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The Eastern Larch Beetle in Alaska

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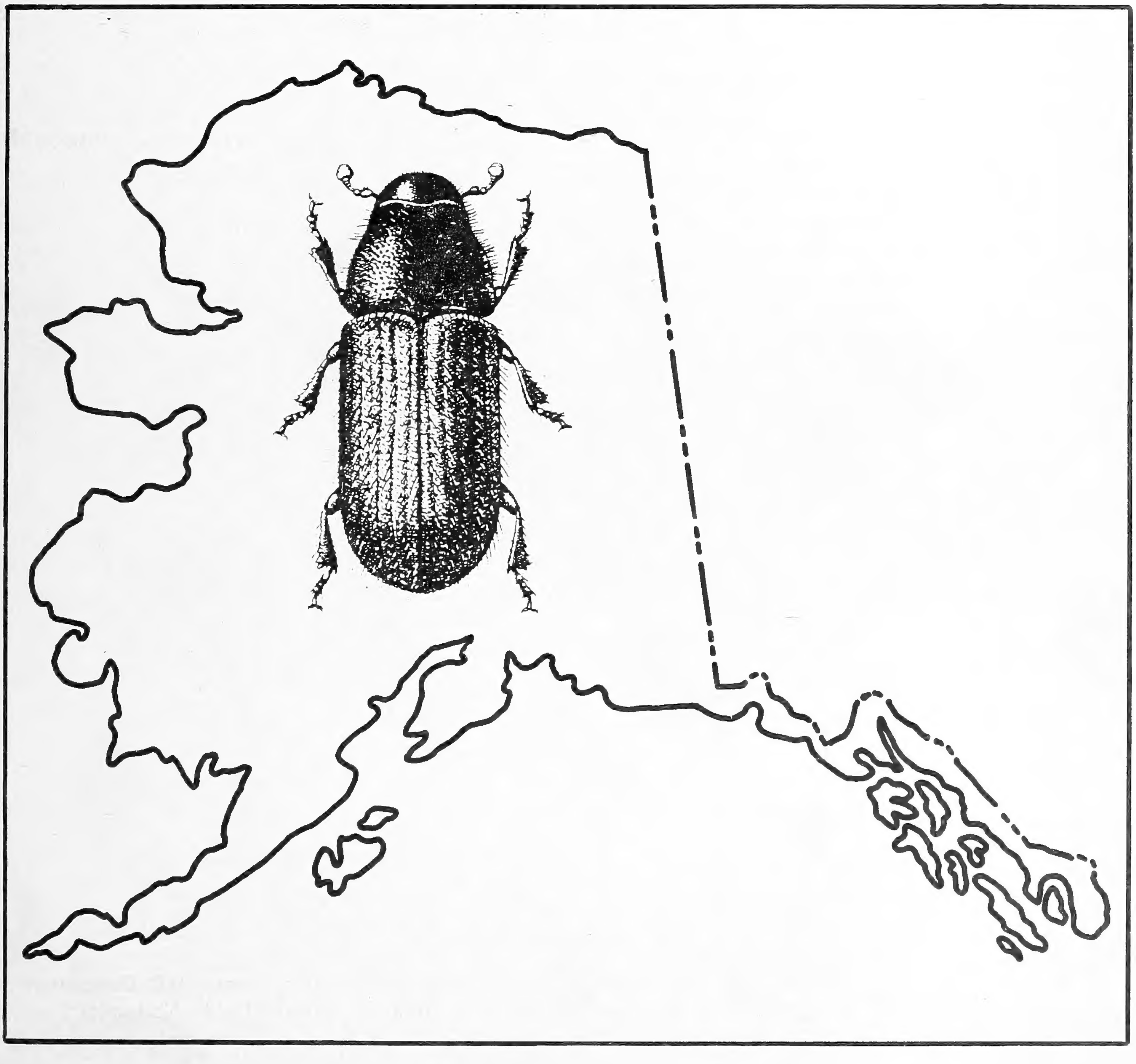

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Abstract

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The eastern larch beetle (*Dendroctonus simplex* LeConte) exists throughout the range of tamarack (*Larix laricina* (Du Roi) K. Koch) in interior Alaska where it has a 1-year life cycle. Beetles overwinter as adults in the bark of the trunk below snowline in infested trees. Tamarack trees that are slow growing because of repeated defoliation by larch bud moth (*Zeiraphera* sp.) or that inhabit cold wet river bottom sites underlain with permafrost are usually susceptible to attack by eastern larch beetles.

Keywords: Insects, insect populations, eastern larch beetle, tamarack, interior Alaska.

Research Summary

The eastern larch beetle (*Dendroctonus simplex* LeConte) has a 1-year life cycle in Alaska and attacks only tamarack (*Larix laricina* (Du Roi) K. Koch). Tamarack stands that occupy river bottom bog areas are stressed by cold wet soils. These stands are vulnerable to cyclic outbreaks of the larch bud moth (*Zeiraphera* sp.) which further reduce the vigor of the stands by defoliating them for 2 or 3 successive years. These tamarack are therefore stressed to the point that they are highly susceptible to attack by the eastern larch beetle. A beetle outbreak in interior Alaska from 1977 to 1979 resulted in 50-percent tree mortality.

Contents

Introduction

Populations of the eastern larch beetle (*Dendroctonus simplex* LeConte) infested 3.3 million ha of scattered tamarack (*Larix laricina* (Du Roi) K. Koch) stands from 1974 to 1980 in interior Alaska (fig. 1) (Baker and others 1974; Hostetler and others 1976; Rush and others 1977; USDA Forest Service 1979a, 1979b, 1980, 1981). The eastern larch beetle normally attacks tamarack weakened by defoliating insects, or trees damaged by fire, logging, or right-of-way clearing (Drouin and Turnock 1967, Furniss and Carolin 1977, Holsten and others 1980, Swaine 1913). The biology of the eastern larch beetle (Hopkins 1909, Simpson 1929) and larval development (Prebble 1933) were previously studied in New Brunswick, Canada.

The beetle occurs throughout the range of tamarack from Newfoundland in eastern Canada to the northern treeline; south into New England, Ohio, West Virginia, and Minnesota; and northwest into British Columbia, Yukon Territory, and Alaska (Wood 1963, 1982). In Alaska, tamarack occurs throughout the river basins between the Brooks Range on the north and the Alaska Range on the south and is especially common along the Yukon, Kuskokwim, and Tanana Rivers (fig. 1) (Viereck and Little 1975).

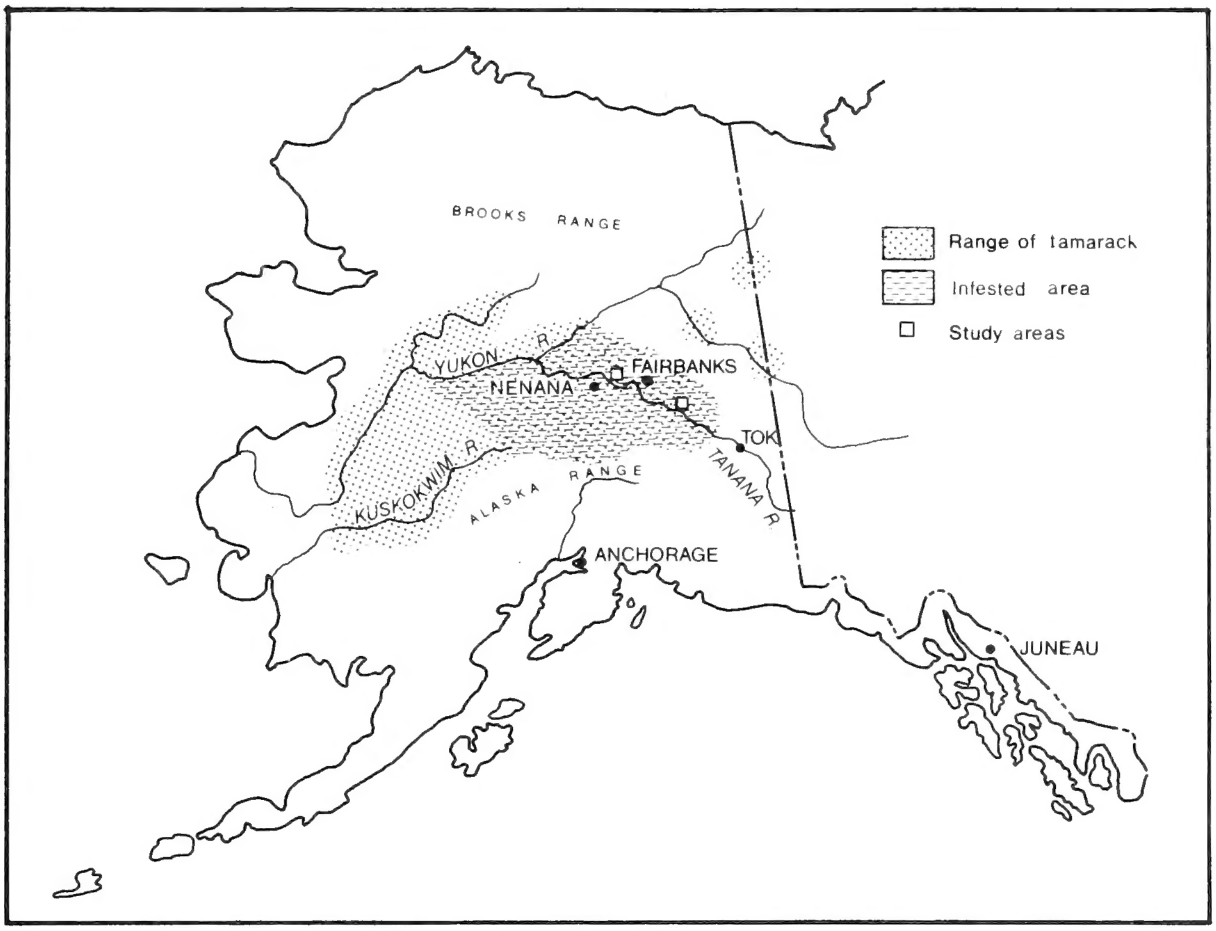

Figure 1.—Range of tamarack in Alaska and areas infested by the eastern larch beetle.

High populations of eastern larch beetle occurred in the Maritime Provinces of Nova Scotia, New Brunswick, and Prince Edward Island from 1976 to 1983 after larch sawfly (*Pristiphora erichsonii* (Hartig)) and spruce budworm (*Choristoneura fumiferana* (Clemens)) outbreaks. An estimated 25 percent of the merchantable tamarack volume in New Brunswick and 60 percent in Nova Scotia were killed by the eastern larch beetle and trees as small as 6 cm in d.b.h. (diameter at breast height) were successfully attacked (Magasi 1983, 1984). In Alaska, the infestation began in 1974 with 52 000 ha infested west of Denali National Park. By 1977, the infestation spread into the Tanana River Valley near Fairbanks. During 1975 and 1976, a species of bud moth (*Zeiraphera* sp.) completely defoliated 240 000 ha of tamarack in the Tanana River drainage (Werner 1980). Tamarack in this same area were subsequently infested by eastern larch beetle in 1977. Two successive years of defoliation could have reduced the vigor of the trees and increased their susceptibility to beetle attack. The susceptibility of tamarack to attack by eastern larch beetle along with observations on the biology and behavior of the eastern larch beetle in interior Alaska are reported.

Methods

Study Sites

The study was conducted in two areas in the Tanana River Valley heavily defoliated by *Zeiraphera* (fig. 1). The sites were the ones used for a previous study (Werner 1980). In May 1977, 20 sample plots were established at an elevation of 122 m in the Bonanza Creek Experimental Forest 40 km west of Fairbanks and 20 plots at an elevation of 335 m near Quartz Lake 134 km east of Fairbanks (fig. 1).

The study sites were located on permafrost but within the zone of discontinuous permafrost. The depth of thaw during the growing season was less than 60 cm at both sites. From 1977 to 1979, the mean temperature of the upper 30 cm of thawed soil was 10 °C from mid-May to mid-August; ambient air temperatures ranged from 2 to 27 °C.

The study plots contained open-grown tamarack mixed with black spruce (*Picea mariana* (Mill.) B.S.P.). The dominant tamarack ranged from about 6 to 9 m in height and about 6.5 to 15.0 cm in d.b.h. Intermediate tamarack and black spruce trees ranged from 2 to 5 m in height and from 2.5 to 5.0 cm in d.b.h. Ground cover consisted of *Sphagnum* spp., 40 percent; *Hylocomium splendens,* 30 percent; and *Pleurozium schreberi,* 30 percent. Shrub cover consisted of *Vaccinium uliginosum,* 20 percent; *Betula glandulosa,* 50 percent; *Myrica gale,* 15 percent; *L. laricina,* 10 percent; and *Picea mariana,* 5 percent (Brown 1982).

Experimental Design

At each site, two adjacent transects were established from the north side of the Tanana River Valley southward 900 m at a constant elevation. Ten circular plots—radius = 16 m—were sampled at 100-m intervals on each of the two transects, which were located 800 m apart. All tamarack trees and saplings greater than 2 cm in d.b.h. were numbered with aluminum tags; diameter at breast height and total height were recorded. Each tamarack in the plots was classified by larch beetle activity as either unattacked live or beetle-killed. Age and radial growth were determined from 2-cm-thick disks cut from the base of the trees 2.5 cm above ground level after the study was completed in May 1980.

Data Collection

Annual radial growth was measured from 1965 to 1980 on the cross section of the disks. Ring widths were measured by use of an increment measuring machine to the nearest one-hundredth of a millimeter. Rings were counted and measured along three radii spaced at equal intervals around the disk surface. Ring widths and numbers were averaged for the three radii per disk.

Four unbaited screened sticky barriers (1450 cm^2) were erected on five randomly selected plots at each study site to monitor flight periods and height of beetle flight. Sticky barriers were placed on each of four poles at ground level, 3 m, 6 m, and 9 m. Poles were located 6 m from the plot center; one in each of the four cardinal directions. Adult scolytids and clerids were removed daily from the traps during the flight period.

New attacks on the tree bole and exposed roots were marked daily on one side of the beetle entrance hole with staples. In late July, the attacked areas (lower 2 m of the bole) of five trees per randomly selected plot per transect were screened to determine the percentage of emergence and the emergence times of new adults prior to dispersal to overwintering sites. Adults were collected twice a week.

Beetle emergence periods from overwintering sites at the base of trees infested the previous year were determined by catching emerging beetles in screened cages attached to the lower 0.5-m section of the tree bole. Traps were placed on the tree in late September after beetle activity ceased. Beetles were collected daily during the emergence and flight period.

Results and Discussion

Description of Development Stages

Adults: Adults of both sexes are stout and cylindrical; average female length was 4.4 $\pm$ 0.31 mm (range 3.2 to 5.3 mm), n = 290; and average male length was 4.1 $\pm$ 0.29 mm (range 3.3 to 5.2 mm), n = 316. Newly formed, callow adults are similar to mature adults except the body is initially tan, eventually changing to dark brown with reddish-brown elytra. The change in color from callow to mature adults occurs in 3 to 4 weeks. Detailed taxonomic characteristics are described by Wood (1963, 1982).

Egg: Small white oval to oblong eggs are 0.87 $\pm$ 0.03 mm long and 0.54 $\pm$ 0.02 mm wide.

Larvae: Prebble (1933) gives a detailed report of the widths of head capsules for the four larval instars. Mature larvae average 4.5 $\pm$ 0.23 mm (range 4.2 to 4.6 mm) in length and have a head capsule width of 0.99 $\pm$ 0.04 mm (range 0.92 to 1.12 mm). Body color is white to whitish yellow (cream) and the head is reddish brown.

Pupae: Pupae are white to yellowish in the early stages of development but appear grayish before transforming to adults. Pupal size varies; average body length is 4.5 $\pm$ 0.91 mm (range 3.4 to 5.3 mm) and width is 1.8 $\pm$ 0.56 mm (range 1.6 to 2.1 mm), n = 350.

Life History and Behavior

The seasonal development of the eastern larch beetle is shown in figure 2. One generation a year is produced by the eastern larch beetle in Alaska. Simpson (1929) reports that as many as three broods were produced in New Brunswick in 1927. Prebble (1933) states that the total development period for eastern larch beetle in Manitoba from the first appearance of eggs to the first appearance of adults is 45 days, whereas in Alaska the development time is 54 days.

Winter is spent in the phloem of roots and lower trunk of infested trees at the ground-tree interface beneath the snow. Overwintering adults successfully survive below snow line at ambient air temperatures as low as -52 °C, which often occur in interior Alaska. The insulation quality of the snow amounts to about 20° above the ambient air temperature (Werner 1978).

Adults usually emerge after mid-May when average daily ambient air temperatures are above 15.0 °C and cumulative degree-day temperatures above 5 °C reach 85 °C. Peak emergence from hibernation sites occurs from mid-May to late May (table 1). Emerged females fly to susceptible green tamarack and initiate attacks. The attacking female produces a sex pheromone that attracts male beetles. The sex pheromone produced by the eastern larch beetle female has not been identified, but males respond to a mixture of seudenol and alpha pinene (Werner and others 1981). The female constructs about 10 cm of egg gallery before producing a sex pheromone. Mating occurs in the egg gallery, and the female continues to excavate the gallery. Eggs are deposited individually in niches constructed at irregular intervals on the sides of the gallery. Egg galleries consist of an irregular winding pattern up and down the bole of the tree. Some beetle attacks originate at the tree-ground interface, and the galleries descend into the phloem of the roots.

Larvae hatch in 4 to 6 days, and the first instars feed on the phloem and tunnel individual mines at right angles to the egg gallery. The mines expand slightly as the first and second instars feed (Wood 1963) and then increase in size in an irregular winding pattern unlike those of *Dendroctonus pseudotsugae* (Furniss 1976), *D. rufipennis* (Werner and others 1977), or *Ips* species. Larval development through four instars usually takes 30 days. Larval transformation to pupae begins about early July and continues to early August. Pupae transform to callow adults within the circular to oblong-shaped pupal chambers starting in mid-July. New adults begin emerging from the host tree by late July (table 1). Whether the new adults feed prior to emergence is not known. Emergence of new adults lasts until late August. New adults walk down the outer bark of the parent tree to the ground-tree interface and bore into the phloem where they construct hibernation sites; new adults that develop in the roots remain there until the next May.

Sex Ratios

Sex ratios for emerging overwintering adults, attacking adults, and emerging new adults were determined for 3 years for three generations (table 1). The sex ratio of all three groups of beetles favored females. The percentage of females emerging from overwintering sites in 1977 was less than in 1978 and 1979. There was no significant difference in the percentage of attacking females and emerging new females during the 3-year period.

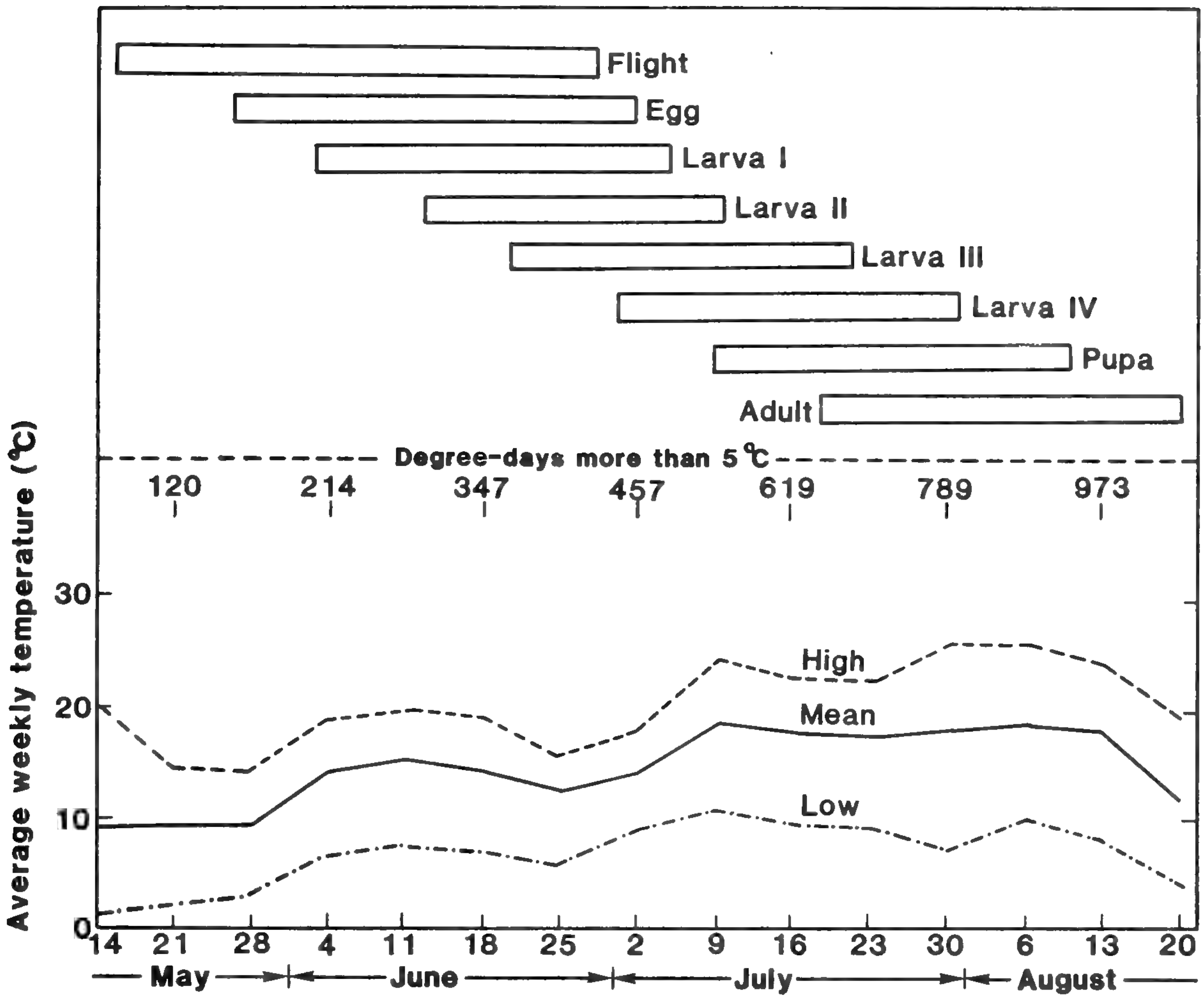

Figure 2.—Seasonal development of the eastern larch beetle and daily temperatures in interior Alaska.

Table 1—Sex ratios of emerging and attacking eastern larch beetles in Alaska

Year	Peak emergence date	Emerging overwintering adults 1/		Peak attack date	Attacking adults 1/		Peak emergence date	Emerging new adults 1/	
		Female:male	Percent female		Female:male	Percent female		Female:male	Percent female
1977	May 19	1.41:1c	56.7b	May 24	1.28:1c	61.4a	July 24	1.72:1a	60.2a
1978	May 22	1.63:1a	60.5a	May 28	1.60:1a	63.2a	July 30	1.56:1b	62.1a
1979	May 18	1.51:1b	61.3a	May 24	1.47:1b	59.6a	July 25	1.68:1a	60.3a

1/ Values followed by the same letter within columns are not significantly different from each other at the 5-percent level

Beetle Flight

The maximum distance that eastern larch beetles usually fly is not known, but this study did determine the height wherein most beetles fly. The majority of beetles (122) were caught on the sticky flight barriers erected at ground level, and 94 beetles were caught at 3 m (table 2). The barriers at ground level actually extended 15 cm above the ground. Peak flight period occurred between May 21 and 28, but flight continued to late June. A total of 272 beetles were caught on the 16 sticky flight barriers. The majority of beetles were caught on barriers located in the east quadrant. This indicates that beetles were flying into the wind which flows in an east to west direction during the daily flight periods. Peak flight periods occurred when cumulative degree-day temperatures above 5 °C ranged from 120 to 155 °C.

Beetle Attacks

The number of attacking female beetles per tree differed significantly ($P<0.05$) by diameter class—lowest in the small diameter trees and highest in the large diameter trees (table 3). There was no significant difference ($P>0.05$) by diameter class (range 0.5 ± 0.1 to 2.2 ± 0.3) in the number of root attacks.

The average length of egg galleries in the tree bole was significantly less ($P<0.05$) in the 0- to 4.0-cm diameter classes; however, egg gallery lengths in the 4.1- to 14.1-cm classes were not significantly different ($P>0.05$) (table 3). Egg galleries found in tamarack roots were shortest in small diameter trees. They were, however, significantly longer ($P<0.05$) than egg galleries in boles. The number of eggs per gallery increased as the tree diameter increased. There was no relationship between tree diameter and percentage of eggs that hatched, although significant differences occurred between diameter classes ($P<0.05$).

Beetle Survival

Fourth instar and pupal survival were highest in tree diameter classes greater than 10.1 cm. The percentage of new beetles emerging as a percentage of total initial brood was highest in tree diameter classes greater than 4.1 cm (table 3). Beetle survival is probably higher during endemic population levels because of reduced competition and mortality from predation. Losses to the new adults usually occur during dispersion after emergence. When beetle survival is low, fewer trees are attacked; but as beetle survival increases, more trees are infested and the population expands to an epidemic level causing greater tree mortality.

Table 2—Eastern larch beetle flight in relation to time, temperature, and vertical distribution on tree bole

Sample date	Degree-day temperatures above 5 °C	Number of beetles caught per 1450 square centimeters at heights of tree bole:				
		0 meter	3 meters	6 meters	9 meters	Total
May 14	90	6	9	0	0	15
21	120	38	26	6	4	74
28	155	32	20	11	7	70
June 4	215	21	17	8	9	55
11	285	10	5	3	3	21
18	345	9	12	0	2	23
25	395	6	5	2	1	14
July 2	455	0	0	0	0	0
Total		122	94	30	26	272

Table 3—Eastern larch beetle characteristics in tamarack stands near Fairbanks, Alaska

Tree and beetle characteristics	Unit	Tree diameter class (centimeters) 1/							
		0-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0	10.1-12.0	12.1-14.0	14.1+
Tree age	Years	9 ± 1.5	15 ± 2.8	28 ± 4.6	36 ± 7.5	49 ± 10.3	61 ± 10.9	72 ± 11.6	84 ± 13.5
Average attacks per tree	Number	3.2 ± 1.1c	3.3 ± .7c	5.5 ± .6c	8.9 ± 1.5b	11.1 ± .9ab	14.4 ± 1.0a	15.5 ± .8a	14.4 ± 1.8a
Average attacks on roots	Number	.7 ± .1	1.1 ± .2	.5 ± .1	2.0 ± .4	2.0 ± .3	1.1 ± .1	2.2 ± .3	1 ± .2
Average gallery length in roots	Centimeters	24 ± 3.6c	25 ± 4.1c	30 ± 2.8bc	47 ± 5.1a	37 ± 4.6b	35 ± 3.2b	33 ± 4.0b	35 ± 1.6b
Average gallery length in bole	Centimeters	17 ± 4.5b	15 ± 3.6b	22 ± 2.2ab	32 ± 5.1a	32 ± 6.2a	28 ± 4.2a	26 ± 3.6a	30 ± 3.8a
Average eggs/gallery	Number	47 ± 9.2c	42 ± 10.4c	53 ± 9.6b	52 ± 15.1b	63 ± 11.8a	66 ± 10.5a	59 ± 8.2a	60 ± 7.6a
Hatched eggs	Percent 2/	85.6 ± 4.2a	79.4 ± 3.2b	89.6 ± 4.9a	78.6 ± 2.1b	91.3 ± 6.6a	84.3 ± 4.4a	80.1 ± 2.1b	87 6 ± 3.8a
Surviving 4th instars and pupae	Percent 2/	15.1 ± 1.3c	18.9 ± 2.1bc	21.3 ± 2.6b	26.4 ± 3.0ab	23.2 ± 1.4b	31.1 ± 3.6a	29.6 ± 2.2a	27.5 ± 3.1a
Emerging new adults	Percent 2/	2.2 ± .2b	5.6 ± .4b	10.1 ± 1.2a	10.8 ± .9a	12.6 ± 1.5a	12.1 ± .8a	11.6 ± 1.2a	10.2 ± 6a
Females	Percent 3/	53.2 ± 3.6c	58.6 ± 4.2bc	59.5 ± 6.6ab	63.4 ± 5.6a	65.4 ± 3.4a	61.6 ± 2.9a	58.4 ± 1.6a	66.3 ± 5.4a

1/ Number of trees sampled was 40 per diameter class. Values are mean ± standard deviation. Values followed by the same letter within rows are not significantly different from each other at the 5-percent level.

2/ Percent of total initial brood.

3/ Percent of emerging new adults.

Attack Distribution

The average attack density per square decimeter of bark surface differed significantly ($P < 0.05$) between different heights of the bole within and between diameter classes. As expected, the lower diameter trees had few attacks per square decimeter of bark surface. The lower 1.5 meters of the tree bole contained the highest density of attacks (table 4). The density of attacks in the lower area of the bole was related to the density of beetles flying at low levels (table 2). Attack height ranged from 0.7 m in the 0- to 2.0-cm diameter class to 4.9 m in the 14.1+-cm diameter class. Because few attacks occurred above 3 m of the bole, attack densities were not determined at greater bole heights.

Beetle Impact

The distribution of tree diameter classes within the two study sites before beetle attack in May 1977 is shown in table 5 as unattacked, live trees. The 8.1- to 10.0-cm diameter class contained the most unattacked live trees (278), whereas the 14.1+-cm class contained the fewest (122).

Overall stand reduction in trees per hectare was 50 percent; the greatest reduction (70-99 percent) was in trees in the three largest diameter classes (table 5). Tamarack trees killed by eastern larch beetle in 1977 exhibited reduced radial growth during the previous 3 years compared with unattacked live trees. The impact of repeated defoliation by *Zeiraphera* on radial growth from 1975 to 1977 is evident in the beetle-killed trees compared with the unattacked live trees (table 6). The effect of defoliation on the radial growth of tamarack not attacked by beetles was less than on trees that were subsequently killed by beetles in 1977. The beetle-killed trees were apparently stressed when defoliation occurred in 1975 and 1976; their radial growth in 1974 was significantly less ($P < 0.05$) compared with the growth of unattacked live trees (table 6).

Table 4—Attack distribution of eastern larch beetle in tamarack stands near Fairbanks, Alaska

Tree diameter class	Trees sampled	Average tree height	Average length of live crown	Total height of attacks	Average attack density at given heights of bole in meters: 1/					
					0.5	1.0	1.5	2.0	2.5	3.0
Centimeters	Number	Meters			Number per square decimeter					
0-2.0	60	1.8	1.1	0.7	0.5 ± 0.1c	0	0	0	0	0
2.1-4.0	50	2.8	2.1	1.0	1.1 ± .3b	1.5 ± .1b	0	0	0	0
4.1-6.0	105	4.1	3.0	2.2	1.6 ± .3b	1.9 ± .2b	0.8 ± .2c	0.6 ± .1c	0	0
6.1-8.0	155	5.8	4.5	2.1	2.1 ± .5a	2.5 ± .4a	1.6 ± .5b	1.1 ± .3b	0	0
8.1-10.0	85	7.1	5.4	2.5	2.3 ± .6a	2.4 ± .4a	1.8 ± .3b	1.4 ± .2b	0.4 ± .1b	0
10.1-12.0	73	11.8	9.7	2.8	2.0 ± .3a	2.6 ± .3a	2.2 ± .4a	1.7 ± .5ab	.2 ± 0 b	0
12.1-14.0	32	12.6	10.6	4.1	2.2 ± .2a	2.5 ± .4a	2.4 ± .4a	2.2 ± .5a	1.4 ± .3a	0.4 ± .1
14.1+	2	14.3	10.4	4.9	2.4 ± .4a	2.5 ± .5a	2.2 ± .3a	1.9 ± .6a	1.5 ± .2a	.3 ± .1

1/ Values followed by the same letter within columns are not significantly different at the 5-percent level.

Table 5—Impact of eastern larch beetle on tamarack trees near Fairbanks, Alaska

Tree diameter class	Sampled plot trees 1/			Trees per hectare		
	Unattacked live trees		Beetle-killed trees, May 1977-Sept. 1979	Unattacked live trees, May 1977	Beetle-killed trees, Sept. 1979	Stand reduction, May 1977-Sept. 1979
	May 1977	Sept. 1979				
Centimeters	Number					Percent
0-2.0	175	137	38	55	12	22
2.1-4.0	169	137	32	53	10	19
4.1-6.0	153	120	33	48	10	21
6.1-8.0	225	141	84	70	22	31
8.1-10.0	278	149	129	87	40	46
10.1-12.0	251	72	179	78	56	72
12.1-14.0	238	7	231	74	72	99
14.1+	122	5	117	38	27	70
Total	1,611	768	843	503	249	

1/ 40 plots at 2 similar sites.

Table 6—Radial growth of unattacked and beetle-killed tamarack trees near Fairbanks, Alaska

Tree diameter class	Unattacked live trees					Beetle-killed trees, 1977			
	1974	1975	1976	1977	1978	1974	1975	1976	1977
Centimeters	Millimeters								
0-2.0	1.11	1.01	0.91	0.70	0.82	0.88	0.62	0.52	0.31
2.1-4.0	1.50	1.42	1.32	1.12	1.20	1.08	.83	.56	.29
4.1-6.0	1.92	1.89	1.68	.91	.90	1.10	.92	.49	.18
6.1-8.0	.83	.79	.74	.68	.81	.97	.65	.32	.21
8.1-10.0	1.26	1.09	.93	.83	1.06	.81	.76	.43	.15
10.1-12.0	1.14	.91	.87	.69	.93	.83	.77	.36	.22
12.1-14.0	.95	.86	.74	.54	.71	.76	.70	.21	.11
14.1+	.86	.74	.63	.53	.52	.78	.69	.32	.16

Radial growth of large diameter tamarack was significantly ($P < 0.05$) slower than that of smaller diameter trees. This could be related to the development of the root systems (Brown 1982). The root systems of large diameter trees descend into the seasonally thawed permafrost area where nutrient availability is limited, whereas small diameter trees have shallow root systems located primarily in the sphagnum moss layer covering the frozen mineral soil. The mineral soils that do thaw during the summer are usually saturated with water which lies on top of the permafrost. Trees whose roots extend into these wet soils are stressed by too much water. Cold wet soils in the root zone of tamarack are probably the major environmental factor that contributes to the stressed condition of tamarack growing in bog areas of interior Alaska. The fact that tamarack trees were successively defoliated 2 years prior to attack by eastern larch beetles indicates susceptibility of this tree species to beetle attack.

Acknowledgments

I thank Joyce Beelman, Laurie Bordelon, Tom Egan, and Tom Ward for assistance in collecting field data and Karen Post for the statistical analyses.

Metric and English Units of Measure

When you know:	Multiply by:	To find:
Centimeters (cm)	0.4	Inches
Hectares (ha)	2.5	Acres
Kilometers (km)	0.6	Miles
Meters (m)	3.3	Feet
Millimeters (mm)	0.04	Inches
Celsius (°C)	1.8 (then add 32)	Fahrenheit (°F)

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The eastern larch beetle (*Dendroctonus simplex* LeConte) exists throughout the range of tamarack (*Larix laricina* (Du Roi) K. Koch) in interior Alaska where it has a 1-year life cycle. Beetles overwinter as adults in the bark of the trunk or below snowline in infested trees. Tamarack trees that are slow growing because of repeated defoliation by larch bud moth (*Zeiraphera* sp.) or that inhabit cold wet river bottom sites underlain with permafrost are usually susceptible to attack by eastern larch beetles.

Keywords: Insects, insect populations, eastern larch beetle, tamarack, interior Alaska.

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