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Development of *Monochamus galloprovincialis* Olivier (Coleoptera, Cerambycidae) in cut trees of young pines (*Pinus sylvestris* L.) and log bolts in southern Finland

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The development of the later juvenile stages of *Monochamus galloprovincialis* Olivier was studied under field conditions in southern Finland, with freshly cut young Scots pines and log bolts as breeding material. Females had oviposited on the breeding material in summer 1988, and observation of the material was continued until July 1991. To complete their life cycle the majority of the larvae appeared to need two years, although roughly 10% emerged following the first winter. Mortality was affected by loosening of the bark, drying of the wood, and probably by certain unidentified Diptera larvae.

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1. Introduction

According to assumed field observations, pine sawyer beetles (*Monochamus* spp., Cerambycidae) would produce one generation per year in southern parts of Norway, Sweden and Finland, whereas in more northerly regions the completion of the life cycle is expected to take at least two years (Trägårdh 1919, 1940, Saalas 1923, Bakke 1960, Kangas & Salonen 1960). However, there appear to be no precise experiments performed in the Nordic countries on the duration of pine sawyer generation time.

The present investigation was started to clarify the development of pine sawyer juvenile stages inside the wood: focusing on the length of the life cycle (from egg to adult) in southern Finland. It was also possible to gather data on the mortality of larvae that had already bored into the wood as well as of the pupae and callow adults. *M. galloprovincialis* Olivier was chosen since it is widely distributed in southern parts of the country.

2. Material and methods

The study site was located in Tuusula (60°21′N, 25°1′E) in southern Finland. Based on the density of egg-laying slits on the cut trees of young pines that constituted most of the breeding material pine sawyers (*M. galloprovincialis*) seemed to be relatively abundant in the area. Based on observations in the field the sawyers had oviposited on these recently felled young Scots pines (*Pinus sylvestris* L.) during summer, 1988. The age class of the pines (n = 111) was 10–15 years, and they had been left on the ground in a small reforestation area following cutting. In addition, larger-sized log bolts (n = 25) cut from older pines were brought into the site and placed on the ground in the close proximity to the young trees. These log bolts had also been oviposited by the sawyers in the summer 1988 at their original location 8 km from the study site. The study site was very dry and open, receiving plenty of sunshine on clear days.

Inspection of the breeding material was begun in spring, 1989 and was continued on a more or less regular basis until midsummer of 1991, excluding the winter months. Upon every sampling day a variable portion of the cut trees and bolts were brought into the laboratory where they were individually examined; data was collected on the following variables: volume of the young pines and the log bolts, thickness of the bark, number of pine sawyer larval entrance holes (oval-shaped holes), location of the sawyers inside the wood (depth in the wood), width of the first sclerite of the larvae, number of pupae, number of callow adults and number of adult emergence holes (round holes). Based on the above measurements and observations it was possible to follow the development rate of the larvae inside the wood, their location (deep inside the wood versus close to the surface) and the timing of the emergence of the new beetle generation. Furthermore, observations were made on the mortality of different life stages of the sawyers, excluding the earliest larval stages that remained between the bark and the sapwood.

The survival rate (SR) of larvae that entered the wood was calculated as the sum of live larvae, pupae, adults and number of emergence holes expressed as percent of larval entrance holes. The depth at which the larvae were found was defined as the shortest distance from the surface of the wood. At the initial stages of the experiment the diameter of the young pines or the log bolts was not measured at the place where the larvae were found. However, since knowing the depth of discovery at different times during the course of development was later considered important, the average diameter of the breeding material was used to substitute for actual diameter measurements.

The Depth Index (DI) gives the depth of the location of the larva relative to the radius of the trunk.

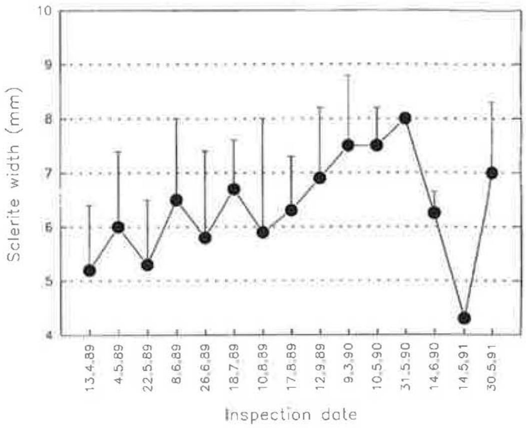

Fig. 1. Width of first sclerite of *Monochamus galloprovincialis* larvae developed in felled young *Pinus sylvestris* and log bolts in Tuusula in southern Finland during 1988–1991. Standard errors indicated by vertical error-bars.

Monthly temperature data was obtained from the Meteorological Institute station at the Helsinki-Vantaa airport five kilometers from the study site. A t-test was used to determine the statistical differences in variable values (larval sclerite width, location of the larvae inside the wood, number of larval entrance holes and adult emergence holes) between the data groups (breeding material with average diameter below 5.0 cm in contrast with material of a diameter exceeding 5.0 cm).

3. Results

Inspection of the first batch of the breeding material was performed 13 April 1989. At this time the average widths of the first larval sclerite were 5.7 mm (n = 23) and 4.2 mm (n = 13) for larvae found in breeding material with diameter less than 5.0 cm (mainly young pines) and over 5.0 cm (mainly log bolts). Thus, the size of the larvae in the breeding material with diameter exceeding 5.0 cm was considerably smaller ($t = 4.81$, $df = 34$, $P = 0.001$***). Because this was the only case of a statistically meaningful difference between these two diameter groups the data from the two size classes were combined (Fig. 1).

During the last study year (1991) only eight live larvae were found (Table 1), and the average width of their first sclerite was 4.1 mm. These larvae were found before June, and all larvae found afterwards were dead (n = 6). The recorded maximum average widths of the sclerite were for larvae found on 3 March and 10 May 1990 (7.4 mm, n = 10). Presumably these represented the larval stage just preceding the pupal stage. Maximum sclerite widths ranged between 9.0–10.0 cm.

A total of 243 adult emergence holes were counted during the whole study (Table 1). The first pine sawyer adults emerged during the period of May 22, 1989 until June 8 of the same year (n = 4) (Table 1). Later the same summer 18 additional sawyers emerged. Hence, roughly 10% of the beetles in the breeding material exhibited a one-year life cycle. The number of emergence holes in the breeding material inspected on May 14 and May 30 1991 (Table 1) very likely represent a number of adults emerging the previous year, since usually at that time, late spring or early summer, the current year's new generation has not yet started to leave their quarters. Accordingly, the year 1990 proved to be the actual emergence year for the new beetle generation, making the life cycle of the majority of the beetles (roughly 90%) two years.

Upon first inspections in spring 1989, approximately 75–95% (survival rate) of the larvae that had entered the wood were found alive (Table 1). Thus, regardless of some relatively low temperatures in November, December, January and April (roughly –23°C), a great majority survived the first winter. The first significant fall in survival rate took place in the beginning of the same summer resulting in survival rate values of as low as 50%. From this point on, survival rate remained at almost the same level until next

Table 1. Life stages of *Monochamus galloprovincialis* in felled young *Pinus sylvestris* and log bolts in Tuusula, southern Finland in 1989, -90 and -91. Sawyer beetles oviposited in summer, 1988. *SR* = Survival Rate (proportion of living life stages and emergence holes of number of larval entrance holes).

Inspection date	Young pines and bolts	Entrance holes	Larvae	Pupae	Adults	Emergence holes	SR (%)
1989							
13.4.	4	43	37	–	–	–	86
4.5.	5	118	114	–	–	–	97
22.5.	2	27	23	–	–	–	85
8.6.	7	53	34	–	–	4	72
26.6.	8	71	33	–	–	–	47
18.7.	9	171	75	–	–	15	53
10.8.	4	60	30	–	–	1	52
17.8.	6	108	48	–	–	2	46
12.9.	6	114	65	–	–	–	57
1990							
9.3.	3	61	37	–	–	–	61
3.5.	1	3	–	3	–	–	100
10.5.	8	121	11	42	–	5	48
31.5.	2	10	1	3	–	–	40
4.6.	5	72	–	12	9	2	32
14.6.	5	113	2	3[1]	21[2]	38	43
5.7.	4	87	–	2[3]	5[3]	27	31
1991							
14.5.	16	183	7	7[4]	24[3]	52	34
30.5.	8	36	1	–	4[3]	17	50
25.6.	16	83	–	6[5]	11[6]	27	35
24.7.	17	119	–	2[1]	14[3]	53	45

[1]1 dead; [2]14 dead; [3]all dead; [4]3 dead; [5]5 dead; [6]10 dead

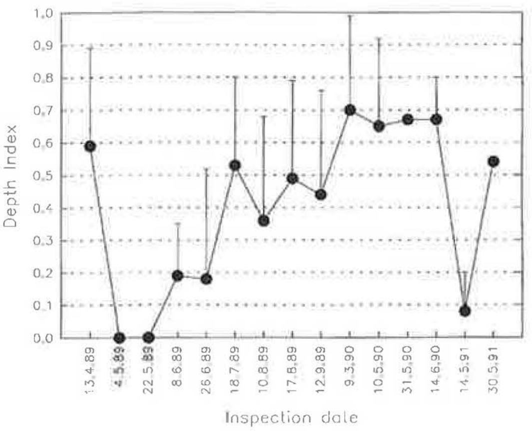

Fig. 2. Depth index of larvae of *Monochamus galloprovincialis* developing in felled young *Pinus sylvestris* and log bolts in Tuusula in southern Finland during 1988–1991. At index value of 0 larvae found just below bark, and at 1, they were located at center. Standard errors indicated by vertical error-bars.

year's midsummer when it reached its lowest value, i.e. 31% (Table 1). Consequently, of all the larvae initially penetrated into the wood only about 30% reached adulthood. Roughly 50–70% of the larvae entering the wood never reached pupal stage. Furthermore, of all the pupal stages and callow adults, 20–25% died inside the wood.

In the beginning of summer 1989, larvae remained near the surface (Fig. 2). In fact, several larvae were actually found between the bark and the sapwood. Later that summer the larvae moved deeper inside the wood, reaching the maximum depth index (DI) levels during the next spring. At about this time, in breeding material with diameter less than 5.0 cm, the larvae were found closer to the center (March 9th 1990: $t = 3.95$, $df = 18$, $P = 0.001$***; May 10th 1990: $t = 2.54$, $df = 19$, $P = 0.05$*). However, since this was the only case where there was a statistically significant difference between the two diameter classes the data in Fig. 2 were combined.

The number of entrance and emergence holes was significantly higher in breeding material below 5 cm in diameter than in material above 5 cm (entrance: 10±6 and 3±2/dm^3, respectively, $t = 6.96$, $df = 66$, $P = 0.001$; emergence: 1±1 and 0.001/dm^3, $t = 3.57$, $df = 52$, $P = 0.001$).

No significant correlation existed between bark thickness and the number of larval entrance holes or the number of adult emergence holes (Spearman correlation coefficients = –0.25 and –0.38, respectively).

Although no systematic survey could estimate the different causes for mortality observed at the different developmental stages, a few more or less random observations could be made. Occasionally, dying or dead larvae were found to be covered with unidentified diptera larvae. On the final inspections during the last study year, dead diptera adults were found in the pine sawyer larval galleries. These appeared to belong to the family Tachinidae (Chinery 1979).

Following the first winter, the bark of the breeding material was so loose as to fall off easily when lightly touched. Sometimes live larvae were found to have fallen on the ground next to the breeding material due to loosened bark.

Dead or dying pupae and callow adults were frequently found in close proximity to branch whorls. Hardness of the wood may have contributed to death at these stages.

4. Discussion

In Japan *Monochamus alternatus* Hope may have a 1- or 2-year life cycle depending on the part of the growing season at which the sawyers have oviposited on weakened pines (Togashi 1989a, b). In the United States, in North Carolina the life cycle of *M. carolinensis* (Olivier) and *M. titillator* (Fabricius) may range from one year to one and a half (Alya & Hain 1985). In the Lake States two years are required for *M. scutellatus* (Say) to complete its life cycle (Wilson 1962). In Missouri the life cycle of *M. carolinensis* is completed in 8–12 weeks when the eggs have been laid prior to the middle of July (Pershing & Linit 1986). In Ontario, Canada, the life cycle of *M. scutellatus* seems to take two years (Belyea 1952, Rose 1957).

On several occasions pine sawyers have been thought predominately to complete one generation per year in southern Norway, Sweden and Finland and in general in Europe (Saalas 1923, Bakke 1960, Kangas & Salonen 1960, Hellrigl 1970, 1971). However, in the most northern parts of the sawyers' distribution in Europe and in Siberia the generation time is usually two years (Bakke 1960, Hellrigl 1971, Isaev et al. 1988). According to Hellrigl (1970), *M. sartor* (Fabr.) in Germany had a 2-year life cycle more frequently when developing at higher altitudes, on sites receiving little or no sunlight or during colder than average summers.

The results of the present study contradict somewhat with the previous findings of the sawyers' having chiefly a one-year generation time in southern Finland. Although under some special circumstances as when breeding on fresh float timber the sawyers might complete their life cycle in one year, as has shown to be the case in Sweden (Trägårdh 1919), that seems to be more or less an exception, at least in Finland. The summers of 1988 and 1989 were relatively warm so apparently majority of the sawyers still waited to emerge until 1990. The life cycle of *Tetropium* spp. (Coleoptera, Cerambycidae) and *Hylobius abietis* (L.) (Coleoptera, Curculionidae) is extended the further north one goes (Juutinen 1955, Bejer-Petersen et al. 1962, Brammanis 1975). It can thus be suggested that the same phenomenon applies also to Finnish pine sawyer populations. Furthermore, the average monthly temperatures in southern Finland during the growing season seem to be considerably below the corresponding averages in Japan and the U.S. (Landsberg 1969, 1970, 1974) which increasingly supports the idea of the Finnish 2-year generation time.

The fact that there were significantly more adult emergence holes in relation to number of larval entrance holes in thinner breeding material may indicate better conditions for development there than in thicker trees. This is further supported by the observation from early stages of the study of larvae in thinner breeding material having a greater sclerite width. On the other hand, since the naturally oviposited large-sized log bolts were brought to the study site from another location, this phenomenon may also reflect genetic variability between the two sawyer populations.

In the present study the mortality rate of the eggs and larvae at the earlier stages was not determined. However, of all the larvae that had penetrated into the wood, only about 37% matured to adulthood. The main mortality factor may have been their falling onto the ground while seeking nourishment in between the surface of the wood and the loose bark. On the ground the larvae would be helpless and easy targets for a variety of predators. The mortality among the callow adults inside the wood was 18% meaning roughly 30% of all the larvae in the wood emerged as adults. According to Hellrigl (1970) sometimes the larvae preparing for pupation may have been over-cautious, making their pupal chambers very deep inside the wood resulting in death of such callow adults due to starvation during emergence. The relatively high number of dead adults found inside the wood of the breeding material, especially in the close proximity of the branch whorls, may therefore indicate a similar cause of mortality in this study, too. Furthermore, some evidence suggested, for instance, parasitic dipteran flies exerting pressure on the sawyer population. Additionally, rapid drying of the wood may have played some role, especially since some of the breeding material was very small in diameter (the thinnest parts of the wood containing sawyer larval galleries and also emergence holes did not exceed 2.0 cm). According to Trägårdh (1923) the diameter of the wood must be at least 4.0 cm to allow the sawyer larva to complete its life cycle.

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References

Alya, A. B. & Hain, F. P. 1985: Life histories of Monochamus carolinensis and M. titillator (Coleoptera: Cerambycidae) in the Piedmont of North Carolina. — J. Entomol. Sci. 20(4):390–397.

Bakke, A. 1960: Insektskader på ubarket gran- og furutømmer i Norge. — Meddel. Norske Skogforsøksvesen 56:284–333.

Bejer-Petersen, B., Juutinen, P., Kangas, E., Bakke, A., Butovitsch, V., Eidmann, H., Heqvist, K. J. & Lekander, B. 1962: Studies on Hylobius abietis L. I. Development and life cycle in the Nordic countries. — Acta Entomol. Fennica 17:1–107.

Belyea, R. M. 1952: Death and deterioration of balsam fir weakened by spruce budworm defoliation Pt.1. — Can. Entomol. 84(11):325–335.

Brammanis, L. 1975: Die Kiefernrindenwanze, Aradus cinnamomoeus Panz. (Hemiptera-Heteroptera). Ein Beitrag zur Kenntnis der Lebensweise und der forstlichen Bedeutung. — Studia Forest. Suecica 123:1–81.

Chinery, M. 1979: A field guide to the insects of Britain and Northern Europe. — William Collins Sons & Co Ltd Glasgow. 352 pp.

Hellrigl, K. G. 1970: Die Bionomie der europäischen Monochamus-Arten (Coleopt., Cerambycid.) und ihre Bedeutung für die Forst- und Holzwirtschaft. — Estratto da REDIA, 1970–71, 52:367–510.

— 1971: Einige neue Erkenntnisse über die Bionomie der europäischen Monochamus-Arten (Col. Cerambyc.). — Anz. Schädlingskunde Pflanzenschutz 44(1):3–8.

Isaev, A. S., Rozhkov, A. S. & Kiselev, V. V. (Исаев, А. С., Рожков, А. С. & Киселев, В. В.) 1988: Fir sawyer beetle Monochamus urussovi (Fisch.). (In Russian) — "Nauka", Publishing House, Siberian Branch. Novosibirsk.

Juutinen, P. 1955: Zur Biologie und forstlichen Bedeutung der Fichtenböcke (Tetropium Kirby) in Finnland. — Acta Entomol. Fennica 11:1–112.

Kangas, E. & Salonen, K. 1960: Über das Vorkommen der Monochamus-Arten (Col., Cerambycidae) und ihre Bekämpfungsmöglichkeiten in Finnland. — Ann. Entomol. Fennici 26:263–272.

Landsberg, H. E. 1969: World Survey of Climatology. 8 — Elsevier, Amsterdam. 248 pp.

— 1970: World Survey of Climatology. 5. — Elsevier, Amsterdam. 253 pp.

— 1974: World Survey of Climatology. 11. — Elsevier, Amsterdam. 420 pp.

Pershing, J. C. & Linit, M. J. 1986: Biology of Monochamus carolinensis (Coleoptera: Cerambycidae) on Scotch pine in Missouri. — J. Kansas Entomol. Soc. 59(4):706–711.

Rose, A. H. 1957: Some notes on the biology of Monochamus scutellatus (Say) (Coleoptera: Cerambycidae). — Can. Entomol. 89(12):547–553.

Saalas, U. 1923: Die Fichtenkäfer Finnlands. Studien über die Entwicklungsstadien, Lebensweise und geographische Verbreitung der an Picea excelsa Link. lebenden Coleopteren nebst einer Larvenbestimmungstabelle. — Ann. Acad. Sci. Fennicae (Ser. A) 22(1. II). 746 p.

Togashi, K. 1989a: Development of Monochamus alternatus Hope (Coleoptera: Cerambycidae) in Pinus thunbergii trees weakened at different times. — J. Jap. For. Soc. 71:383–386.

— 1989b: Development of Monochamus alternatus Hope (Coleoptera: Cerambycidae) in relaton to oviposition time. — Jap. J. Appl. Entomol. Zool. 33:1–8.

Trägårdh, I. 1919: Tallbocken, Monochamus sutor L., en viktig teknisk skadegörare bland långhorningarna. — Meddelanden från Statens Skogsförsöksanstalt. 15:221–232. (Särtryck ur Skogsvårdsföreningens Tidskrift 1918). Centraltryckeriet, Stockholm.

— 1923: Tallbocken. — Flygblad 27:1–6.

— 1940: Tallbockens angrepp på vattenlagt virke. — Skogen 6. 4 pp.

Wilson, L. F. 1962: White-spotted sawyer. — U.S. Dept. Agric. For. Serv., For. Pest Leaflet. 74. 7 p.

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