XYLEBORUS SAXESENI, ITS LIFE-HISTORY AND FLIGHT BEHAVIOUR IN NEW ZEALAND

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ABSTRACT

The biology of **Xyleborus saxeseni** (Ratz.) in New Zealand is described and compared with that reported from the Northern Hemisphere. The life cycle occupies a minimum of 8 weeks with emergence most probable between September and February. Brood size and sex ratio vary greatly with a high proportion of nests producing no males. The significance of virgin females in nest failure is discussed. In the central North Island two and possibly three generations occur annually. Emerging adults attack radiata pine (**Pinus radiata** D. Don) logs one week after felling.

Flight never occurred before noon. During mid-afternoon, provided that temperatures exceeded 21°C beetles flew readily, but above 32°C flight ceased. Following flight exercise the initially positive phototropic response of the beetles was reversed. Thirty-one indigenous and exotic tree species are recorded as hosts; the insect was very selective of the condition of host material it utilised.

INTRODUCTION

The ambrosia beetle *X. saxeseni* is recorded by Chararas (1962) as occurring throughout Europe, North Africa, Asia Minor, the Caucausus, and North America. Its establishment in New Zealand about 1957 (Milligan, 1969) has extended this range to the Southern Hemisphere. Field studies on the biology of *X. saxeseni,* which spanned three summers from August 1968 to April 1971 in Tauhara Forest, north of Lake Taupo, and experimental work at the Forest Research Institute, Rotorua, are reported in this paper.

The most comprehensive study on *X. saxeseni* is that of Fischer (1954) who investigated its behaviour and its effect on apple trees in Germany. He describes in some detail the development of the nest system and suggests an evolutionary sequence of decreasing complexity in certain scolytid gallery types. He considers the complicated forked galleries of *Anisandrus dispa F.* to be the most primitive, leading to the *Xyleborus monographus* type which is confined to a single growth ring. *X. saxeseni* with a single transverse gallery, he suggests, is the most advanced. He describes the activity of the female parent in nest initiation and outlines the pattern of brood development. He also discusses fertilisation, the fungal symbiont, and control of this insect in orchard trees. His literature review appears to be complete up to 1954.

Chararas (1962) adds little information except to comment on the insect's significance

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in coniferous forests. The synonymy of the species is outlined by Chamberlin (1958) who also records several hardwood hosts in the United States of America. The most recent contribution concerning the biology of X. *saxeseni,* by Milligan (1969, 1970), discusses the first recorded instance of attack on sawn timber, and outlines the probable circumstances leading to the establishment of this species in New Zealand. He also summarises the beetle's biology as it was known in this country and its possible significance to forest industries.

The distribution and spread of X. *saxeseni* in New Zealand (Fig. 1) is least confused in the South Island where one definite point of establishment is evident at Nelson. A second possible point is Dunedin, where a single infested tree was recorded.

In the North Island, points of establishment are less clear but Coromandel and Wairakei both appear possibilities. Without a detailed survey it is not possible to determine the origin of infestations at Gisborne, Napier and New Plymouth.

The host list for the Northern Hemisphere includes a wide range of hardwoods and softwoods (Blackman, 1922; Chamberlin, 1949, 1958; Chararas, 1962; Doane *et al.,* 1936; Hopkins, 1898). In New Zealand attack has been recorded on 30 species of exotic and indigenous trees (Appendix 1), and has been confined to dead and dying trees. Infestations are often present in waste logs, stumps, and windthrown trees.

No detailed studies have been made previously on the life history and habits of this beetle in coniferous trees. The observations recorded in this paper mainly concern broods in radiata pine. The literature contains few references to emergence patterns and daily flight activity of X. *saxeseni.* This paper deals with these aspects in some detail. Some mention is made of deviations in behaviour which might be attributed to the new environment.

Estimation of the number of generations per year is complicated by the protracted emergence from many nests. As the summer period progresses the overlapping of successive generations makes observation of the offspring of overwintering broods impossible under field conditions. For this reason field observations were confined to the overwintering generation.

MATERIALS AND METHODS

In the field, cages were placed over active nests in the winter months and the emergence of brood was recorded at weekly intervals throughout the following summer. Emerged adults were sexed and the presence of frass or nest cleanings noted. When emergences had ceased, logs containing caged nests were cut into billets and each nest was dissected to determine the size and complexity of the brood chamber and to count the brood which had failed to emerge. The emergence cages were small, transparent, plastic pill-boxes with a hole the same diameter as an X. *saxeseni* entry tunnel, drilled at the centre point of the base (Fig. 2). They were attached by a rubber based adhesive to debarked logs. Cages were placed over 350 active nests in the course of the study. Infested material collected by the writer, and that forwarded by the Forest Biology Survey, was dissected as it came to hand and details of host species, brood, and extent of damage were recorded.

To determine how soon damage could be expected in logs after felling, three freshly cut logs 1.5 m long were placed in the Tauhara Forest study area at weekly

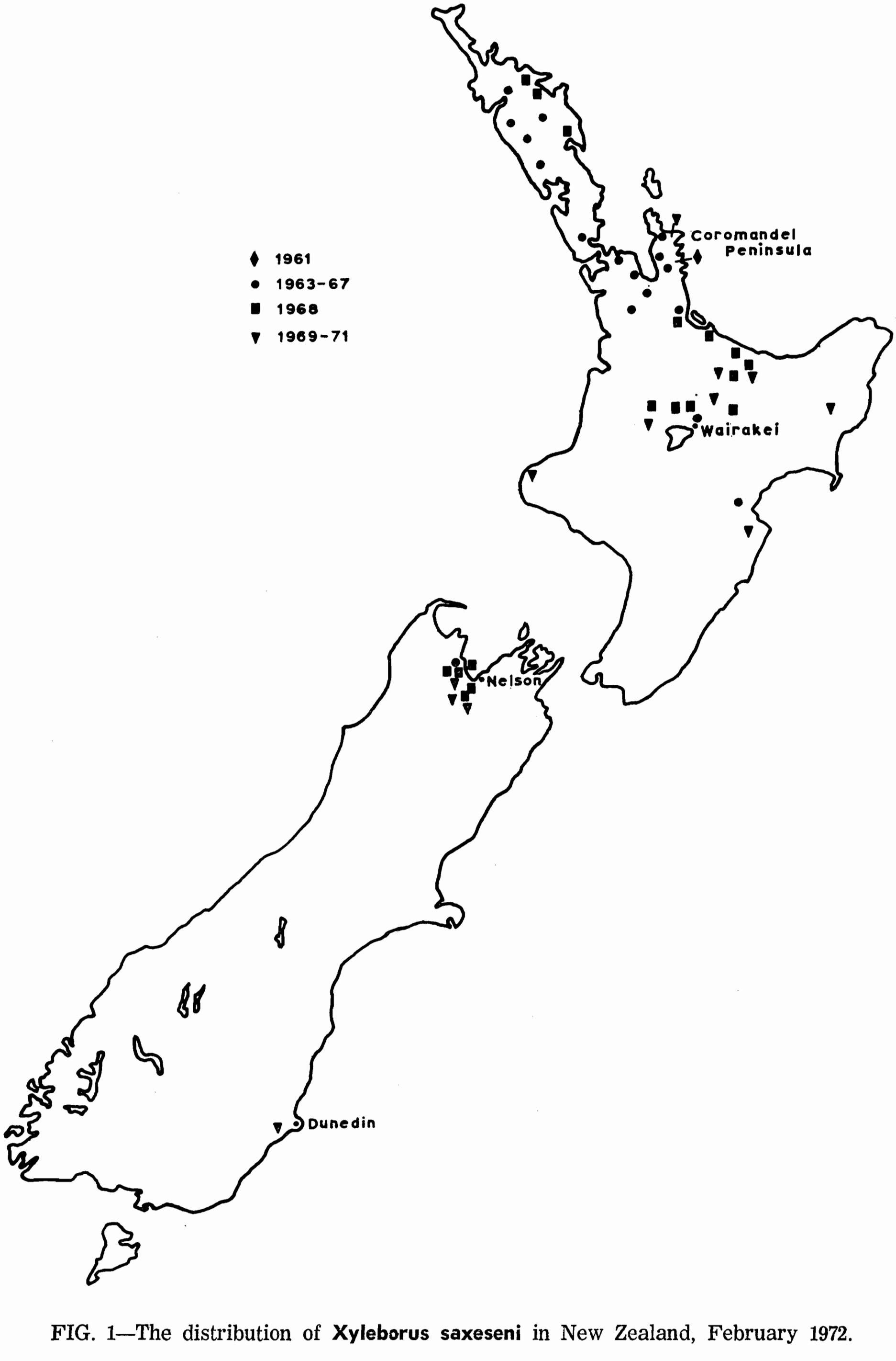

FIG. 1—The distribution of **Xyleborus saxeseni** in New Zealand, February 1972.

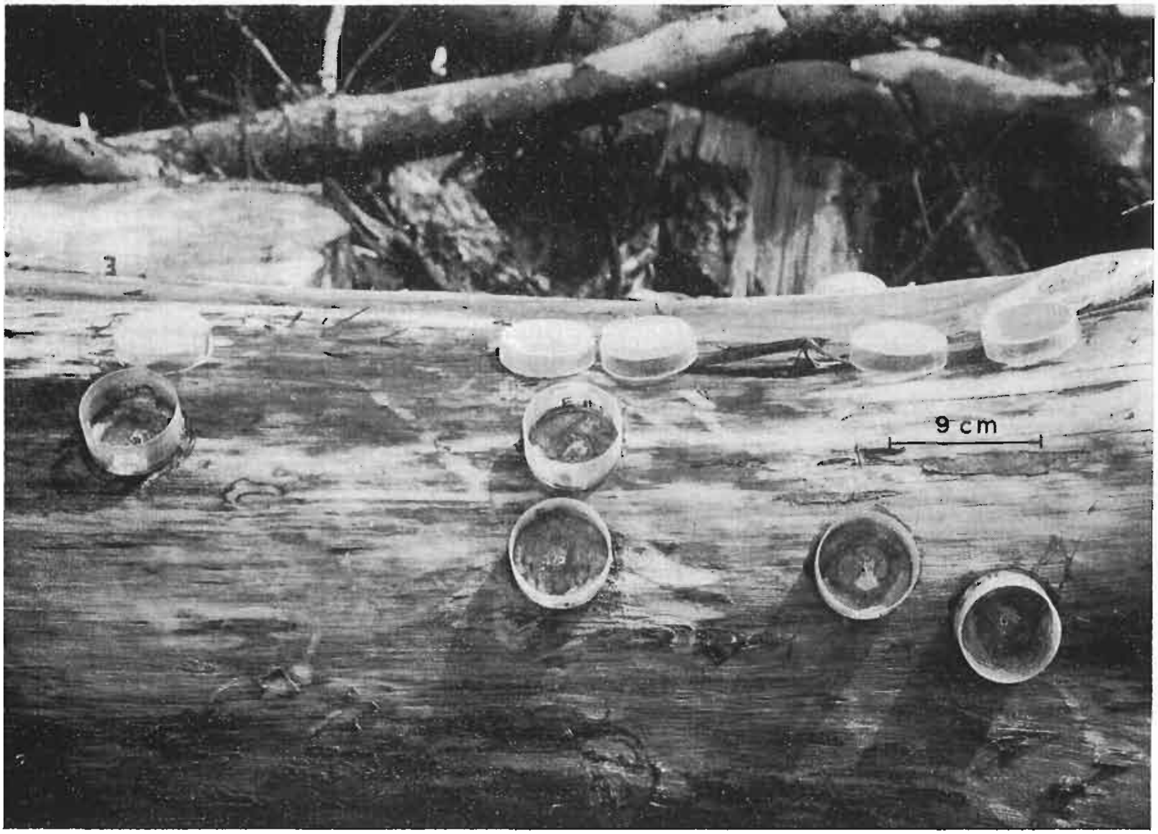

FIG. 2—**Xyleborus saxeseni** field traps in place with tops removed.

intervals throughout the 1968-69 summer. Attacks were recorded weekly and at the end of the emergence period the logs were dissected.

A hygrothermograph gave a continuous record of temperature and relative humidity in the study area during the 1968-69 and 1969-70 emergence seasons.

The small size of the adults precluded any attempts at field observations of flight activity. Studies on this aspect of its behaviour were made in an insectary with free air movement and light penetration through nylon screen cloth. During the period of flight activity, temperature, relative humidity, and light intensity were recorded at 15 minute intervals. Counts of insects in flight and on areas of screen cloth selected with regard to light intensity were made on the same time scale. The area to which the data of Fig. 6 apply was subject to highest light intensity.

Adults in flight were counted visually by means of a simple grid while they hovered near the insectary ceiling. Counts made by three observers when approximately 200 insects were flying agreed within ± 2.5%. Observations were made on consecutive days whenever flight activity was evident.

Radiata pine logs felled 3 weeks earlier were provided in the insectary so that nest initiation following flight could be observed. The presence of host material may also have helped simulate more closely field conditions. The insects studied emerged from six heavily infested *Knightia excelsa* logs. Flight observations were made over two summer periods, 1969-70 and 1970-71.

RESULTS

Host Selection

Attack on coniferous trees is confined to the main stem and larger branches with few nests in material under 15 cm diameter. In some indigenous hardwoods, e.g. *Weinmannia racemosa* and *Knightia excelsa,* many nests were found in limbs as small as 5 cm diameter. Fischer (1954) states that nests predominate in the lower surfaces of the branches but this was not apparent in radiata pine logs nor in dead standing *K. excelsa* examined.

Radiata pine logs were first attacked between 1 and 2 weeks after felling. About twice as many nests initiated 2 to 3 weeks after felling were abortive compared with those started at 6 weeks, and broods in the fresher logs were much smaller. On this evidence 6 weeks after felling was considered the optimum age for nest initiation. Preliminary experiments and field observations suggest that anaerobic breakdown of wood, as postulated by Graham (1968), may be an important factor in the selection of host material. Although high populations have been found in scorched logs and stumps, scorching does not appear to be a prerequisite for high density attack.

Nest Initiation

Adult female X. *saxeseni* were observed attacking radiata pine logs during the late afternoon after a period of flight activity. The beetles spent up to half an hour wandering over the bark surfaces before commencing to bore. Preferred sites were beneath edges of bruised or broken bark where the sapwood was exposed, and bark crevices, although a number of insects commenced boring on quite smooth surfaces. When boring occurred on smooth areas the body was held at right angles to the bark surface. The hind pair of legs was not in contact with the host material in the early stages of attack. As excavation proceeded the insect rotated its body through 360° about the mid-line.

Adult frass is not easily distinguished from larval frass except under a microscope. Although the particles are of similar size, the adult material is distinctly fibrous in appearance while the larval frass is made up of irregular shaped pellets cemented together by digestive secretions.

Beetles bored in at the rate of almost one body-length (2.5 mm) in 2½ hours.

Nest Patterns

The five types of primary tunnel system described by Fischer (1954) could not be distinguished in the material examined. In the excavation of more than 1,000 tunnel systems in 25 host species no branched primary tunnels were found. The parent gallery was always associated with a solitary female. The direction of the gallery was quite variable. In radiata pine the length might exceed 4 cm and penetrate radially, or curve at any point to follow a growth ring.

Successful nests produced adult frass for about 2 weeks, after which a mixture of adult and larval frass was evident. The proportion of larval frass increased until after about 6 weeks no further adult frass was produced. Some unsuccessful nests continued to produce adult frass for 12 to 14 weeks. Dissection of these nests invariably revealed a solitary dead female at the end of a long, unbranched tunnel.

The shape of the final nest system in radiata pine is extremely variable, the only common feature being an entrance tunnel leading to one or more chambers extending laterally in the spring wood bands. The greatest variability in nest form is seen in indigenous hardwood hosts. The shape and extent of the brood chamber was found to depend on the host species and the stage of nest development. In radiata pine the brood chambers were most often developed along the spring wood bands with a single radial connecting chamber (Fig. 3); while in *Knightia excelsa* the chambers almost

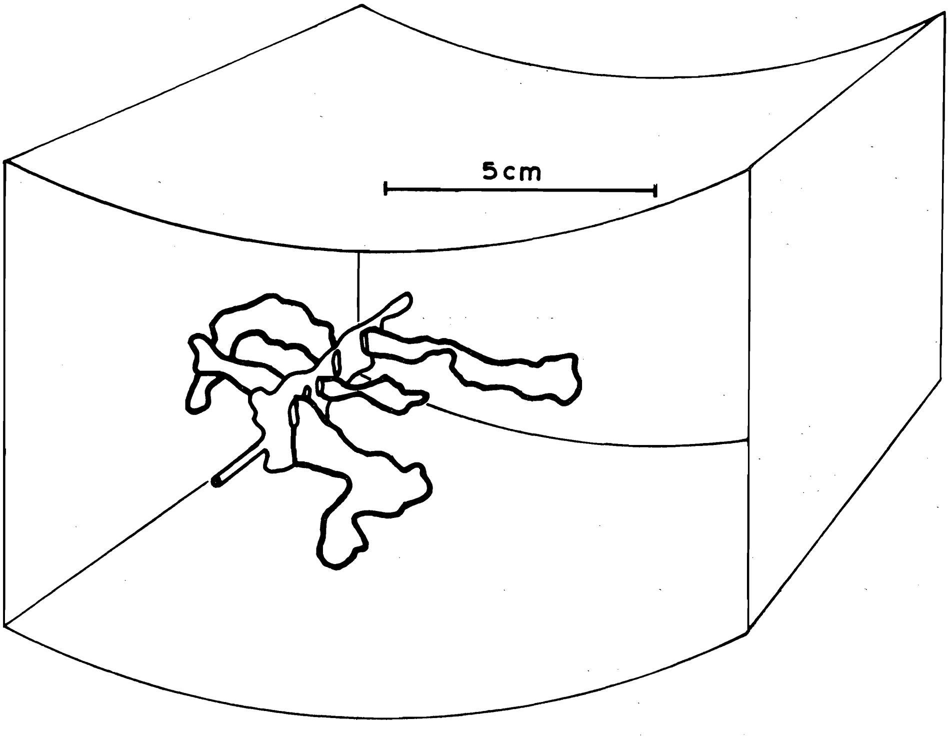

FIG. 3—Part of a large diameter radiata pine log showing a well developed nest of **Xyleborus saxeseni** as a transparency.

always penetrate radially. All stages from the simple parent tunnel to multi-chambered nests were present in both radiata pine and *K. excelsa.*

Interconnections between nests, even in heavily attacked material, were rare; only two instances were recorded. Some, in *Eucalyptus* spp., had multiple entrance tunnels. These apparently arose when abortive entrance tunnels became linked as larvae extended the parent gallery parallel with the grain of the wood.

Mating

Observations on the nature and time of insemination support Fischer's (1954) conclusion that mating always occurs between individuals of the same nest. The flightless males are smaller than the females (length 1.5 mm) and more convex when viewed laterally. They are invariably ejected from the parent nest by the emerging brood. All females examined from nests containing males harboured live sperm in their spermathece. There is no evidence to suggest the nest interconnections are of any significance in genetic mixing or that males move from one nest to another.

Brood Development

Oviposition occurs as described by Fischer (1954) but probably over a period of up to 12 rather than 2 weeks. The early instars extend the parent gallery to form an irregular brood chamber. As the larvae enter later instars, extension of the chamber ceases and the dark staining of the walls becomes more pronounced. The final gallery may contain up to 12 chambers leading from the expanded parent gallery into the spring wood bands (Fig. 3). The teneral adults do not appear to take part in nest extension as suggested by Fischer, but congregate in the central gallery near the entrance tunnel. Brood development is described in some detail by Fischer and the only important departure from his observations is in the overwintering stages. In New Zealand very few individuals overwinter in the egg or first instar stages, most being found as adults or third instars.

Head capsule measurements (Fig. 4) confirm the presence of three instars as

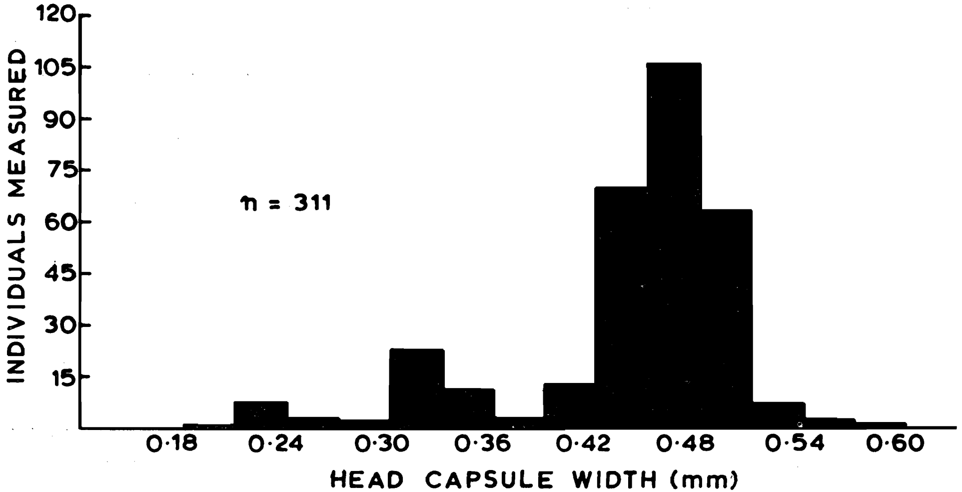

FIG. 4—Instars of **Xyleborus saxeseni** as expressed by larval head capsule measurements.

recorded by Fischer (1954) who determined this on the basis of mandible dimensions. The relative frequency of larvae in each size class shown in Fig. 4 should not be taken as an indication of their frequency in a natural population. The sample used was a composite one including larvae collected from both overwintering and summer nests.

The size of the brood was extremely variable, with certain hardwood hosts such as *K. excelsa* consistently harbouring large nests; one nest containing over 300 individuals at different stages of development was dissected. Brood sizes in coniferous trees were generally much smaller than these, a number of nests in radiata pine producing only two females.

The brood size was invariably proportional to the surface area of the final nest. Mortality of larvae and adults in the nest was very low.

The function of the female parent during brood development appears to be the removal of frass from the nest. She is almost invariably found in the short entrance tunnel, probably also preventing the entry of ants and other predators. "Death chambers" as described by Hopkins (1898) were not found in the material studied. In a few nests, sections of the gallery system were filled with frass but this was always associated with the loss of the parent female and hence a breakdown in nest sanitation.

The shortest periods from nest initiation to the presence of teneral adults were 8 weeks in radiata pine and 9 weeks in *K. excelsa.*

Nest Failure Rate

During 1968 and 1969 it was difficult to find sufficient entrance tunnels on which to place emergence cages and all tunnels found were used. Those tunnels which showed activity but failed to produce brood were recorded as failures. The failure rates of attempted overwintering nests caged in the spring of 1968, '69, '70 were respectively 40%, 44% and 20%. In all cases attempted nests from which no brood emerged had failed in the early stages, usually before any extension of the parent gallery had occurred. Early instar larval remains were found in only two failed nests.

Preliminary observations on logs suggest that the time elapsed since felling is most important in determining the success or failure of nests. Four-week-old host material produced an average of only 1.25 individuals for each of the 57 attacks recorded. Logs felled for 20 weeks produced an average of 7 individuals for each of the 17 attacks. Both observations were on logs from the same tree.

Most nests produced between 10 and 25 brood with a logarithmic decline in the number of nests producing larger broods. The relationship between brood size (y) and number of nests in each size class (x), is given by the regression equation $y = 46.5 - 1.3 \log x$. Broods were grouped in classes increasing by 10 individuals over the previous class. The equation is based on all productive field nests for the 3 years of the study, and clearly expresses a rapid decline in the number of nests in the larger size classes. Conversely, 70% of the broods were made up of 30 or fewer individuals. However, the range was great; 3.6% of trapped nests produced broods in excess of 100 individuals.

The ratio of males to females declined over the 3 years of the study from 1 : 4 in 1968-69 to 1 : 19 in 1969-70 to 1 : 64 in 1970-71. There was great variation of the sex ratio in individual broods. In some the sexes were present in equal numbers, while in others only one male to more than 100 females was found. Maleless nests formed

64% of productive nests in 1968-69, 53% in 1969-70, and 70% in 1970-71. The chance of a nest producing no males increased inversely with the size of the brood (Fig. 5). This relationship is linear up to broods of 45 individuals after which the number of large broods sampled was too small to indicate whether the trend continued or not.

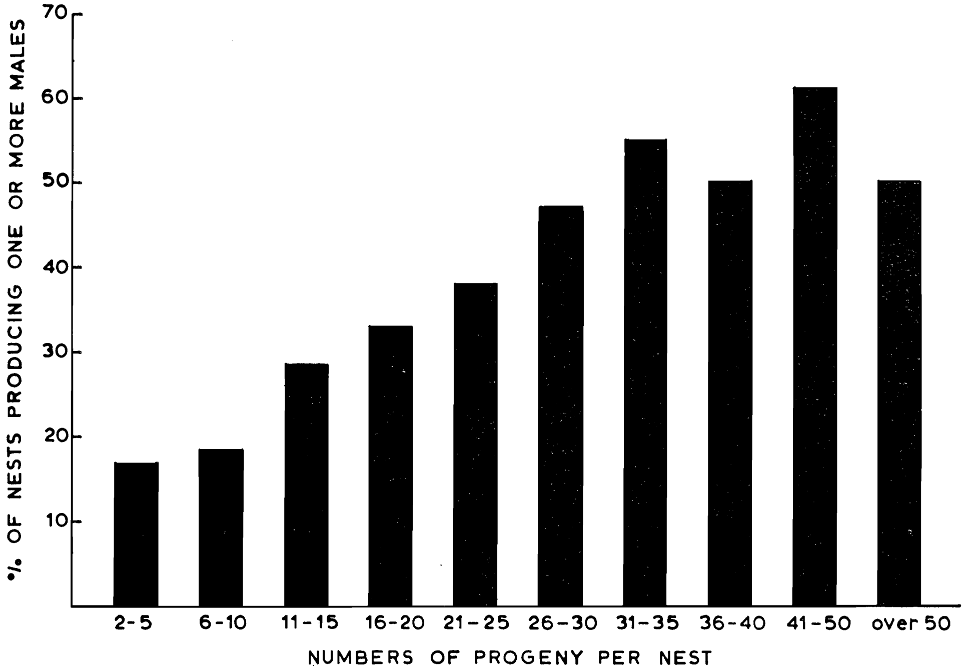

FIG. 5—The presence of males in broods of different sizes.

Emergence of Overwintering Brood

Field emergence was studied over three complete summers in an area that was being logged throughout this period. Only a small proportion of the logging waste became infested. Because the number of cages placed varied from year to year: 61 in 1968-69, 49 in 1969-70, and 240 in 1970-71, the emergence for each 7-day period shown in Fig. 6 is expressed as a percentage of the total emergence for the season.

The mean time for a brood to complete emergence was about 7 weeks (Table 1) but varied between 3 and 12 weeks depending on the size of the nest. The greater the number of brood in a nest the longer the period over which they emerged. Caged nests examined daily showed some emergence almost every day. The pattern of emergence from larger nests does not show any large initial emergence.

During cool weather mature adults did not emerge but accumulated within the nests. This behaviour led to erratic emergence over each summer with mass flights on the first warm day and greatly reduced flights on successive warm days. Few insects failed to emerge from developed nest systems (Table 1) and those that did not emerge had usually died in the inner regions of the nest. Some overwintering brood may remain in the nest for over 7 months.

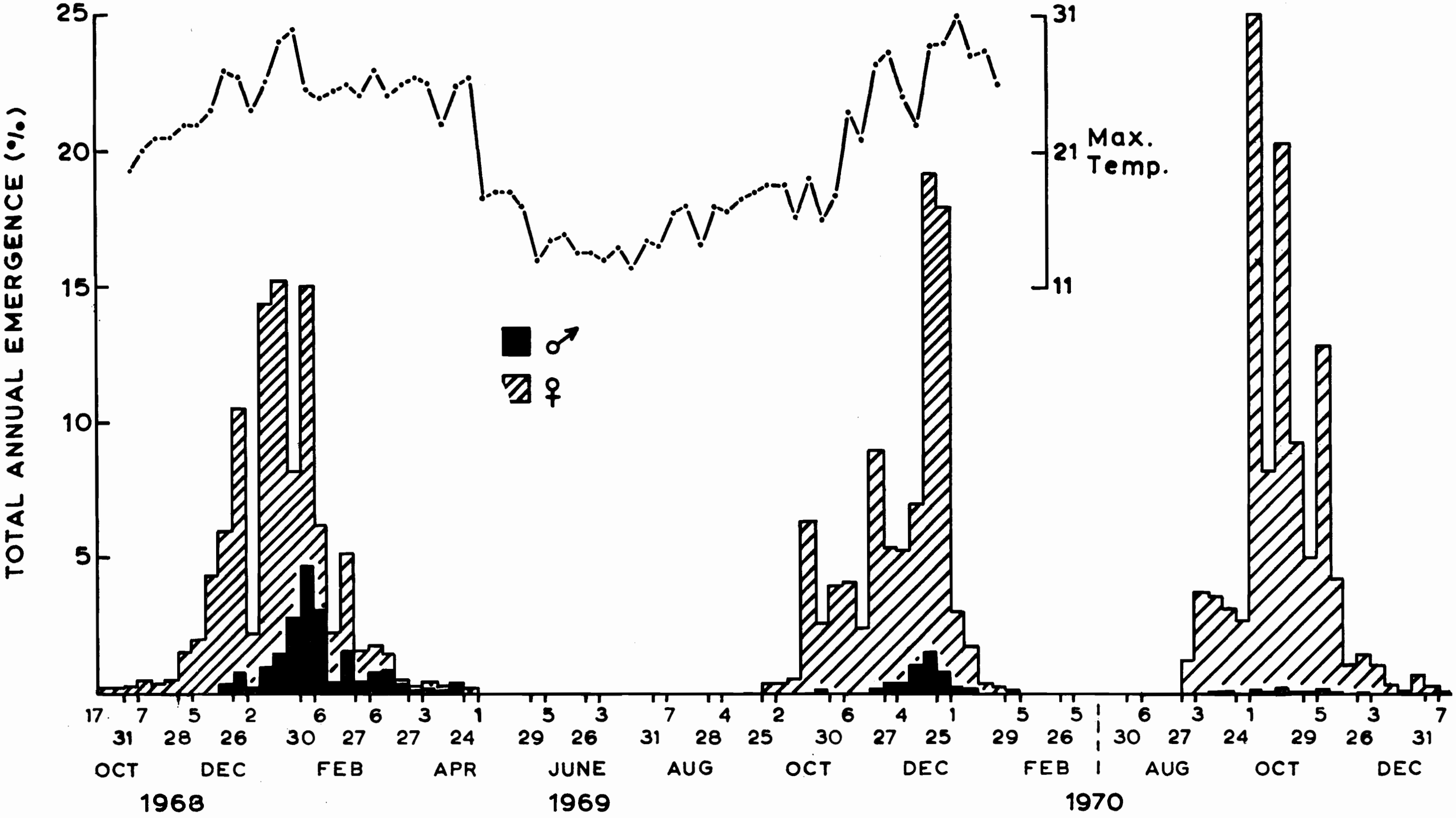

FIG. 6—**Xyleborus saxeseni** weekly emergence pattern of overwintering nests related to maximum temperature.

Two generations a year have been recorded in both radiata pine and *K. excelsa*, one beginning to emerge in early October and the second in mid-December.

TABLE 1—**Xyleborus saxeseni,** nest emergence period and emergence failure

Summer period	1968-69	1969-70	1970-71
No. of productive nests[1]	36	28	240
Mean No. weeks for nest emergence	7.6 SD = 5.27	6.65 SD = 3.66	7.28 SD = 3.22
No. nests with incomplete emergence	7 (16 females)	2 (5 females)	22 (41 females) (4 males)
(No. of adults shown in parentheses)			

[1] Nests from which more than one adult emerged

Flight Activity

The peak of flight activity always occurred between 3.00 p.m. and 5.30 p.m. provided the weather remained favourable, but cloud or showers interrupted this pattern.

Temperature clearly affected flight behaviour more than did light intensity. A temperature of 21°C by early afternoon was a prerequisite for flight activity, and a stable 26° to 29°C was required for maximum flight. Flight activity ceased when the temperature exceeded 32°C. However, irrespective of morning temperatures, no activity occurred before early afternoon. At temperatures between 16° and 21°C emergences occurred with considerable numbers of insects crawling up the screens, but they did not fly.

Marginal temperature for flight is shown in Fig. 7a with a large number of insects

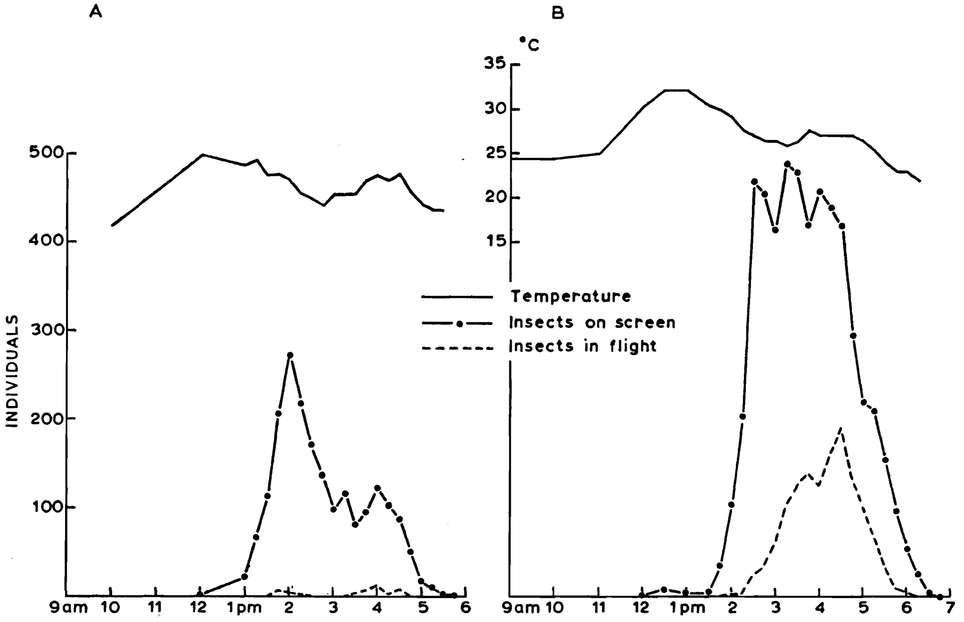

FIG. 7—The influence of temperature on flight and phototrophic behaviour of **Xyleborus saxeseni.** A—marginal temperature for flight. B—optimum temperature for flight.

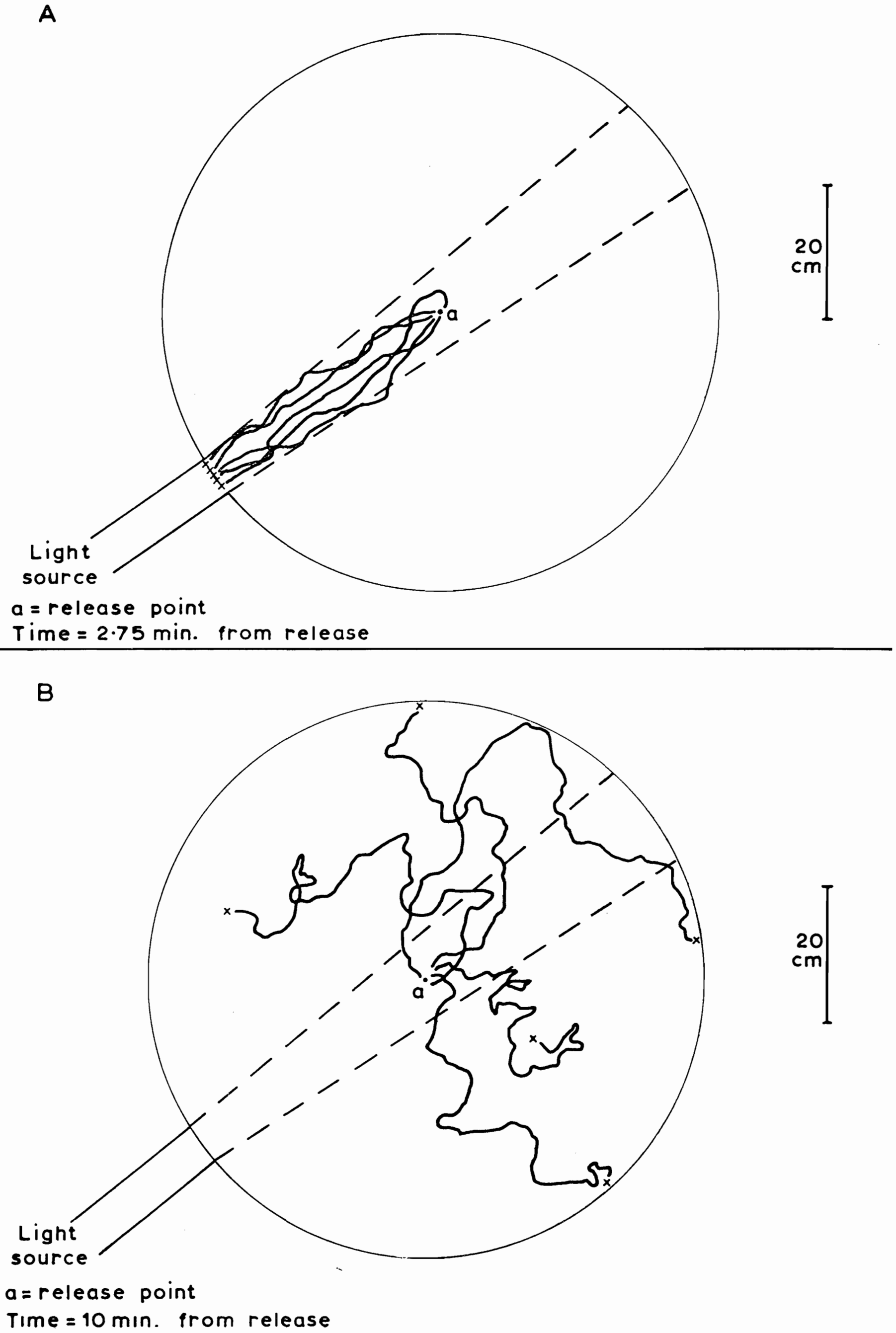

FIG. 8—The response of two groups of emerged beetles to an artificial light source. A—before showing tunnelling activity. B—after showing tunnelling activity.

emerging but only a brief period of flight involving few individuals.

The distribution of insects on screens and in flight showed them to be initially strongly photopositive. Only those areas exposed to high light intensity attracted insects, and the area to which Figs. 7a and 7b apply was subject to highest light intensity.

The adult insects flew for a maximum of 1 or 2 consecutive days after which a strongly photonegative response was evident, the insects gathering in any darkened areas of the insectary. Tests were made using a narrow light beam in an arena olfactometer (Wood and Bushing, 1963) to determine the insects' response to light under more controlled conditions (Fig. 8).

Insects caged overnight in glass containers after one day's flight activity still showed a photopositive response on the second day (Fig. 8a). Howeevr, when they were confined under a petri dish on damp blotting paper they attempted to bore into the paper at the dish edge and exhibited a strongly photonegative response on the second day (Fig. 8b). This reversal of response to light was found to have occurred in all adult female insects tested after they had commenced boring, irrespective of the host material or the time since emergence.

DISCUSSION

Host Selection

It would appear that this insect, while attacking a wide range of tree species, is very selective in the condition of material it attacks. The intensity of attack on some material suggests an attraction originating from some logs but not others. However, in contrast with scolytids which are known to respond to aggregating pheromones, *X. saxeseni* did not invade radiata pine in high densities. A maximum of 50 borings per 0.1 sq m was recorded compared with 200 in *K. excelsa.* Although this observation does not preclude the presence of pheromones, it suggests that some other factor, such as anaerobic decay, might cause certain material to become attractive. Heavy attack often found on standing trees which have been killed by fire would tend to support this theory. Trees killed by fire often retain a high stem moisture content creating favourable conditions for anaerobic decomposition soon after death.

Fischer (1954) records attack on living apple and apricot trees. In New Zealand, with one exception, all observed attack has been confined to dead material. A single instance of attack on living *K. excelsa*, situated near large numbers of emerging brood, was abortive.

Nest Patterns

Brood chambers of the complexity shown in Fig. 3 were commonly found in all species of host material. Fischer (1954) proposes an evolutionary progression for certain scolytids from complex to simple galleries. The multichambered galleries of *X. saxeseni* are not compatible with its position at the culmination of Fischer's series.

Brood Development

The symbiotic relationship between this insect and the ambrosia fungus on which it feeds was investigated by Fischer (1954). He found a species of *Penicillium* to be the fungus involved in Germany. No work has been published on the new ambrosia fungus in New Zealand.

The importance of the ambrosia fungus in nest success and its influence on brood development (Fischer, 1954), may explain the variation in failure rate and brood size of nests initiated at different intervals after the felling of host material. Sapwood nutrient levels at the time of felling will vary both within and between host species, as will also the breakdown of complex carbohydrates to simple sugars. The influence of the host material on the development rate of this insect will in the main be indirect, through its influence on the growth of the ambrosia fungus. A number of climatic and physiological factors will affect the establishment and growth of the symbiont and may well decide the success or failure of nests in marginal material.

Emergence

Under constant laboratory conditions emergence was continuous, so the intervals of up to a week when no emergences occurred in the field are most likely the result of local climatic variations, especially temperature. Even under the most favourable conditions emergence is spread over several weeks. Fischer (1954) suggests that limitations on food supply and space within the brood chamber favour the development of groups which mature and emerge together, allowing a further group of suppressed individuals to proceed. I consider it more likely that the female lays the eggs in batches over a more protracted period as the nest system develops. In the nests examined, the brood appeared to occupy about half of the available space. Larvae in different parts of the nest were often in different instars. Large nests which had been initiated and caged during the summer and in which the brood emerged in the same season, showed no regular grouping of emergences even though they might be expected to be those most subject to crowding.

Flight

The flight activity of X .*saxeseni* occurs only within a narrow range of temperature. Relative humidity appears to have little influence on this behaviour. Other environmental factors were not assessed but under field conditions air movement might be expected to be of some importance. Favourable conditions appear to be realised less frequently in Germany than in New Zealand.

The experimentally determined temperature threshold for flight is in accord with temperatures recorded at sawmills during periods of attack on sawn timber, and during emergences at Tauhara Forest.

The use of semi-transparent screen cloth on the insectary compartments in which observations were made, together with their siting on the edge of Whakarewarewa Forest, helped reduce the artificiality of the situation.

It appears that observations on flight in the insectary are applicable to the field in calm conditions.

Reproductive Potential and Population Levels

The lack of evidence of brood in the great majority of failed nests suggests that nest failure is related to failure to produce offspring rather than adverse conditions arising in the host material after brood is established. The lack of brood and presence of a solitary female in most failed nests would argue against parthenogenetic reproduction as suggested by Beal and Massey (1945) and Entwhistle (1964) for other *Xyleborus* spp. Almost two-thirds of all nests caged during the course of the study failed to produce males. If it is accepted that mating occurs only within the nest before emergence, many virgin females must be present in the population. It is probable that nests which show prolonged activity but fail to produce brood are those initiated by virgin females.

It is clear that in material suitable for the growth of the ambrosia fungus, virgin females will be a major factor contributing to nest failures. Maleless broods increased with the decline in brood size. This relationship suggests that maleless broods are the result of chance acting on a very unequal sex ratio rather than parthenogenetic reproduction. If parthenogenetic reproduction occurred the maximum number of maleless nests should be associated with the most commonly occurring brood size and not the smallest broods as was found.

The decline in the ratio of males to females over the 3 years of the study is more difficult to explain. The trend appears to be real and not linked with the sampling method. As far as could be determined the population studied was relatively small and isolated geographically, with no other detectable populations within 0.80 km. It is in this small, isolated nature of the population that a possible explanation for the change in sex ratio may be found.

Hamilton (1967) describes the phenomenon of gametic drive which involves the presence of a mutation on the X or Y chromosome giving a sperm carrying the mutated form a greater chance of effecting fertilisation than sperms carrying the normal form. He discusses its theoretical implications in closed populations. He cites instances of driving X chromosomes found in wild populations of *Drosophila* and discusses the spread of such mutations through populations.

The presence of this type of mutation on a single X chromosome in a population causes a change in the sex ratio very similar to that found in the study of X. *saxeseni.* Since the X chromosome is not exposed to selection in every generation the change in the sex ratio in favour of the female is gradual. Further, if the gametic drive is not complete (i.e., the gametes bearing the mutated X chromosome do not always win the race to fertilise the egg) some males might still be expected in any one brood.

No evidence was found to suggest that a female may produce more than one brood.

The duration of the life cycle of summer broods was determined in the insectary. With a second generation beginning to emerge in mid-December, three generations could occur in any year, two between October and January and a third overwintering. While those insects which emerge early from each successive brood may be involved in a three generation cycle it is doubtful if those last to emerge from an overwintering brood could give rise to two further generations in the summer.

The significance of slash in the build up of bark beetle and ambrosia beetle populations has been discussed by Beal and Massey (1945). Although X. *saxeseni* has so far failed to utilise all the breeding material available to it, the possibility of future epidemics cannot be dismissed.

SIGNIFICANCE OF THE STUDY TO CONTROL MEASURES

Careful attention to sawmill hygiene is the most effective way of controlling X. *saxeseni* in its irregular attacks on green sawn timber and logs destined for overseas markets. Populations of this insect in reject logs, logging debris and stumps in and around mills may only become evident when broods emerge in the early summer.

Careful analysis of daily temperature records for areas where X. *saxeseni* is prevalent should indicate periods of high risk when the limited use of contact insecticides may be necessary.

This study has shown many minor and several major differences in the biology of this insect from that recorded in Germany by Fischer (1954). I consider this to be primarily the result of two factors: geographic location, and scope of the study.

Clearly with aspects of an insect's biology that are so affected by weather, major differences in the development rate, flight periods, and population levels must be expected when two different climatic regions are compared. It is likely that variations in these aspects on a more limited scale exist even within the insect's New Zealand distribution.

ACKNOWLEDGMENTS

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APPENDIX 1

HOST LIST, XYLEBORUS SAXESENI, JANUARY 1972

Indigenous Softwoods:
- **Agathis australis** (Salisb.).
- **Dacrydium cupressinum** (Lamb.).
- **Podocarpus dacrydioides** (A. Rich.).
- **P. spicatus** (R. Br.).

Exotic Softwoods:
- **Cupressus macrocarpa** (Hartw.).
- **Larix decidua** (Mill).
- **Pinus echinata** (Mill).
- **P. nigra var. laricio** (Poir.).
- **P. patula** (Schlechtend and Cham.).
- **P. pinaster** (Ait.).
- **P. ponderosa** (Dougl.).
- **P. radiata** (D. Don).
- **Pseudotsuga menziesii** (Mirb.).
- **Sequoia sempervirens** (Lamb.).

Indigenous Hardwoods:
- **Aristotelia serrata** (J. R. et G. Forst.).
- **Beilschmiedia tarairi** (A. Cunn.).
- **B. tawa** (A. Cunn.).
- **Knightia excelsa** (R. Br.).
- **Leptospermum ericoides** (A. Rich.).
- **L. scoparium** (J. R. et G. Forst.).
- **Neopanax arboreum** (Murr.).
- **Weinmannia racemosa** (Linn.).

Exotic Hardwoods:
- **Acacia** sp.
- **Albizzia lophantha** (Benth.).
- **Eucalyptus botryoides** (Sm.).
- **E. globulus** (Labill.).
- **E. macarthuri** (Deane and Maiden).
- **E. saligna** (Sm.).
- **Lupinus arboreus** (Sims).
- **Prunus persica** (Stokes).
- **Quercus** sp.

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