

NEW ZEALAND
JOURNAL OF FORESTRY SCIENCE

New Zealand Forest Science,
Forest Research Institute, Rotorua

Editor: J. B. Lowry

VOLUME 7

JUNE 1977

NUMBER 1

ARHOPALUS FERUS (COLEOPTERA : CERAMBYCIDAE);
ITS BIOLOGY IN NEW ZEALAND

G. P. HOSKING and J. BAIN

Forest Research Institute, New Zealand Forest Service, Rotorua

(Received for publication 9th September 1976)

ABSTRACT

The development and biology of the introduced cerambycid *Arhopalus ferus* (Mulsant) is discussed. This insect was first discovered in North Auckland in 1963 and since that time has spread throughout the North Island and is also found at various locations in the extreme north of the South Island.

The duration of the life-cycle is either 1 or 2 years and is influenced mainly by the stage at which larvae destroy the subcortical zone and are forced to move into the sapwood, and by temperature. In heavily attacked material, where the larvae move into the sapwood early in their development, severe damage to infested logs can occur within 12 months.

This study suggests that *A. ferus* may cause severe economic loss during the salvage of windthrown or fire-killed trees.

INTRODUCTION

The biology of the cerambycid *Arhopalus ferus* (Mulsant) was first described by Smith (1905). This beetle is distributed throughout the Western Palearctic Region and possibly as far east as China, and is found as an introduced species in New Zealand. Smith's observations were made on insects inhabiting stumps of *Pinus sylvestris* L. in Great Britain. A more detailed study describing its life-history and habits, and the effects

of environmental factors on this insect was made by Wallace (1954) in Great Britain. However, his observations, which were confined to insects developing in partially decayed pine stumps, vary widely from present observations in New Zealand.

A paper by Kuhne (1975) deals with the biology of a closely related species, *Arhopalus rusticus* (L.). He includes an extensive bibliography and discusses most aspects of the insect's biology and development.

Hosking (1970) provides an introduction to *A. ferus* in New Zealand, outlines its establishment in this country and its biology as it was then known, and gives an assessment of its probable economic significance. Further information is contained in a Forest Research Institute (1973) newsletter.

Arhopalus ferus, believed to have been in New Zealand since the mid-1950s (Hosking, 1970), was first detected in 1963 in fire-killed radiata pine (*Pinus radiata* D. Don) at Mamaranui, 210 km north of Auckland. Figure 1 shows the spread of the insect since this time. It is possible that establishments due to the agencies of man, may have occurred at both Nelson and Hokitika. However, *A. ferus* has shown a rapid southward spread throughout the North Island from the Auckland region over the past 10 years. The insect may be expected to ultimately spread to all parts of the country wherever there is suitable host material.

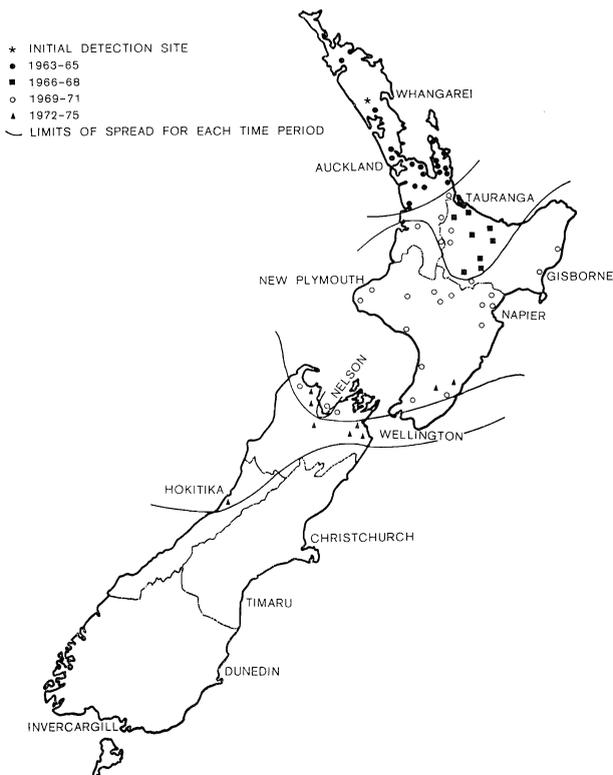


FIG. 1—The distribution of *Arhopalus ferus* in New Zealand, showing its spread up to 1975.

Research on *A. ferus* in New Zealand was begun after the summer of 1969-70 when the adults were found sheltering in packets of radiata pine and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) at mills and ports (Hosking, 1970). To comply with New Zealand's Forest Produce Import and Export Regulations 1966 such packets must be fumigated or subjected to other acceptable treatment before they can be cleared for export, even though no evidence was found in the field to suggest the insects damage or oviposit on sawn timber.

The problem of adults sheltering in packets of timber intended for export has since diminished, due mainly to greater attention to mill and port hygiene, especially to removal of burnt pines from surrounding areas. The beetles are attracted to burnt pines and freshly sawn timber, and locally high populations result.

Present interest in *A. ferus* concerns its possible impact after extensive windthrow or accidental fire in pine forests, and its role in the degrade of recoverable timber. This paper summarises the results of a 3-year research project on the biology of this insect in New Zealand.

MATERIALS AND METHODS

Field and Insectary Studies

Field studies were conducted in the eastern Taupo region over three consecutive summers between 1970 and 1973. The sites were on a Department of Lands and Survey land-development block being cleared for pastoral farming. Prior to clearing, the land supported *Leptospermum ericoides* A. Rich. (kanuka) and scattered groups of *Pinus pinaster* Ait. The clearing process involved a series of annual burns which provided material for continuing study.

Trees burnt in the summer and heavily attacked by *A. ferus* were selected during the winter months. A trap band was delineated between 1 and 2 m above the tree base. During the spring small, clear, tubular plastic traps (Fig. 2) were placed over the exit holes cut by the prepupal larvae. The traps were placed in position and adults collected at weekly intervals. A hygrothermograph was maintained in the area during the emergence periods.

Insectary studies were carried out at the Forest Research Institute (FRI) at Rotorua using infested material collected from the field sites. The trees were felled and trap zones transferred to the insectary after the first summer emergence, and further traps were used to monitor emergence during the second summer. Exit hole dimensions and densities were obtained from insectary material.

Fecundity Determination

Insectary-emerged beetles were accumulated over several days and held at 4°C. They were sexed and paired in plastic enclosures which were provided with scorched bark for oviposition sites. All eggs laid were counted. After they died the females were dissected and the number of mature unlaidd eggs was determined. The length of all females was recorded.

Flight Observations

Observations on flight activity were made throughout the study period and were supplemented by more detailed observations made in the insectaries during 1976.



FIG. 2—Tubular plastic traps used to collect emerging *A. ferus* adults.

RESULTS AND DISCUSSION

Host Selection

The presence of freshly felled host material acts as a strong attractant to the female beetles but appears to have little effect on males, which were found to remain in the emergence area. Although male response is still unclear, female beetles are strongly attracted to fire-scorched pines. Attraction occurs immediately after burning; large numbers of eggs have been recorded in the Taupo area within 5 days of burning. The nature of the attraction is unknown but almost certainly involves an olfactory response. Smoke generated by burning pine bark clearly excited the beetles but they failed to show any directional attraction. Volatiles emitted from the rapid breakdown of burnt tissues may be a factor in the concentration of attack. This breakdown, which presumably occurs more slowly in unburnt stumps and logs, may be responsible for the much more protracted infestation period for unburnt host material which may remain unattacked for several years.

Attack has been recorded only on *Pinus* species*. Stumps, logs, and dead trees are

* Host list of *Arhopalus ferus* in New Zealand as at February 1976: ***Pinus contorta*** Dougl., ***Pinus echinata*** Mill., ***Pinus muricata*** D. Don, ***Pinus nigra*** Arnold, ***Pinus patula*** Schlecht. et Cham., ***Pinus pinaster*** Ait., ***Pinus ponderosa*** Laws, ***Pinus radiata*** D. Don.

infested. On standing trees, infestations are generally confined to the main stem and to branches down to about 6 cm diameter. Attack is restricted to areas where the bark is firmly attached and, provided this is so, material several years old may be attacked or re-infested. Stumps have a particularly long period of susceptibility due to slow drying and strong bark retention. Infestations in stumps have been found to extend in the roots more than 45 cm below the damp sand surface on Matakana Island. Almost all suitable host material is utilised in areas where the insect is present.

Oviposition

The eggs, which measure 0.5 by 1.8 mm, are opaque, white, and cigar-shaped. They are laid in crevices and beneath bark flakes in groups of 10-50. In heavy infestations the groups are spaced evenly over the host surface about 15 cm apart. The spacing is generally much wider in unburnt host material. The incubation period varies from 9 to 12 days and oviposition extends throughout the life of the female adult, which varies from a few days to almost 3 weeks.

Fecundity

The mean potential fecundity of 71 females was found to be 217 (S.E. = 19.4) eggs, while the realised fecundity of the same insects was 159 (S.E. = 16.2). The considerable range in realised fecundity (12-1092) contrasts sharply with the findings of Kuhne (1975) for *A. rusticus* (mean 441 and range 207-841 for 14 insects), of which the most surprising aspect is the lack of females laying only a few eggs.

Almost all the variation in potential fecundity is accounted for by size variation in the beetle (Fig. 3). The curvilinear relationship between mean potential fecundity and adult length undoubtedly results from the relationship between adult length and abdominal volume, the latter having a direct influence on ovary size and hence egg production.

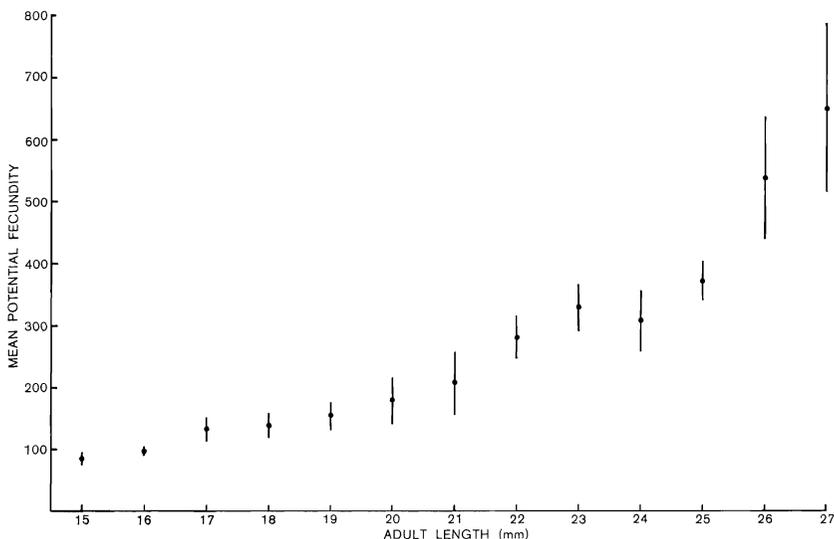


FIG. 3—Relationship between potential fecundity and length of adult female (lines show s.e. of mean).

The difference between potential and realised fecundity appears primarily to be a function of length of adult life; short-lived females generally laid fewer eggs than long-lived ones. However, under field conditions the presence of attractive host material, abundance of oviposition sites, and climatic factors all probably influence the number of eggs laid. The oviposition period ranged from 4 to 18 days (mean 9) under laboratory conditions and corresponded closely with the life span of the female after mating. All females dissected after oviposition contained only mature eggs.

Larval Development

The newly emerged larvae enter the bark directly beneath the egg and proceed to bore through to the subcortical zone. This zone is the preferred feeding site throughout larval development, probably because of its superior nutritional value. Cowling and Merrill (1966) showed a 10- to 40-fold greater nitrogen content in conifer cambium as compared to mature xylem. Nitrogen as an important constituent of extracellular and intracellular enzymes, nucleic acids, lipoprotein membranes, and chitin is of particular importance during periods of rapid growth.

Heavy infestations result in the rapid destruction of the entire subcortical zone and the larvae are forced to move into the bark or sapwood. The great majority choose the sapwood, again probably a nutrient response. Contrary to the findings of Wallace (1954) the larvae are able to establish themselves in sound wood and complete their development.

The change in larval distribution throughout the three zones (bark, phloem-cambium, and sapwood) in a heavily attacked tree (about 25 larvae/100 cm²) over an 18-month period is shown in Fig. 4. Six months after initial attack a sharp increase in the number of larvae entering the sapwood occurred, and by 13 months no larvae remained in either the bark or the subcortical region. Larvae may completely destroy the subcortical zone in less than 6 months from the time of initial attack. Early invasion of the sapwood by the developing larvae results in severe damage to the timber, making it virtually worthless for commercial purposes within 12 months (Fig. 5). H. S. Litchwark (pers. comm.) found deepest penetration of larvae occurred along bark-encased knots, especially during initial sapwood invasion.

Larval workings in the subcortical zone are irregular and appear to be influenced by the availability of unmined material. However, on entering the sapwood the larvae mine parallel with the grain and loosely pack the tunnels with a mixture of frass and woodshavings. Extensive larval workings lead to weakening of the wood, and severe wind-breakage in standing trees occurred in all study sites 12 to 14 months after initial attack. Breakage occurred below ground level, due to damage to the main roots, as well as at all points up the stem.

Observations on 15 burnt trees leaning at angles between 10° and 45° showed much heavier attack on the lower surface than on the upper. Desiccation was not considered to be a factor influencing this distribution as all the trees were located in dense groves with no evidence of drying in the subcortical zone of the upper surface. The two most noticeable differences between the upper and lower surfaces were the thinner bark and the greater staining of the sapwood on the lower surface. Wallace (1954) showed optimum development of *A. ferox* larvae to be in slightly decayed wood. The situation under discussion may reflect nutritional advantages of feeding zones invaded by bluestain fungi.

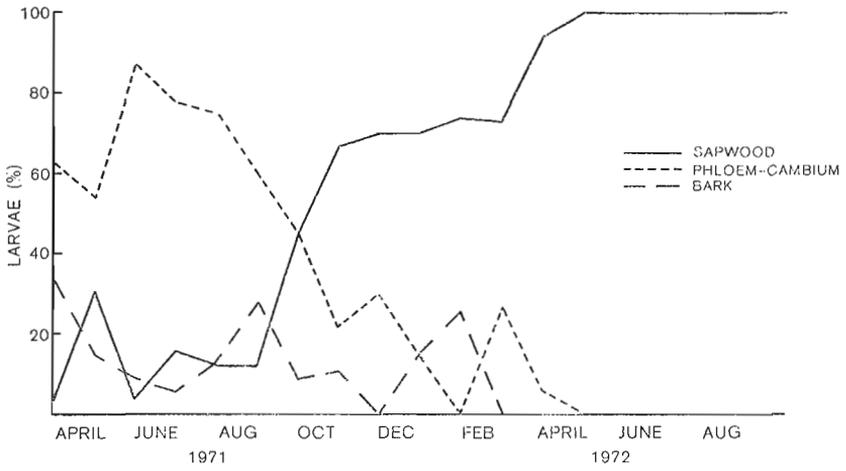


FIG. 4—Changing distribution of larvae in the sapwood, phloem-cambium, and bark zones over an 18-month period.



FIG. 5—Damage to log 12 months after first attack.

Larval survival in green sawn timber has not been fully investigated. Preliminary observations suggest that under suitable conditions of moisture and temperature a small proportion of larvae hatching from eggs laid on the surface become established. However, future development and survival are likely to be strongly influenced by moisture content changes within the host material. Kuhne (1975) and Eaton (1959) demonstrated a greater tolerance of low moisture content by older larvae of *A. rusticus* and *A. productus*, respectively, and there is ample evidence that the former species can survive in and emerge from sawn timber (Milligan, 1970; Bain, 1974).

Wallace (1954) found that larvae of all ages lost weight when reared in sound wood. This is contrary to findings in New Zealand where many larvae collected from the field are found developing in wood that shows no evidence of fungal invasion. Standing burnt trees, heavily attacked by *A. ferus*, often show little evidence of fungal invasion at the time adult insects are preparing to emerge. Development of *A. ferus* larvae in sound wood has also been recorded by Harris (1952) and similarly by Eaton (1959) for larvae of *A. productus*.

Prior to pupation, the larva cuts an exit hole through the bark to the outer surface. In the summer of 1971-72 exit holes were cut over a 20-week period, peaking in mid-January. The following summer they appeared over a 16-week period, peaking in mid-December. The duration and timing of the period over which exit holes are cut is strongly influenced by prevailing climatic conditions. On all study sites exit holes first appeared on the warm north side of the trees and 1-2 weeks later on the south side.

The exit hole is oval and averages 6.3 mm in long diameter. In a study of four logs, 307 exit holes appearing 1 year after attack had a mean long diameter of 5.9 mm (range 3.0 mm to 10 mm), while 363 exit holes cut 2 years after attack averaged 6.8 mm (range 3.0 mm to 16.5 mm). A statistically significant difference at the 1% level was found between 1- and 2-year dimensions for each log. This is to be expected because adults developing from 2-year larvae are generally larger than 1-year individuals from the same material. The mean diameters of exit holes given below (in mm; number of holes in parentheses) show a consistent size increase for each log.

Log	1	2	3	4	Mean
1-year	5.4 (71)	6.2 (70)	5.8 (87)	6.2 (79)	5.9
2-year	6.7 (91)	7.2 (92)	6.5 (77)	6.7 (88)	6.8

The number of larval instars could not be determined. The conventional method of head capsule measurements is difficult to apply to *A. ferus* because of the great size variation both within and between adult males and females. The number of larval instars is most likely to be clarified by direct observation of larvae reared in artificial media. Although what is probably the best medium presently available (Gardiner, 1970) was used, great difficulty was experienced in getting early instars to accept the diet. Our observations suggest Wallace's (1954) division of larvae into age classes on the basis of head capsule measurement may be subject to considerable error. In view of the small sample he used and the relative continuity of the histogram presented, we consider it unlikely that any statistical treatment could suggest meaningful growth classes, especially in view of our observations regarding the extremely variable growth rates among larvae developing in the same material.

Pupal Period

After cutting the exit hole, the larva retreats to a prepared pupal chamber and blocks the upper end with coarse wood shavings. The pupal chamber is parallel with the grain and is usually 1-2 cm below the sapwood surface, although some may be as deep as 4 cm. The larva, positioned head upwards in vertical material, becomes shortened and more robust during a prepupal stage which averages 7 days at 21°C. The pupal stage averages 13 days at the same temperature, and a pre-emergence resting period a further 12 days. These periods, determined in the laboratory, are probably longer under field conditions due to greater temperature variation. However, we do not know the length of the period between the cutting of the exit hole and the beginning of the prepupal stage.

Figure 6 shows the relationship between the appearance of exit holes and adult emergence in the summers of 1971-72 and 1972-73. The period between peak exit hole appearance and peak emergence was 10 weeks in 1971-72 compared with only 6 weeks in 1972-73. Field temperature records for these two periods show a mean maximum temperature of 23.3°C over the 10 weeks in 1971-72, and 29.4°C over the 6 weeks in 1972-73. Wallace (1954) demonstrated the strong influence of temperature on the time of pupation. Although the peaks of the exit-hole-to-emergence graph are closer together in the 1972-73 summer than in 1971-72 (Fig. 6), the mean period from exit hole to emergence for those insects trapped was the same in both summers, 53 days. This apparent contradiction is accounted for by the areas under the graphs in Fig. 6.

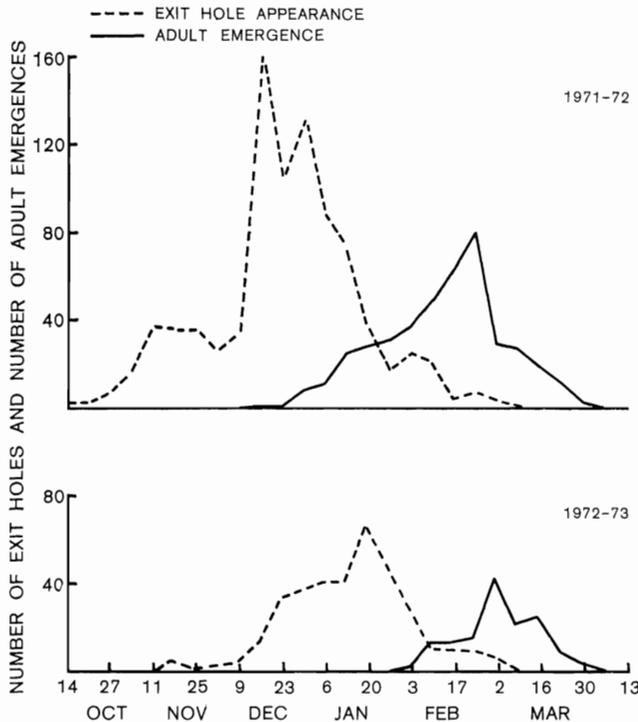


FIG. 6—Exit hole appearance (.....) and adult emergence (—) of *A. fesus* over the summers of 1971-72 and 1972-73 at Taupo.

In 1971-72 the greatest proportion of exit holes was cut after the peak while the greatest proportion of emergences occurred before the peak. In 1972-73 this situation was reversed, especially for exit holes. Thus the mean exit-hole-to-emergence period is almost exactly the same over both seasons, as is the frequency distribution of exit-hole-to-emergence periods shown in Fig. 7.

The pattern of exit-hole-to-emergence period is almost certainly intimately associated with temperature patterns both before and during the pupation period. The influence of single warm days is greatest on the peaks of exit hole cutting and emergence. However, the key point of temperature influence appears to be at the exit-hole-cutting stage (Fig. 8) which signals the onset of the pupation period and to a large extent determines the future emergence pattern. The critical mean maximum temperature appears to lie somewhere between 18° and 25°C. A 5.5°C rise in mean maximum weekly temperature between 9 and 16 December 1971 was accompanied by a sharp increase in exit hole appearance (Fig. 8). A similar response was recorded in 1972.

Emergence

Males emerge a few days before females (Fig. 9). Field observations suggest mating occurs on or near infested trees, soon after the females emerge. They then disperse in

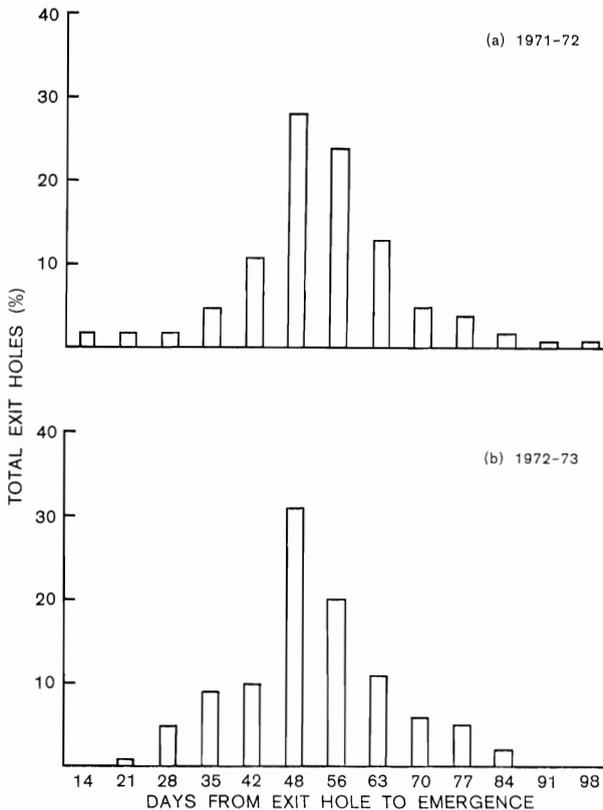


FIG. 7.—Frequency distribution of exit-hole-to-emergence period for the summers of (a) 1971-72 and (b) 1972-73 for *A. ferus* at Taupo.

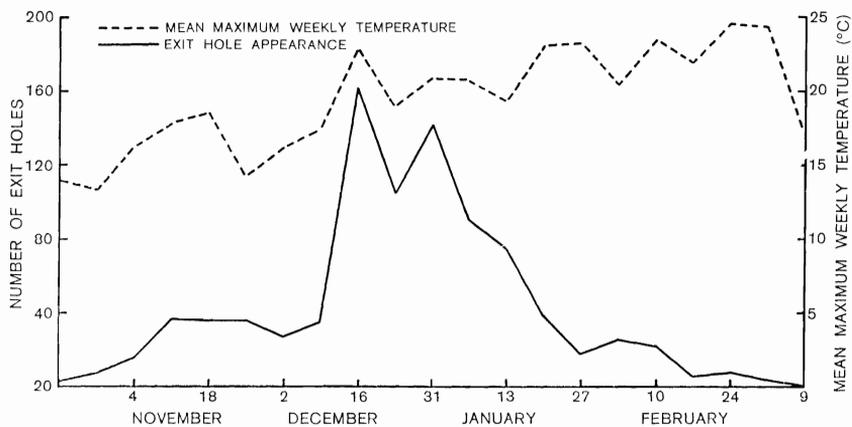


FIG. 8—Relationship between mean maximum weekly temperature (.....) and exit hole appearance (—) during 1971-72 for *A. fergus* at Taupo.

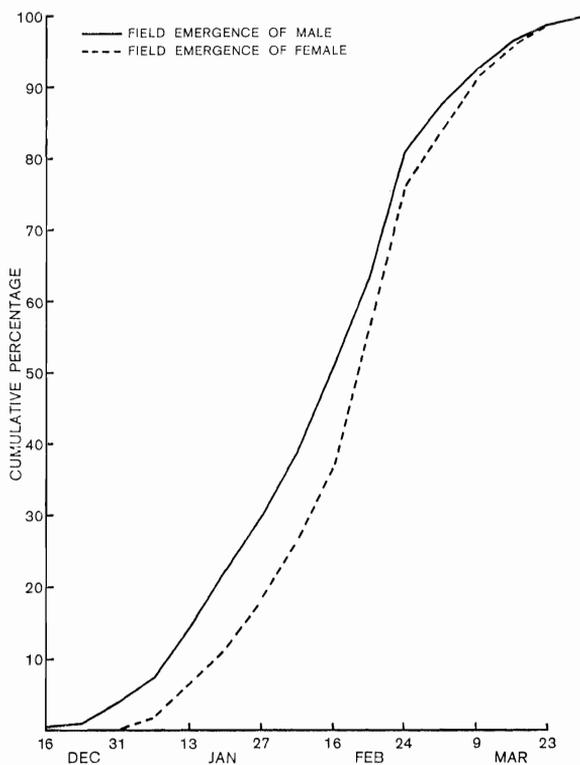


FIG. 9—Field emergence of male (—) and female (.....) *A. fergus* during the 1971-72 summer at Taupo.

search of suitable oviposition sites. In the field females are usually found in freshly logged and/or burnt areas and males in the old infestation areas, i.e., in the areas where they emerged. This observation argues strongly in favour of the above mating arrangement, which also appears logical in terms of mating efficiency.

Multiple emergences of up to three individuals from the same trapped exit hole occurred on a number of occasions. These were probably the result of intersection of tunnels leading from the pupal chambers to the bark surface.

Adult activity is greatest about 1 hour after dark on warm nights (about 15°C and above) and continues into the early morning hours. Activity initially involves walking on the surface of the bark, followed by flight. The insect is not strongly attracted to artificial light. During daylight it seeks shelter beneath bark, fallen branches, and other debris in contact with the ground. Sheltering behaviour is characterised by crawling into confined spaces so that the body is in firm contact with the upper and lower surfaces.

The male:female sex ratio of emerging adults was found to be 2:1 in both insectary and field studies. However, individual study sites yielded ratios of from 1:1 to 3:1.

Developmental Period

The developmental period varies between 1 and 2 years in New Zealand. Infested trees studied during the 1971-72 summer were protected from re-infestation and transferred to the FRI insectaries for second-year emergence. Of the total population, 64% emerged 1 year after infestation and 36% emerged after 2 years. Although a number of environmental factors undoubtedly affect the duration of the developmental period, intraspecific competition and temperature are believed to be the two most important factors. Greatest growth is consistently shown by larvae feeding in the subcortical zone. When larvae are forced out of this nutritionally superior zone at an early age, growth is probably slowed to the extent that pupation is not possible after only 1 year, especially under unfavourable temperature conditions.

Mortality

The generation mortality rate for *A. ferus* has not been determined. However, our work has given some indication of stages at which mortality is occurring.

Females lay eggs only after they have been mated, and laboratory tests have shown that virtually all eggs laid hatch. Competition for food and space in the early larval instars probably accounts for the greatest mortality.

Previous reports of high mortality in the pupal stage (New Zealand Forest Service, 1973; 1974) are now viewed with suspicion. Established mortality at this stage was 14% in 1971-72 and 10% in 1972-73. For each year 28% and 20%, respectively, of the traps placed over exit holes failed to yield adults but examination of the pupal chambers failed to reveal any evidence of adult or pupal remains and showed the frass plug was absent in most cases. It is possible that adults emerged around the edge of the traps in numbers larger than expected or cut new exit holes on finding the hole trapped. H. S. Litchwark (pers. comm.) estimated 25% mortality in the pupal stage.

Elaterid larvae and ants have occasionally been found in association with dead *A. ferus* adults and larvae but are not believed to play a significant role in mortality.

CONCLUSION

The present study has shown *A. fesus* to be a potential threat to New Zealand's forest industry, especially after windthrow or fire. The high fecundity of this insect allows its populations to build up rapidly in suitable host material, and the lack of significant mortality factors other than intraspecific competition and unfavourable temperatures is likely to ensure that these population levels remain as long as there is suitable host material available.

The insect's biological potential is enhanced by its utilisation of a wide variety of pines and its adaptability in selection of host material. *Arhopalus fesus* is unlikely to cause problems in areas of normal forest activity and is in fact beneficial, assisting in the breakdown of logging wastes such as slash and stumps. However, our work suggests that serious damage to recoverable timber may occur within 1 year following fire or other environmental damage such as windthrow.

ACKNOWLEDGMENTS

We would like to express our appreciation to Richard Marquand, Lindsay Wells, and John Hutcheson for assistance with both field and laboratory studies.

REFERENCES

- BAIN, J. 1974: Overseas wood- and bark-boring insects intercepted at New Zealand ports. **N.Z. For. Serv., For. Res. Inst., Tech. Paper No. 61.** 24pp.
- COWLING, E. B. and MERRILL, W. 1966: Nitrogen in wood and its role in wood deterioration. **Canad. J. Bot.** **44**: 1539-54.
- EATON, C. B. 1959: Observations on the survival of *Arhopalus productus* (Le Conte) larvae in Douglas fir lumber. **Pan Pacific Ent.** **35(2)**: 114-6.
- FOREST RESEARCH INSTITUTE, 1973: A problem wood-borer. **What's New in Forest Research, No. 6.**
- GARDINER, L. M. 1970: Rearing wood-boring beetles (Cerambycidae) on artificial diet. **Canad. Ent.** **102**: 113-7.
- HARRIS, E. C. 1952: A note on *Criocephalus fesus* Muls. (Col. Cerambycidae, Aseminae) in French maritime pine, *Pinus pinaster* Aiton. **Ent. mon. Mag.** **88**: 145-7.
- HOSKING, G. P. 1970: *Arhopalus fesus*, an introduced cerambycid borer. **N.Z. For. Serv., For. Res. Inst., Res. Leaflet No. 29.** 4pp.
- KUHNE, Von H. 1975: Lebensweise und Umweltabhängigkeit des Grubenhalsbocks (*Criocephalus rusticus* (L.), Cerambycidae, Col.). **Mater. u. Organ.** **10(3)**: 161-201.
- MILLIGAN, R. H. 1970: Overseas wood- and bark-boring insects intercepted at New Zealand ports. **N.Z. For. Serv., For. Res. Inst., Tech. Paper No. 57.** 80pp.
- NEW ZEALAND FOREST SERVICE, 1973: **For. Res. Inst., Rep. 1972.**
- NEW ZEALAND FOREST SERVICE, 1974: **For. Res. Inst., Rep. 1973.**
- SMITH, F. G. 1905: The habits of *Asemum striatum* and *Criocephalus fesus*. **Trans. ent. Soc. Lond.** **1905**: 165-76.
- WALLACE, H. R. 1954: Notes on the biology of *Arhopalus fesus* Mulsant (Coleoptera: Cerambycidae). **Proc. R. ent. Soc. Lond. (A)** **29**: 99-113.