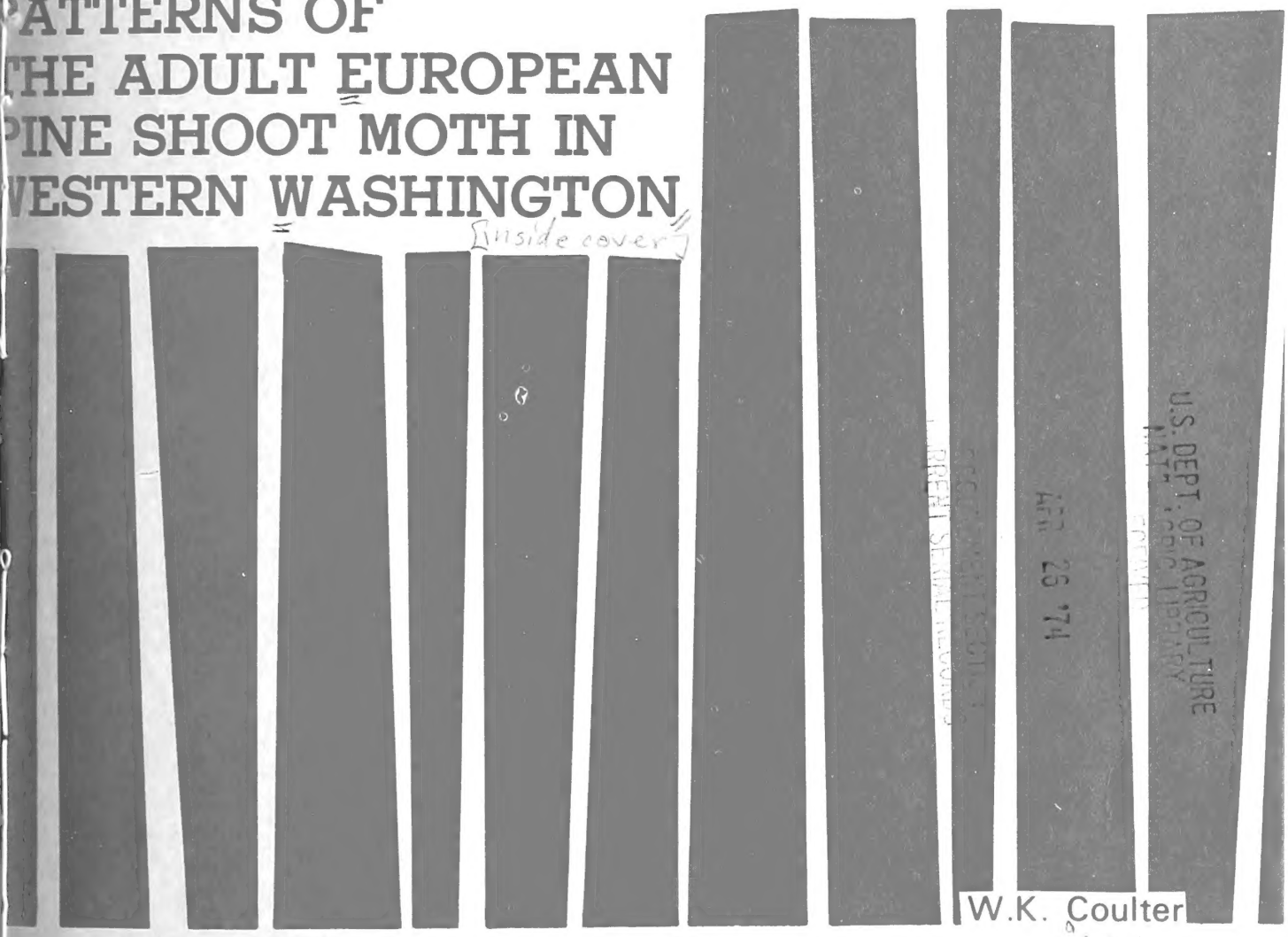
EMERGENCE AND PREMATING BEHAVIOR PATTERNS OF THE ADULT EUROPEAN PINE SHOOT MOTH IN WESTERN WASHINGTON



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ABSTRACT

Adult emergence and premating activity were recorded for the European pine shoot moth in western Washington. These records are compared with those reported for Eastern United States and Canada. Most comparisons are with records for southern Ontario which are the most comprehensive for North America. Observations were also recorded on the possible effects of some ecological conditions related to the urban locality which are unique in the western infestations.

Adult emergence was generally similar to emergence recorded elsewhere. However, there were important differences in the emergence patterns of the sexes as related to weather, intensity of infestation, and host species. There were also differences in the behavior of the sexes after emergence. Observations indicate that both sexes are more active during the daytime than recorded elsewhere, and the average male is much more active than the average female. Disturbances associated with urban landscape plantings also probably affect dispersal of virgin adults before mating can occur.

KEYWORDS: Forest pest control, European pine shoot moth, [*Rhyacionia buoliana*], ornamental trees, western pines.

[*pinus]

CONTENTS

INTRODUCTION

The European pine shoot moth, *Rhyacionia buoliana* (Schiff.), was discovered in 1959 infesting ornamental pine in Bellevue, Washington. This was the first record of the foreign pest in Western United States although it had been found in British Columbia as early as 1925. After the initial observation, it was found at many locations in the Pacific Northwest. The history of this destructive pest in Eastern United States and Canada indicated that its presence in the Northwest was a threat to native pine stands. Quarantines were invoked, techniques developed for pest control by tree fumigation, and in 1964 a research program was begun to investigate procedures for eradication by the sterile-male release technique. One phase of the research program was to record the biological characteristics of the adult shoot moth which were pertinent to the release and dispersion of sterilized males. These biological records are being presented in two papers: This paper discusses emergence and premating behavior and deals mainly with observations of adult activity on the twig or tree from which the adult emerged; the second paper will discuss flight and dispersion and will deal with observations of adult activity beyond the tree from which they emerged.

These studies of adult behavior were the first biological investigations of the shoot moth in the West. Previous research was concerned with chemical eradication by fumigation with methyl bromide. For North America, the general biology of emergence and premating behavior is known mainly from studies in southern Ontario. Pointing (1961) described the stages of emergence, and Green (1965) reported the daily emergence rhythms in relation to time and duration of the various stages. Green (1965) also reported on adult behavior after emergence. Seasonal emergence records are reported by Friend and West (1933) for Connecticut, by Miller and Neiswander (1955) for Ohio, and by Pointing (1961) for southern Ontario. All data in this report were recorded from field studies in suburban areas of Seattle, Washington.

The term "daily rhythms" is used here to refer to the 24-hour period of a day and night cycle. "Diurnal" is used as a subordinate term referring only to daytime.

EMERGENCE

There are three behavioral characteristics of adult emergence which are pertinent to the sterile-male release technique: definitive stages of emergence, daily rhythms, and seasonal rhythms. They relate to the number of sterile males needed and the time of their release to bring them into effective competition with normal fertile males. Numbers and timing are critical because of the relatively short adult life of the shoot moth and the need for advance preparation in rearing and sterilizing (Knipling 1964).

Adult emergence begins when the pupa moves from its chamber to a fixed position protruding from the shoot; in the next stage the moth emerges with its wings folded and wet; next, the folded wings are extended; then the extended wings are raised vertically to dry; and finally, the dried wings are lowered to the normal position after which the moth is capable of flight. These processes usually occur on the foliage, but occasionally the pupa will move, fall off the shoot and drop to the ground, or newly emerged adults will drop from the foliage while their wings are folded and wet.

Methods

The emergence stages were recorded by use of a system similar to the one described by Pointing (1961). In 1965, 300 infested shoots of mugo pine (*Pinus mugo* Turra) were arranged on rows of small nails to facilitate examination. Each shoot was examined every 15 minutes from dawn to dark for 7 days from June 25 to July 1. In 1966, 192 infested shoots were attached to the branches of six potted pine trees. Each of these shoots was examined every 10 minutes from dawn until 1000 hours P.d.t. from June 22 to June 30. Records were made of the duration of emergence stages, time of daily emergence, and diurnal activity periods. Since over 30 percent of the 300 invested shoots studied in Washington in 1965 proved on final examination to be empty and possessed suspect emergence holes, a simple test was set up during emergence studies in 1966. A 4- by 4-foot burlap cloth was placed on the ground under each potted tree. Examinations were made to record dropping pupae or adults during the 9-day period of the daily emergence study.

Seasonal emergence was recorded by periodic examination of all infested shoots on selected host trees. The examinations were made every other day throughout the period of emergence. Empty pupal cases were removed and subsequently sexed to record the seasonal occurrence and emergence rate of adults. In 1965, emergence was studied in a Seattle city park on the shore of Lake Washington where landscaping was mainly lawn and scattered ornamental shrubs including about 100 mugo pine. Twelve of these mugo pine, ranging from lightly to heavily infested, were included in the study. In 1967, the study involved the influence of different host species on adult emergence. A wide variety of hosts is one of the unique characteristics of western Washington infestations. The hosts investigated were mugo pine, Scotch pine (*Pinus sylvestris* L.), lodgepole pine (*P. contorta* Dougl.), and Japanese red pine

(*P. densiflora* Sieb. & Zucc.), all of which are widely planted as ornamentals in western Washington and heavily attacked by the shoot moth. A total of 30 pine trees was used: 15 mugo, and 5 each of lodgepole, Scotch, and Japanese red. All were 6 years old, of unknown seed source but of good vigor and bud complement. All were planted in 15-inch wood fiber pots. None of the trees had been infested before the study began. The trees were given heavy infestations in 1966 by a combination of natural and forced attacks. Natural attacks on the test trees were induced by placing the potted trees in an infested area when ovipositing females were in flight. Since this procedure produced a total infestation of less than 10 percent of the available shoots, additional attacks were obtained by fastening infested shoots near uninfested buds. The adult emergence from these trees was recorded by continuous examination during June and July of 1967.

Results and Discussion

Stages of Emergence

Total elapsed time from protrusion of the pupa until the new adult was capable of flight ranged from less than 30 minutes to over 110 minutes. Comparing these elapsed times in minutes with those recorded by Green (1965) for the Ontario study of 1958, shows the latter to be about one-third longer.

	Ontario 1958	Washington 1965	Washington 1966
Range	46 - 98	30 - 90	30 - 110
Average	71	54	56

The duration of the emergence stages comprising the total elapsed times are presented in table 1.

Table 1.--*Average duration of the stages of adult emergence of European pine shoot moth at Seattle, Washington, in 1965 and 1966*[1/]

Emergence stages	1965		1966	
	Males	Females	Males	Females
	- - - - - - - - - - *Minutes* - - - - - - - - - -			
Adult escape from protruding pupal case	22	19	22	14
Extending wings	16	15	26	21
Drying wings	18	16	18	17
All stages	56	50	66	52

[1/] The 1965 records are based on 11 males and 12 females, and the 1966 records on 11 males and 15 females.

The duration of the emergence processes determines the period of vulnerable exposure to predators. However, the percent mortality in emerging pupae and adults that may be caused by predators is not known. Juillet (1961) in his studies on arthropod predators of the shoot moth did not consider emergence as one of the periods of greatest vulnerability. Pointing (1961) studied adult predation using radioactive tagging to identify and record predators. He stated that although it is likely that most moths eventually fall prey to some predator, relatively few predators are capable of capturing large, vigorous individual moths. Green (1965) pointed out that the emerging pupae and the teneral adults are particularly vulnerable to birds and arthropod predators. He recorded the duration of these vulnerable stages for the shoot moth in Ontario during 1958. The studies in Washington have shown similar elapsed times.

Other sources of mortality during adult emergence include the complete issuance and dropping of pupae from infested shoots and the dropping of teneral adult moths. The dropping of pupae from the shoots is considered a mortality factor because of the increased exposure of the pupae to predators and because adults may not readily emerge from the free pupae. Pointing (1961) reported that of 240 pupae dissected from infested shoots only 29 percent produced adults, whereas the emergence from 1,127 pupae in buds was 81 percent. Green (1965), reporting on laboratory studies, stated that 25 percent of the pupae held in continuous darkness emerged completely, dropped to the floor of the cage, and failed to produce adults. Pointing (1961) also reported that normally in Ontario only about 1 percent of the pupae completely emerge.

No pupae or adults were recorded dropping from the foliage of the six potted trees in 1966. Although only 36 adults were actually observed emerging (42 emerged unseen, either between 10-minute examinations or in the afternoon hours), there was no evidence that either pupae or teneral adults dropped. In 1965 the dropping of new emerged adults from shoots secured on nails was observed only five times, and three of these were judged to be spontaneous movements not caused by disturbances. However, over 30 percent of the recorded emergences were unobserved, the adults escaping from their pupal case and leaving the shoot between 15-minute examinations. The proportion of these adults which were teneral and incapable of flight is not known.

Apparently in western Washington, as in southern Ontario, pupae rarely emerged completely from their shoots, and normal undisturbed teneral adults seldom drop from the foliage. Therefore, the behavior activities of immature forms are not considered important mortality factors. The effect of urban disturbances on the behavior of fully mature adults is discussed later in this paper.

Daily Emergence Rhythms

Daily emergence was found to be completely diurnal in the field with no emergence before 0510 hours and none later than 1930 hours P. d. t. The pattern of daily emergence for 1965 showed a primary peak in the early morning at 0800 and a secondary peak in the evening at 1900 hours (fig. 1). About 76 percent of

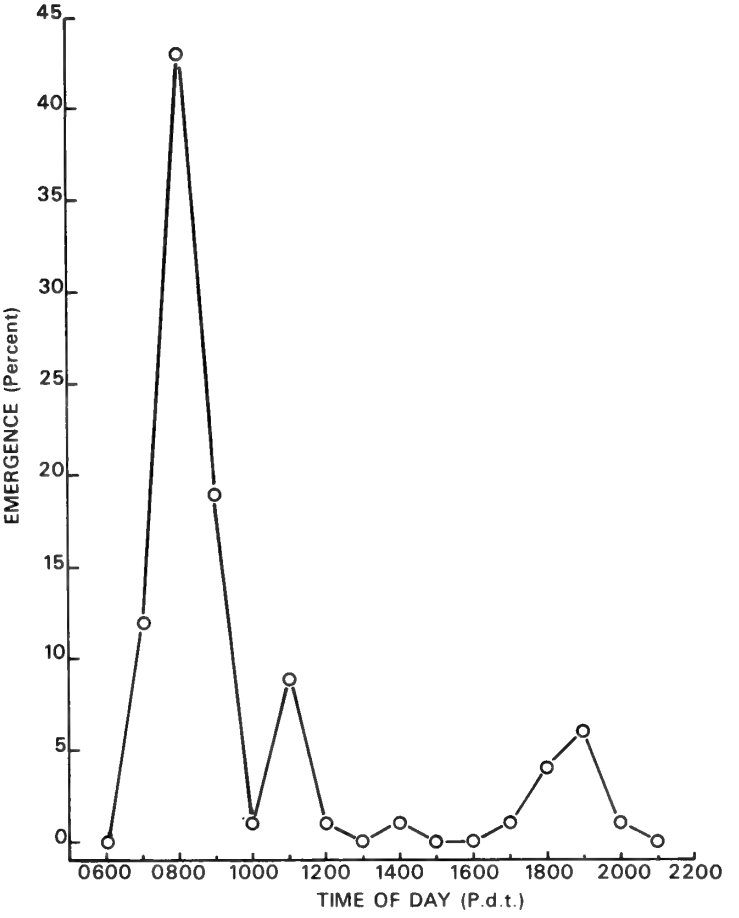

Figure 1.--*Daily field emergence pattern of 32 male and 38 female adult European pine shoot moth at Seattle, Washington, 1965.*

the total emergence occurred between 0600 and 1000 hours. These data agree closely with records from infestations in Ontario (Green 1965). Our studies also recorded the emergence patterns by sex (table 2). The early morning peak was similar for both sexes, but only the females showed an evening peak.

In 1966, daily emergence was diurnal but lacked the definite morning peak. Only 55 percent of the total emergence occurred before 1000 hours, whereas emergence during comparable periods was 70 percent in Ontario in 1958 (Green 1965) and 76 percent in Seattle in 1965. This variation in emergence pattern is attributed to differences in weather. Comparing Seattle weather for the 2 years shows the study period in 1965 was about average with temperatures below normal on 3 days and above normal on 3 days. Cloud cover averaged 50 percent for the daylight hours with 1 day completely overcast and 1 day with a trace of morning rain. In 1966, the weather was abnormal with temperatures below normal on all 9 days of the study. Cloud cover averaged 80 percent, with 3 days completely overcast and 4 days with rain recorded in the morning.[1/]

[1/] Data taken from U.S. Weather Bureau records, Local Climatological Data, Seattle-Tacoma Airport, Washington.

Table 2.--*Daily emergence of European pine shoot moth adults at Seattle, Washington, 1965*

Time (P.d.t.)	Adult emergence		
	Male	Female	Total
0600	0	0	0
0700	6	3	9
0800	11	19	30
0900	11	2	13
1000	1	0	1
1100	1	5	6
1200	1	0	1
1300	0	0	0
1400	0	1	1
1500	0	0	0
1600	0	0	0
1700	0	1	1
1800	1	2	3
1900	0	4	4
2000	0	1	1
Total	32	38	70

These data corroborate earlier observations in Washington and in Ontario (Green 1965) that although cool field temperatures may affect the pattern of peak daytime emergence they do not alter the diurnal emergence cycle. Even during the relatively long periods of unseasonably dark, cool weather in 1966, all emergence was diurnal. No extreme changes in behavior were observed such as the excessive dropping of pupae that Green (1965) reported when they were held in complete darkness.

Seasonal Emergence Rhythms

Adult emergence in western Washington during the studies of 1965 and 1967 occurred in a period of about 5 weeks in June and early July. This is similar to other published records. Friend and West (1933) cite 13 references to emergence or flight periods in Europe and western Asia. These and later records from United States and Canada are:

Area	Period	Reference
Europe and western Asia	June and July (5-6 weeks, average flight period)	Friend and West (1933)
New Jersey	June 8 - July 5 (flight period)	Hamilton (1931)
Connecticut	June 8 - July 2 (emergence period)	Friend and West (1933)
Ohio	June (about 4 weeks, (average emergence period)	Miller and Neiswander (1955)
Southern Ontario	June - July (3-4 weeks, average emergence period)	Pointing (1961)

The seasonal pattern of emergence is in general a rapid increase to a peak followed by a more gradual decline (tables 3 and 4). This agrees with biological records from studies in Eastern United States and Canada. However, these eastern studies also characterize seasonal emergence as protandrous with a higher proportion of female adults (Friend and West 1933, Miller and Neiswander 1955, Pointing 1961). The present study shows that these characteristics may be nullified or even reversed by variations in intensity of infestation or by the species of host.

In 1965, the total emergence from 12 mugo pine was protandrous. Table 3 shows males emerging ahead of females until about 6 days after peak emergence when females began to proponderate. When these data are segregated according to severity of infestation and compared graphically, emergence is protandrous only on the six lightly infested trees. On the six moderately to heavily infested trees, the emergence rate of the sexes was similar (fig. 2).

The study of seasonal emergence from different host species in 1967 suggests variations in the periods of emergence, in the protandry of emergence, and in the adult sex ratio. The patterns of total emergence for four common host species are presented in table 4. The pattern of the combined total emergence from all species is similar to that observed in 1965; however, the period of peak emergence is about 1 week later. Figure 3 compares the emergence patterns graphically and indicates emergence from mugo and lodgepole pine occurring before Scotch and Japanese red pine. It also indicates the bulk of emergence from mugo pine may be 2 to 4 days later than from the other hosts. The variation in the emergence patterns of the sexes on different hosts is shown in figure 4. Mugo and Scotch pine show protandrous emergence. On Japanese red pine the emergence is nearly coincident. Lodgepole pine shows the unusual pattern of females 3 to 5 days ahead of the males. For the different hosts, male numbers emerging equaled or exceeded female numbers in most cases. On Japanese red pine, the proportion of males to females was nearly 2:1; whereas on mugo pine, males exceeded females only slightly.

Year	*Host*	*Total adults*	*Female sex ratio*
1965	Mugo pine	264	0.48
1967	Mugo pine	208	.45
1967	Japanese red pine	52	.35

The adult emergence records for 1967 include adults originating from both natural and artificially induced infestations on the same study trees. Whether the study methods had an effect on the sex patterns is not known. It should also be noted that the number of adults from lodgepole and Scotch pines was small, and therefore these emergence patterns may not be truly representative.

Analysis of these variations in emergence rhythms is beyond the scope of this study. It is apparent, however, that variables such as sex priority in rate of emergence and sex ratio during the mating period would influence a program of sterile male release. The pertinent factors affecting the sterile male competitiveness would be loss of vigor by aging and the availability of released males in efficient and adequate numbers to insure overflooding the normal male populations.

Laboratory studies by Daterman (1969) showed that mating efficiency decreased for both sexes after they were 4.5 days old, also that females older than 2.5 days at the time of mating oviposited significantly fewer eggs than females fertilized at a younger age. If males are vigorous up to 4.5 days and female fecundity does not decline until after 2.5 days, a protandrous emergence of up to 2 days would not be detrimental to the population. Protandry of more than 2 days could influence natural control by lowering male vigor and population fecundity. Also, if females emerge more than 2.5 days before males, as recorded on lodgepole pine in 1969, the effect would be a lowering of female vigor at mating time.

The number of females in the emerging adult population is probably more important than the number of males since the insect is polygamous. Pointing (1961) found that under insectary conditions, males are capable of mating at least four times. Campbell (1961) makes an interesting observation regarding polygyny in *Choristoneura* spp. that may apply here as well--that the more virile males in a population may mate with so many females as to prevent the weaker males from contributing to the gene pool of the next generation. Likewise, the more vigorous sterile males may eliminate the weaker normal males from competition for the females.

Table 3.--*Seasonal emergence of the European pine shoot moth at Seattle, Washington, June 15 - July 17, 1965*[1/]

Date	Number of adults			Sex ratio
	Male	Female	Total	
6/15 (and earlier)[2/]	52	42	94	0.45
6/17	19	19	38	.50
6/19	11	8	19	.42
6/21	14	11	25	.44
6/23	7	16	23	.70
6/25	7	9	16	.56
6/27	6	6	12	.50
6/29	7	4	11	.36
7/1	5	4	9	.44
7/3	5	0	5	--
7/5	2	4	6	.67
7/7	0	1	1	--
7/9	1	0	1	--
7/11	1	0	1	--
7/13	0	0	0	--
7/15	0	0	0	--
7/17 (and later)	0	3	3	--
Total	137	127	264	.48

[1/] Based on the total emergence from 12 mugo pine.

[2/] Records for this date include emergence for an estimated period of 10 days.

Table 4.--*Seasonal emergence of the European pine shoot moth from four host species of pine at Seattle, Washington, 1967*

Date	Pine				Total
	Mugo	Lodgepole	Scotch	Japanese red	
6/12	1	0	0	0	1
6/14	0	0	0	0	0
6/16	5	4	2	2	13
6/18	9	4	2	1	16
6/20	1	0	0	2	3
6/22	34	3	0	11	48
6/24	18	7	1	9	35
6/26	17	3	1	2	23
6/28	34	7	9	16	66
6/30	19	9	1	2	31
7/2	31	0	0	1	32
7/4	13	0	1	2	16
7/6	6	1	1	3	11
7/8	5	1	1	1	8
7/10	8	0	0	0	8
7/12	5	0	0	0	5
7/14	1	0	0	0	1
7/20	1	0	0	0	1
Total	208	39	19	52	318

Figure 2.--*Seasonal emergence patterns of the adult European pine shoot moth infesting mugo pine at Seattle, Washington, 1965: A, Total emergence was 25 males and 22 females for trees with less than 25 percent of the shoots with current attacks; B, total emergence was 112 males and 105 females for trees with more than 25 percent of the shoots with current attacks.*

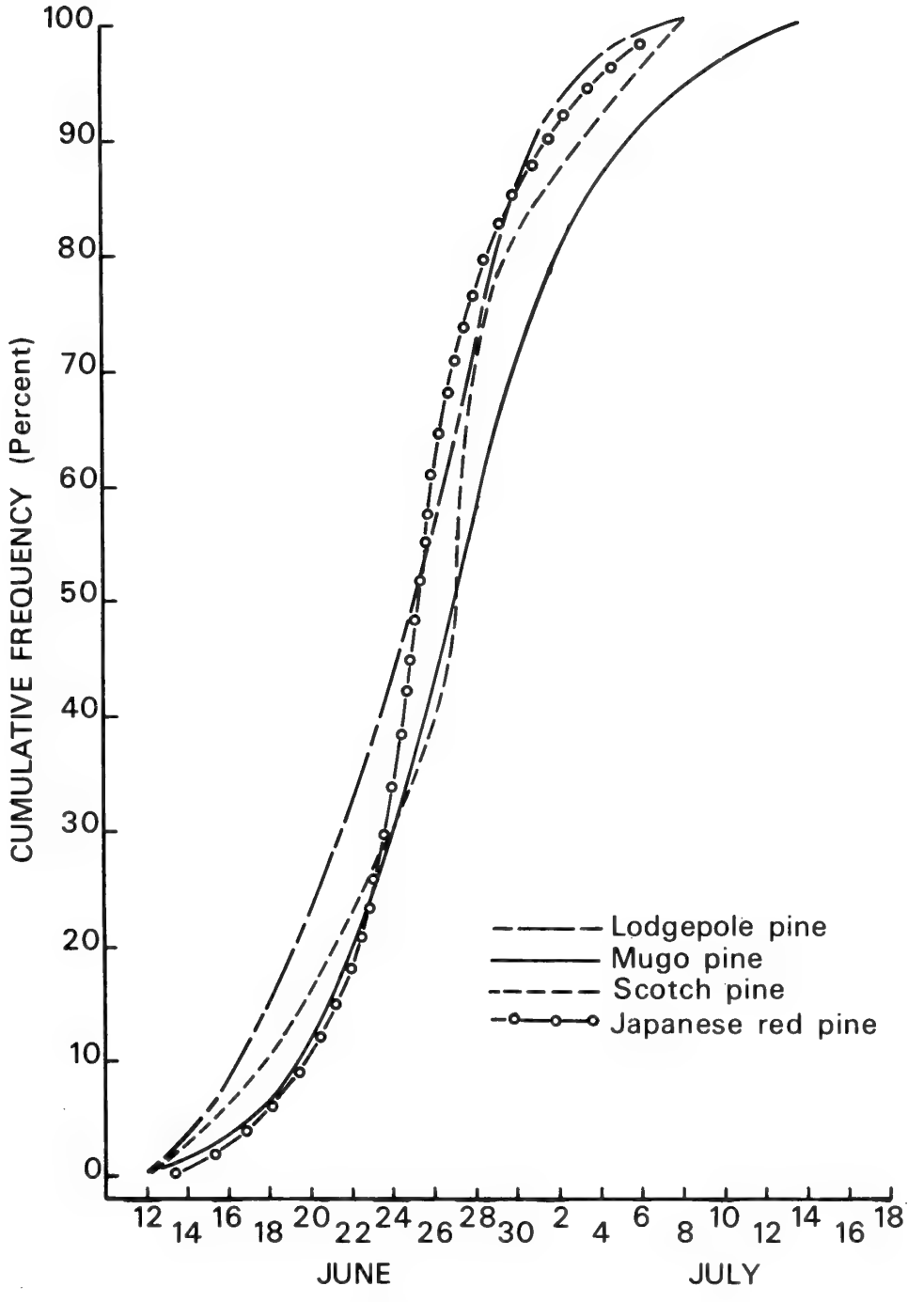

Figure 3.--*Seasonal emergence patterns of the adult European pine shoot moth from four host species, Seattle, Washington, 1967.*

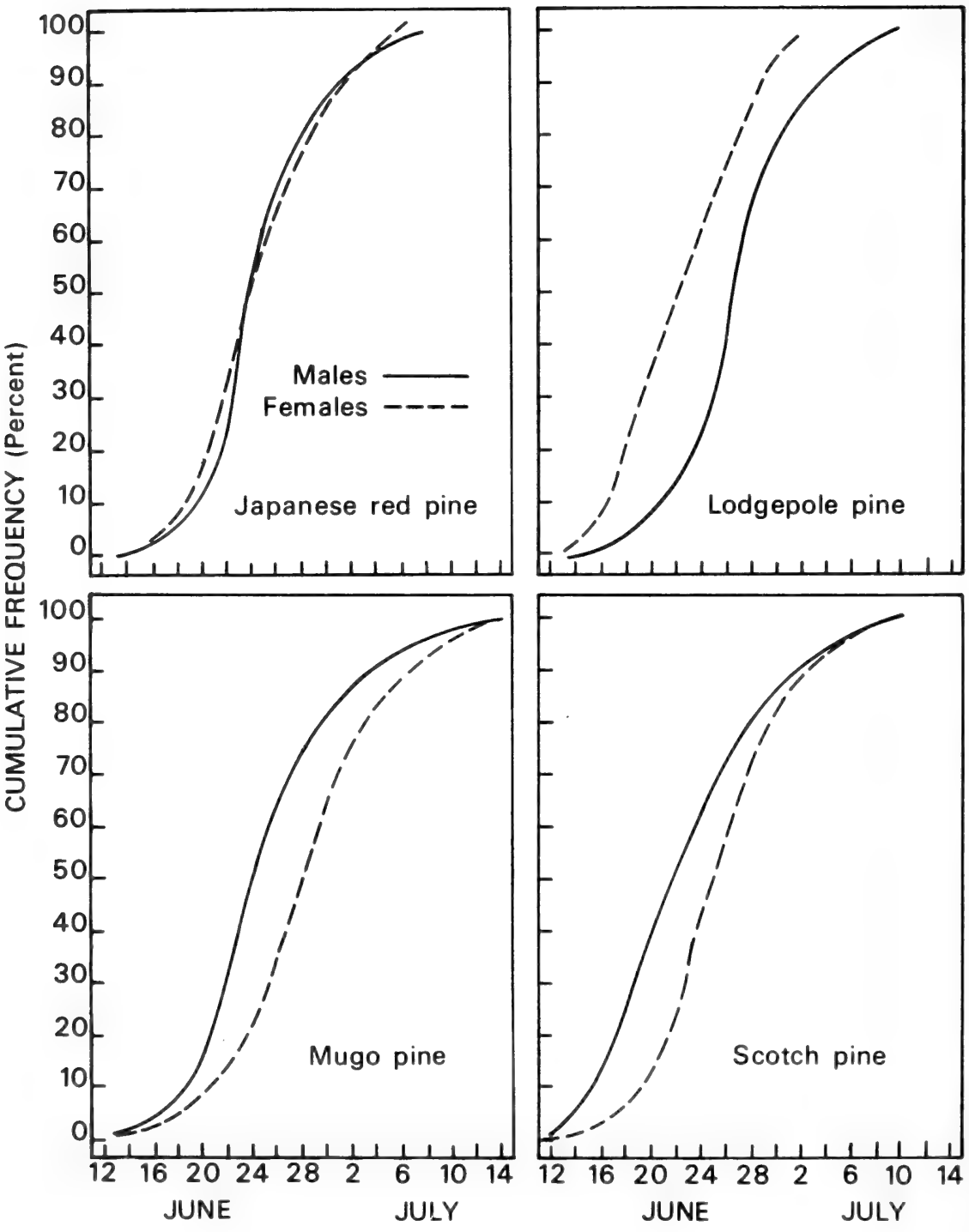

Figure 4.--*Seasonal emergence patterns of male and female European pine shoot moths from four host species, Seattle, Washington, 1967.*

BEHAVIOR AFTER EMERGENCE

The activities of adults before mating could be very important to the success of control techniques using sterile insects. Since all segments of a population must be adequately overflooded, the sterile insects must be distributed so as to achieve effective and efficient mating competition with normal insects.

The basic behavior characteristics of new adults is known from studies in Europe and eastern North America. After emerging in the morning, the adults crawl about the trees shifting their positions in adjustment to daytime air temperatures. About sunset, the virgin female moths move to the tips of the foliage where they remain until after mating. The males take flight in search of receptive females. Mating usually occurs during the evening of the day on which the females emerged, or the following evening (Green and Pointing 1962). Green (1962), in a report on factors affecting flight behavior, recorded that if the insects are disturbed, at least some of them will fly strongly even without stimulating conditions of light and temperature.

Since the life cycle and habits of the shoot moth had not been studied in the West, it was important to determine if the behavior of virgin adults followed the normal patterns recorded elsewhere. It was also important to determine if certain unique characteristics of the western Washington infestation might affect normal behavior. These characteristics relate to the urban nature of the infestations where mechanical disturbances, such as movements of people and vehicles, and artificial lighting might disrupt normal behavior patterns.

Methods

The crawling and flight activities of virgin adults and the effect of outside disturbances on these activities were investigated concurrently with the previously described studies on emergence. These activities were readily recorded during the 1965 studies where the shoots and adults were examined at 15-minute intervals. The data recorded included frequency of crawling and flying at the eclosion site and the pattern of dispersal from the site.

Results and Discussion

Crawling Activity

All adults crawled at least once and some as often as eight times. The total distance moved by each adult ranged from 0.5 inch to 9.0 inches and averaged 2.6 inches. Daily weather affected the frequency and distance the adults crawled. The following tabulation shows that in 1965 the average undisturbed adult crawled more frequently and a greater total distance during cool weather than during warm weather. The temperatures given are daily maximums

recorded in Local Climatological Data, U.S. Weather Bureau, Seattle-Tacoma Airport, Washington.

Dates and temperatures	*Adults* (Number)	*Daily frequency*	*Daily distance* (Inches)
Cool weather:			
June 25 (66°) June 28 (76°)	17	3.4	3.3
Warm weather:			
June 29 (82°) June 30 (89°)	16	1.3	1.6

The daily pattern of these crawling movements on a warm day showed a peak in the early morning, very little movement during midday, and a second peak in late afternoon before the evening premating flight. The pattern on cooler days was similar, but the morning peak occurred later. The recorded movements during one daytime period of completely overcast and unseasonably cold weather were sporadic throughout the day without an obvious peak.

Flight Activity

The flight of 80 virgin adults away from the shoot from which they emerged is summarized in table 5. Three main categories of flight behavior were observed: spontaneous daytime flight before the evening mating flight period, disturbance-caused daytime flight, and evening flight only. The behavior of the males followed a consistent pattern. Nearly all left their shoots during the daytime. This agrees with unpublished data on adult dispersion which show that virgin males normally disperse during the day of emergence.[2/] They appeared to be more excitable than the females, and they were more often disturbed into leaving their shoots. The females showed three different behavior patterns occurring at about equal frequency: leaving their shoots soon after emergence, leaving their shoots throughout the daylight hours, and remaining on their shoots until the evening flight and mating period.

Table 5.--*Flight of virgin adult European pine shoot moth during the day of emergence at Seattle, Washington 1965*

Sex	Number of adults	Spontaneous daytime flight		Disturbed daytime flight[2/]	Remained until evening flight and mating period
		During development period[1/]	After fully developed		
		Percent			
Male	36	50	27	17	6
Female	44	27	38	5	30

[1/] Departed from shoots between 15-minute examinations during adult development; therefore, some may have dropped as teneral adults.

[2/] Included disturbed immature adults which dropped from shoots and disturbed mature adults which took flight.

[2/] Data from adult dispersion studies by the author which will be published in a second paper.

None of the adults leaving their shoots during the development period were seen; only empty pupal cases were found. Their behavior is largely speculative, but none of these adults are believed to have been disturbed, and both teneral and fully mature adults may be represented--the former dropping to the ground and the latter flying to other shoots or nearby vegetation. Over 25 percent of the mature females spontaneously left their shoots during the daytime. Some of these adults were observed to fly; probably most of them took flight rather than dropping to the ground. The third behavior pattern--remaining until evening on the shoot from which they emerged--was recorded for 30 percent of the virgin females. Of these, 85 percent were observed to mate that same evening. Those that remained on the shoot but apparently did not mate that evening had emerged earlier that same evening. However, other females did emerge and mate during the same evening, one individual as soon as 2 hours after emergence.

Most moths in copulation at darkness remained on their shoots. Of nine pairs observed, one pair left their shoot and three additional males and one female left their shoots. The four pairs which remained until dawn separated during the night but crawled very short distances.

Disturbed Adults

Observations during daylight hours recorded predators and observers as the only disturbing elements to cause adults to move away from their shoots. However, predators were rare and their effect was minor.

Adults were readily disturbed by the approaching observer, and special care was necessary to observe normal behavior. The procedure was to approach no closer than 12 to 18 inches and to avoid casting a shadow over the moth. Even when these precautions were taken, 16 percent of the adults leaving their shoots did so because they had been disturbed by the observer. It may be speculated that since most infestations occur in urban landscaped plantings at residences, schoolyards, parks, playgrounds, golf courses, churchyards, etc., many adult moths will be disturbed by human activities. At least some of these disturbances can be assumed to result in an abnormal daytime dispersal of the population.

The daily time of observer-caused disturbances, recorded in table 6, shows a uniform reaction throughout daylight hours but an increase at sunset. These results disagree with Pointing (1961) who recorded in Ontario that moths were less readily disturbed in the evening. Disturbances at this time could be very critical because that is when the sterilized males must compete with normal males in finding and mating with the females. More information is needed to determine if adults are actually more sensitive to mechanical disturbances during the crepuscular mating period, to determine if artificial lighting is a disturbing factor, and to determine the effect of these behavior changes on the sterile male release technique.

Table 6.--*Daily distribution of disturbances causing European pine shoot moths to leave shoots in field at Seattle, Washington, 1965*

Time (P.d.t.)	Adults disturbed	Time (P.d.t.)	Adults disturbed	Time (P.d.t.)	Adults disturbed
0700	0	1300	2	1900	1
0800	2	1400	2	2000	1
0900	0	1500	1	2100	6
1000	0	1600	1	2200	3
1100	1	1700	1		
1200	1	1800	0	Total	22

CONCLUSIONS

1. The general character of the adult shoot moth emergence and premating behavior in western Washington is similar to that recorded for other locations in Europe and North America.

2. During the emergence stages when pupae and teneral adults are in an extremely exposed condition, there is no evidence that important mortality occurs due to predators or mechanical disturbances.

3. Daily and seasonal emergence rhythms may be altered by unseasonably cool weather.

4. Intensity of infestation and the species of the infested host may cause important changes in the emergence patterns of the sexes and in the sex ratio.

5. Virgin adults, particularly the males, are more active during the daytime than is generally recorded.

6. Disturbances such as mechanical movements and artificial lights may cause some abnormal redistribution of adults.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

Mailing address: Pacific Northwest Forest and Range Experiment Station
P.O. Box 3141
Portland, Oregon 97208

The FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.