

# ARHOPALUS FERUS, THE INFLUENCE OF SUBCORTICAL TEMPERATURE ON DEVELOPMENT AND GROWTH

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(Received for publication 8 December 1976)

## ABSTRACT

A strong relationship exists between solar radiation, resulting subcortical temperature of the tree host, and rate of development and growth of the introduced cerambycid *Arhopalus ferus* (Mulsant). The larval, prepupal, and pupal stages are shorter in duration at elevated temperatures. Adult emergence patterns appears to be determined by the time of larval entry into the prepupal stage which is in turn determined by prevailing temperatures.

The degree of exposure to solar radiation in the field may play a role in determining whether the insect's life cycle extends over 1 or 2 years.

## INTRODUCTION

A strong relationship has been shown to exist between temperature and rate of development and growth for a number of insect species (Andrewartha and Birch, 1954; Chapman, 1971; Howe, 1967; Powell, 1967; Richards, 1957). The population dynamics of such insects may be affected by temperature variations occurring in their natural environments. This influence can be of special significance in the ecology of those species whose generation time is either 1 or 2 years.

The biology of the introduced cerambycid *Arhopalus ferus* (Mulsant) (Coleoptera: Cerambycidae) has been discussed by Hosking (1970), and Hosking and Bain (1977). The observations reported here, made in the course of the latter study, concern the effect of temperature on the larval, prepupal, and pupal periods of the insect's development.

Wallace (1954) made a number of laboratory observations on *A. ferus* relating larval growth to temperature, while Kuhne (1975) provided additional data along similar lines for the closely related species *A. rusticus* (L.). Both workers demonstrated the strong influence of temperature on development rate for their respective species but neither related their results to the field environment.

## MATERIALS AND METHODS

Field studies were carried out from 1971 to 1973 at a site 7 km east of Taupo. The study area, approximately 100 ha, was on a Department of Lands and Survey development block which was burnt-over on 23 February 1972 at the peak of the *A. ferus* emergence period. The area contained scattered groves of *Pinus pinaster* Ait.

which were completely scorched, providing ideal host material for *A. ferus* emerging from dead trees on surrounding blocks.

An isolated grove covering approximately 0.5 ha and containing about 800 trees was selected in April 1972 and two north-south transects were established (Fig. 1). Only well-formed, non-leaning trees were used for sampling. Sampling, carried out in July 1972, consisted of the removal of  $15 \times 15$  cm of bark from both north and south faces of each tree 1.2 m above the ground. All larvae in the quadrat were collected, sapwood entrance holes were counted, and the percentage of phloem-cambium zone destroyed was estimated. Larval head-capsule widths and body lengths were determined at the Forest Research Institute (FRI).

During the summers of 1971-72 and 1972-73 many trees were monitored for the appearance of exit holes. Small clear plastic tubular traps (Hosking and Bain, 1977) were placed over the holes, and emerged adults were collected at weekly intervals and sexed.

Pupation studies were carried out at the FRI. Final instar larvae which had ceased feeding were placed in individual glass tubes  $6 \text{ cm} \times 2.5 \text{ cm}$ , containing damp celloscane, and allowed to complete their development at temperatures of 13.0, 18.5, 21.0 and 26.5°C. Twenty-five larvae were reared at each temperature and inspected daily to determine the duration of the prepupal and pupal periods.

## RESULTS AND DISCUSSION

### *Larval Development*

The product of head-capsule width and body length was used to characterise larval size for all samples. This index, combining both growth and development, provides a conservative basis for the comparison of individual larval samples.

The two sample transects were combined on the basis of tree distance from the northern boundary of the grove and the data are presented in Tables 1 and 2. A negative correlation exists between the larval index of both north- and south-facing samples and their distance from the northern edge of the grove (positional effect). However, the negative correlation is much stronger for the north-facing samples (Table 1). The negative correlation is also strongest in the northern half of the transect and becomes weaker as the southern limit is approached.

A paired sample t-test shows a significant difference ( $P < 0.005$ ) in the larval index of north- and south-facing samples over the length of the transect (directional effect).

No correlation is found between larval density and percentage of larvae in the sapwood for north-facing samples, while a strong correlation is found for south-facing samples (Table 2). The correlation between percentage of phloem-cambium destroyed and percentage of larvae in the sapwood is weaker for north-facing than south-facing samples.

It appears reasonable to assume the three major influences likely to affect the rate of development of a subcortical insect such as *A. ferus* are temperature, moisture and nutrition. In the environment under discussion, moisture is unlikely to be a limiting factor since all sample trees were infested immediately after being killed by fire. The sapwood moisture content of such material generally exceeds 130% 12 months after burning (G. Hosking, unpublished report), a level which is unlikely to be limiting to larval growth (Kuhne, 1975).

FIGURE 2

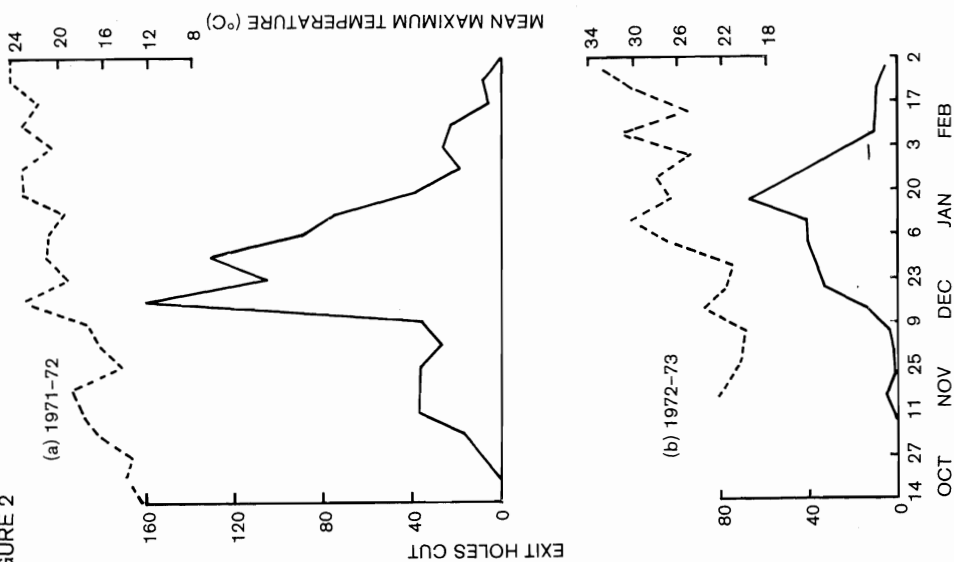


FIGURE 1

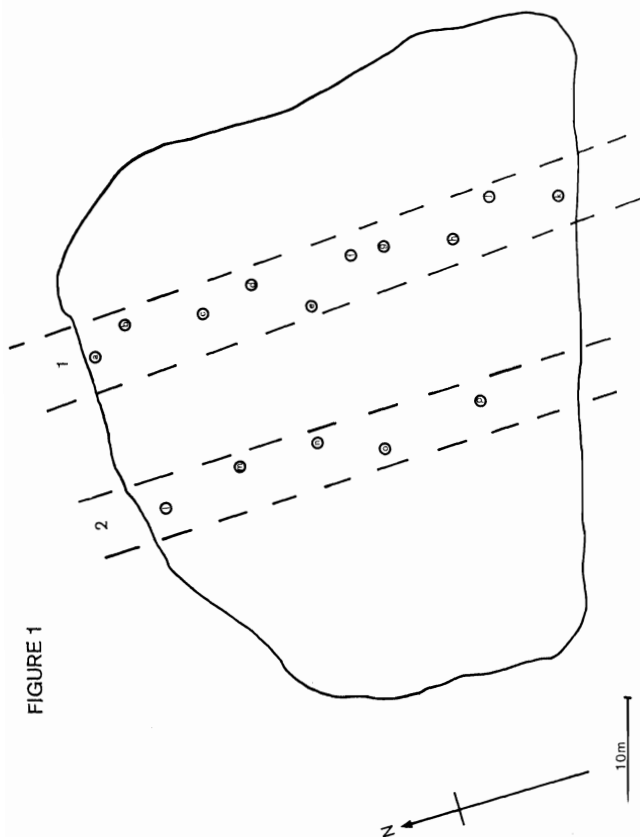


FIG. 1 (above).—*Arhopalus ferus* development transects through a burnt *Pinus pinaster* grove showing location of sample trees.

FIG. 2 (right).—Relationship between exit hole appearance (—) and temperature (- - -) for 1971-72 and 1972-73 summer periods.

TABLE 1—Relationship between tree distance from the north edge of the sample area, and mean larval index for north- and south-facing samples

Tree Position (m from north edge)	North	Mean Larval Index		
		S.E.	South	S.E.
1	44.6	6.1	18.4	1.2
2	39.6	5.4	12.8	1.2
4	29.1	1.9	12.1	1.0
10	27.9	3.5	13.7	1.2
12	19.5	3.3	11.7	1.1
17	11.0	1.2	5.5	0.6
18	32.6	3.9	14.2	2.4
22	19.4	0.9	7.7	0.7
23	14.8	1.2	8.6	1.1
27	16.5	1.0	14.5	1.5
30	21.4	1.1	9.4	1.4
34	11.7	0.9	4.2	0.5
37	15.9	0.8	—	—
42	8.8	1.0	—	—
48	15.6	0.9	10.3	1.8

$r = -0.77$                        $r = -0.50$   
(P < 0.005)                      (P < 0.05)

TABLE 2—Relationship between larval density, percentage phloem-cambium utilised, larval migration into the sapwood, and distance from north edge of sample area

Tree Position (m from north edge)	Larvae/1000 cm <sup>2</sup>		Phloem utilised (%)		Larvae in wood (%)	
	North-facing	South-facing	North-facing	South-facing	North-facing	South-facing
1	36	84	100	100	58	30
2	21	39	100	40	52	13
4	45	43	75	25	31	5
10	46	23	75	40	48	9
12	18	44	50	30	44	0
17	47	44	50	25	15	2
18	41	17	75	15	49	0
22	110	44	100	25	34	2
23	25	24	40	30	0	0
27	41	26	50	40	7	0
30	58	15	90	10	7	0
34	33	14	50	5	3	0
37	104	0	100	0	19	0
42	22	0	15	0	0	0
48	50	9	50	5	0	0

$r = 0.03$       0.79      0.62      0.9  
P not sig.      < 0.005      < 0.01      < 0.005

The importance of nutrition in the development of *A. ferus* has been discussed by Hosking and Bain (1977) especially with regard to feeding in the 1- to 3-mm deep phloem-cambium zone as opposed to the sapwood. The lower nutritional value of the sapwood was of greater significance to the larvae from north-facing samples than those from south-facing samples at the time the study was made. Any influence on larval growth will have resulted in a conservative interpretation of the data. Over the whole period of larval growth, if density of larvae is comparable on both north and south faces, nutrition should have little influence on rate of development.

Subcortical temperature variations resulting from different degrees of exposure to solar radiation are suggested as the major factor accounting for differences, both positional and directional, evident in Tables 1 and 2. During the autumn and winter months when most larval growth occurs, the sun remains in an arc well to the north throughout the day, creating sharp thermal gradients from the north face inwards. These gradients would be greatest along the north edges of isolated groves and progressively decrease as southern boundaries are approached.

The strong negative correlation between the distance of the sample tree from the northern boundary and the larval index for north-facing samples (Table 1) supports this hypothesis. The influence of solar radiation on the south-facing samples, even though they are close to the northern boundary, is greatly reduced resulting in a much weaker correlation between tree position and larval index.

At the time of sampling, larval entry into the sapwood was still a reflection of larval density in south-facing samples (Table 2). However, the data for north-facing samples show no such correlation. Larval mortality associated with early instars (Hosking and Bain, 1977) had probably already occurred in the more advanced north-facing samples, especially at the northern end of the transect, eliminating any correlation between sapwood entry and larval density.

Entry into the sapwood is clearly a nutritional response associated with depletion of the phloem-cambium zone. The different rate of depletion of this zone in north- and south-facing samples, as reflected by the percentage of larvae entering the sapwood, offers support to the contention that solar radiation may strongly influence development rate.

The evidence suggests that the occurrence of 1- and 2-year life cycles in this species (Hosking and Bain, 1977) may, under certain environmental conditions, be strongly influenced by subcortical temperature ranges and their effect on the rate of larval development. Larvae on the south side of trees may fail to reach the prepupal stage before the end of the summer and be forced to overwinter as final instar larvae.

#### *Prepupal Period*

The appearance of exit holes cut by the final instar larvae is an accurate indication of the onset of the prepupal phase (Hosking and Bain, 1977). The relationship between exit hole appearance and the mean maximum daily temperature for both the 1971-72 and 1972-73 field seasons is shown in Fig. 2. The temperature and exit hole graphs are clearly related over much of their length, diverging only late in the season when temperatures continue to rise while most of the insect population have already passed the exit hole stage.

No correlation was found between adult emergence pattern and temperatures

recorded in the study area during the summers of 1971-72 and 1972-73. The time from appearance of the first exit hole to adult emergence was fairly constant at between 50 and 60 days, with a mean of 53, for both years. This would suggest that emergence patterns are determined by the timing of larval entry into the prepupal phase, which shows a strong relationship to temperature (Fig. 2), rather than by temperatures prevailing at the end of the pupal period. By the time pupation is complete, daily temperatures probably already exceed those necessary to stimulate adult emergence.

Observations on burnt pines at Mt Maunganui in 1971 offer further support to the contention that temperature is important in the timing of the prepupal stage. An exit hole count made in the early spring on 10 trees exposed to direct solar radiation showed an average of 89.9 (S.E. = 10.3) exit holes per 3000 cm<sup>2</sup> on the north side and 34.5 (S.E. = 4.8) for the same area on the south side. By late December both sides supported about equal numbers.

Laboratory studies indicate a linear relationship between duration of the prepupal period and temperature over a range from 13.0 to 26.5°C (Fig. 3). Under field conditions with sharp diurnal variations in temperature, the effect on the prepupal stage is unlikely to be so dramatic.

*Pupal Period*

A strong linear relationship is evident between duration of the pupal period and temperature over the range 13.0 to 26.5°C (Fig. 3). The pupal period is reduced by more than 50% with a change from 13.0 to 26.5°C.

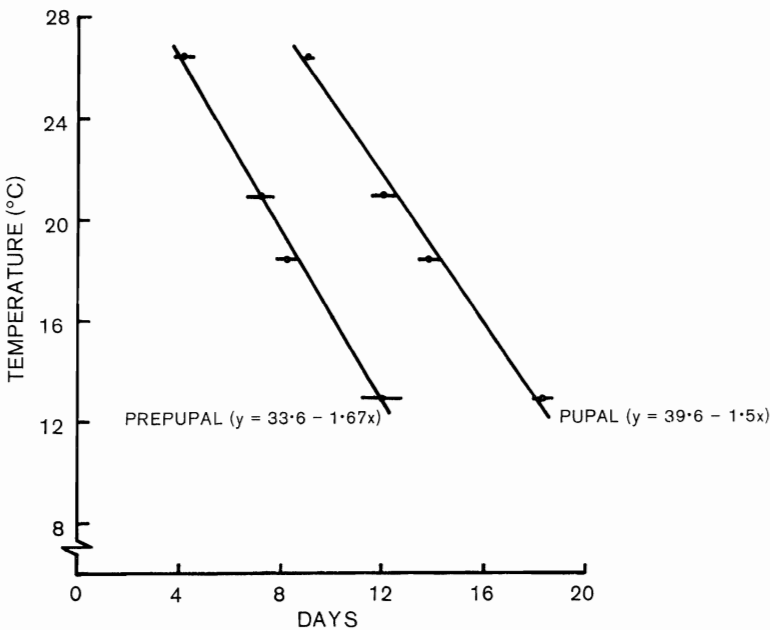


FIG. 3—Relationship between the duration of the prepupal and pupal periods and temperature (lines = S.E.).

The linear relationship suggests temperatures between 13.0 and 26.5°C are well within the insect's lower and upper thresholds. The curvilinear relationship usually associated with the approach of these thresholds (Chapman, 1971) is lacking from the data.

### CONCLUSIONS

The data presented in this paper support the hypothesis that subcortical temperatures, resulting from host interception of solar radiation, are a major environmental factor in the rate of growth and development of *A. ferus* under field conditions. Elevated subcortical temperatures on the sides of infested trees exposed to direct radiation result in a significant increase in larval growth rates.

In fire-killed pines, either open-grown or along the northern edge of plantation blocks, subcortical temperature may be of greater importance than intra-specific competition in determining a 1- or 2-year life cycle for this insect.

It is probable the emergence time of *A. ferus* adults is largely determined by temperatures affecting the initiation of the prepupal stage.

The observations discussed in this paper, made in the course of a general study of the biology of *A. ferus*, suggest a number of lines of investigation which should clarify some of the speculative details. These include: monitoring of subcortical temperatures in burnt and unburnt trees; rearing of larvae under varying temperatures on artificial media; replicated pupation studies under varying temperatures; and detailed examination of 1- and 2-year development and its relationship to temperature.

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