LIFE HISTORY STUDIES OF THE OLD HOUSE BORER, *Hylotrupes bajulus* (L.) (COLEOPTERA: CERAMBYCIDAE)

by

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By many words wit is exhausted;
it is better to retain what is in the heart.

Loa Tzu

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INTRODUCTION

The old house borer (OHB), Hylotrupes bajulus (L.), is an important structural insect pest in eastern and southeastern United States. Larvae of this cerambycid beetle tunnel in the sapwood portion of seasoned softwoods (pine, spruce, fir) used in the construction of houses and buildings. The larvae can remain alive and feed for several years within the wood. This often results in loss of structural integrity, cosmetic damage to the wood surface, psychological damage resulting from the clamorous rasping-ticking sounds of feeding larvae and financial losses incurred in the treatment and replacement of infested wood. Contrary to the insect's common name, a survey of professional pest control operators and homeowners in Virginia showed that OHB infestations occurred most frequently in houses 2-7 years old (Cannon and Robinson 1982a).

The OHB is native to the Atlas Mountains of Northern Africa where it is found surviving under natural conditions in pine slash and stumps. This insect has been introduced, through infested wood, into all major continents (Becker 1979). OHB biology and pest status in England were reviewed by Hickin (1975), Parkin (1934) and White (1959); in Germany by Cymorek (1968) and Becker (1942a 1942b); in Denmark and Norway by Rasmussen (1961), and Knudsen (1966); in South Africa by Durr (1954 1956), and Tooke and Scott (1944); and in Australia by Howick (1972). In the above countries, with the exception of Australia, the OHB is considered an established pest, capable of surviving under natural

conditions in unprocessed lumber, as well as seasoned structural timber. According to Howick (1972) the OHB has been successfully eradicated from the continent of Australia.

The OHB was probably introduced into the U.S. about 200 years ago in wood from England or Europe. The mild, humid climate along the east coast provided favorable environmental conditions for its establishment and spread. It now occurs in the states along the entire Atlantic seaboard and Gulf Coast with the majority of infestations reported from Mid-Atlantic states (Moore 1978). St. George et al. (1957) ranked the OHB second to subterranean termites in its occurrence and damage to buildings and wooden structures in eastern U.S. According to Moore (1978) and Snyder (1955), the OHB does not live outside of man-made structures in the U.S. However, Cannon and Robinson (1982a) found OHB larvae surviving outside of conventional structures in unprocessed lumber, indicating that the OHB may be extending its habitat in eastern U.S.

Presently, all published reports of OHB biology and life history in the U.S. are based on data derived from South Africa, Europe and on field observations (St. George et al. 1957, McIntyre and St. George 1961, Moore 1978). Cannon (1979) showed, through laboratory and field observations, that the life history and biology of the OHB under N.A. environmental conditions differ considerably from both South African and European populations.

Deficiencies in basic biological data and inconsistencies in published reports justify further research on this structural insect pest. Several independent but closely related experiments were

designed to investigate various aspects of OHB behavior and life history. The objectives of this research are outlined as follows:

1) To define the North American biotype of the OHB and compare it, under controlled laboratory conditions, to its European counterpart;

2) To investigate means of reducing the developmental period of larvae through the development of an artificial diet;

3) To study the mating behavior and egg production of the OHB under various mating regimes;

4) To examine the wood utilization and metabolic efficiencies of OHB larvae under several temperature regimes.

Section II

LITERATURE REVIEW

Life History

The family Cerambycidae constitutes one of the largest groups of wood-boring insects. Most of the 1,200 described species are wood feeders and generally inhabit forest environments (Linsley 1961, Hickin 1975). However, several species attack forest and shade trees, orchards, shrubs and finished wood products (Nielsen 1981). The bionomics of the more injurious species have been reviewed by Hickin (1975), Linsley (1959 1961), Serment (1976), Durr (1954 1956), Becker (1949), and Michelson (1966). Included in this group of injurious species is the old house borer, Hylotrupes bajulus (L.). The old house borer (OHB) is a member of the subfamily cerambycinae and tribe callidini (Serville 1834).

The OHB is the most important pest of seasoned softwood (pine, spruce, fir, hemlock) in Europe, England, and South Africa (Becker 1944 1949 1963, White 1962, Durr 1954 1956). In the United States St. George et al. (1957) ranked the OHB next to termites in importance as a pest of buildings in Eastern U.S. Simeone and MacAndrews (1955) reported that the attacks and damage caused by the OHB in Eastern U.S. presented some of the most formidable control problems.

The OHB apparently originated in the Atlas Mountains of Northern Africa, and has been introduced through infested wood into all major continents (Becker 1979). A majority of the research on the life history and control of the OHB has centered in Europe and South Africa

(Becker 1943, Durr 1954). In Germany detailed studies of OHB life history, habits, and distribution have been conducted by Becker (1942a 1942b 1943 1949), Weidner (1936), Schuch (1937), Eckstein (1920), Steiner (1937), Körting (1960 1965). Becker (1942a 1944) reviewed the status of the OHB in Germany and found it to be the most important economic pest of coniferous timber. His studies showed that OHB larvae cannot survive or develop in deciduous wood. According to Tooke (1949) coniferous wood in the genera Pinus, Abies and Picea are most often attacked. Weidner (1936) reported that the OHB is primarily a pest of buildings over 20 years old in Germany. A combination of moderate temperatures and consistently high relative humidity are required for larval development (Weidner 1936). Optimal conditions for larval development were determined by Becker (1943) to be 82.4 - 84.2° F and 40-50% RH. Becker (1938) proposed that the amount of protein in wood was an important factor in growth of OHB larvae. Studies by Schuch (1937) showed that larvae prefer to feed in the springwood zone of the annual rings. He attributed this directional feeding to the thinner cell wall, greater cell content and higher nutritional value of the springwood zone. OHB larvae do not require gutsymbionts for cellulose digestion. Studies by Parkin (1940) showed that larvae digest cellulose through the action of endocellulose and exocellulase enzymes. In related studies, Falck (1930) found that larvae remove from 20-30% of the cellulose and hemicellulose in wood and almost no lignin. Rasmussen (1957 1961 1967) conducted experiments with larvae and found that growth and development were accelerated through the additions of peptone and yeast extract to feeding blocks. Cholesterol and other

sterols were found to have a minimal effect on growth and development (Rasmussen 1958).

There is considerable variation in the duration of the life stages and fecundity of the OHB. In Germany, Eckstein (1920) reported that males lived longer than females (16 days vs 8 days, respectively). However, Steiner (1937), also from Germany, found that females outlived males (13.5 days vs 10 days, respectively). Neither study provided environmental data or statistical comparisons. Durr (1956) stated that the average longevity of males in South Africa was 16.4 days and females 8.9 days, based on 145 males and 104 females at room temperature. Steiner (1937), working in Germany, reported that the average number of eggs per female was 105.2 and were deposited in 1-7 egg batches. Becker (1943) stated that the number of eggs per female may be as high as 400. Parkin (1934), in England, reported the females laid 30-40 eggs. In South Africa, Durr (1954) found that females averaged 119.4 eggs, deposited in 2-3 egg batches. The incubation period of eggs in Germany was reported by Eckstein (1920) to be 8 days, by Deckert (1933) to be 10-12 days and Schwarz (1935) reported 19 days incubation period at room temperature. An average incubation period of 14 days, at room temperature and 69% RH, was reported by Durr (1956) in South Africa. Durr (1954) showed that the upper and lower limits of egg hatch occurred at temperatures of 98.6° F and 51.8° F, respectively.

The larval developmental period was reported by Eckstein (1920) to range from 3 to 11 years in Germany. In South Africa, Tooke and Scott (1944) reported 2 to 3 years, and in England 4 years was reported

by Parkin (1934). The pupal stage is reported to last 3 weeks in Germany (Weidner 1936), 14 days in England (Parkin 1934 and White 1954) and from 29-44 days in South Africa (Durr 1956).

The biology of the OHB in the U.S. was reviewed by St. George et al (1957) and McIntyre and St. George (1961). Their research indicated that the OHB was probably introduced into the U.S. prior to 1821 in lumber from England or Europe. OHB distribution in the U.S. is restricted to states east of the Mississippi River. Infestations are common along the Atlantic seaboard from Massachusetts to Florida and along the Gulf of Mexico to Texas. Pine (Pinus spp.) and spruce (Picea spp.) lumber are the preferred hosts in the U.S. (St. George et al 1957, Moore 1978). Studies on OHB biology in the U.S. are incomplete and questionable.

The longevity of adults in the U.S. is reported to last from 8 to 16 days, with males living longer than females. The egg stage requires 2 weeks, larval stage several years, and pupal stage 2 weeks (St. George et al. 1957, McIntyre and St. George 1961). Moore (1978) reported that OHB females lay from 150-200 eggs, but 40-50 are probably more near the average.

Becker (1954), Simeone and MacAndrews (1955), and Robinson and Cannon (1979) reviewed the distribution of OHB in Massachusetts, New York State, and Pennsylvania, respectively. According to St. George et al. (1957) the OHB is found primarily in new structures in the U.S. ($\leq$ 10 yrs).

Biotype Discrimination

In recent years the term biotype has been applied to biological differences arising among isolated insect populations. Biotypes are nontaxonomic categories recognized on the basis of common names. They are named after a particular biological attribute of the population which includes its host and/or geographic range (González et al. 1979). Sabrosky (1940) and Frizzell (1933) reviewed the usage of infraspecific terminology in entomology and found biotype to be standard terminology and not nomenclatural. Eastop (1973) believes biotypes are temporally unstable, numerically infinite, and difficult to detect morphologically. González et al. (1979) and Berlocher (1979) define biotypes as individuals consisting of equal genotype. According to Eastop (1973) "equal genotype" refers to similar biological attributes under a given environmental condition. Studies by Mayr (1973) showed that most species exhibit a certain amount of non-genetic variation under different environmental conditions. The amount of biological variation present in a species is the result of interactions between the genotype and environment. Examples of criteria used to discriminate biotypes include studies of behavior, host preference, genetic composition, genetic variation, physiological responses to environmental changes, reproduction analysis and resistance to environmental stress (Eastop 1973, Gallun 1978, May and Holbrook 1978, Den Hollander and Pathak 1981). The majority of biotype discrimination studies have been conducted on aphid populations (Van Emden et al. 1969, Eastop 1973) but there is substantial work on insects used in biocontrol (Messenger and Van den Bosch 1971), as well as on Diptera and Hymenoptera (Claridge and

den Hollander 1980, den Hollander and Pathak 1981, Hatchett and Gallun 1970, Gallun 1978).

A hierarchy of tests have been proposed by González et al. (1979) for characterizing a particular biotype. González et al. (1979) believed that highest level of discrimination should be standard genetic technique, such as electrophoresis, secondary tests include hybridization and behavior and the subordinate level includes physiology tests (host preference, reproductive potential and physical factors).

Biotypes arise through the introduction into an area and subsequent isolation (Eastop 1973). The resulting populations are geographically separated and genetic drift and natural selection occur (Mayr 1973). Becker (1979) conducted research on the distribution of the OHB and reported it on every major continent. This obvious interruption of gene flow and geographical isolation could result in biotypes on each continent (Durr 1954). However, the lack of population studies has failed to substantiate this assumption.

Artificial Diets

Development of a suitable artificial diet for the OHB is a requisite to development of mass-rearing programs intent on laboratory studies of life history, behavior and control of this insect pest. Ishii(1959) defined artificial diets as food which is not the natural diet of the insect but has been synthesized or processed. According to Vanderzant (1966) it is any diet that is not the natural food of the insect. McKinley (1971) applied the term artificial diet to one which does not include the insects natural food except in minute amounts.

The most elaborate definition is provided by Singh (1977), as unfamiliar food which has been formulated, synthesized, processed and/or concocted by man on which an insect in captivity can develop through all or part of its life cycle.

Singh (1977) classifies artificial diets into 3 separate categories based on the composition and purity of the dietary ingredients. Holidic media are those in which the constituents are exactly known chemically and are primarily used for studies of nutrition and metabolism. Meridic media are composed of a holidic base to which is added at least one substance or preparation of unknown structure of uncertain purity (yeast extract, wheatgerm, diatase, peptone). Oligidic media are composed mainly of crude materials designed to imitate the natural food. These diets are assumed to have all the required nutrients and are most commonly developed for insect laboratory mass-rearing.

The majority of diets developed for rearing cerambycids are of the oligidic variety (Hatchett et al. 1973, Wollerman et al. 1969, Payne et al. 1975 and Gardiner 1970). Over 19 families of Coleoptera and between 50-60 species of Cerambycidae have been reared on artificial media (Gardiner 1970, Singh 1977). Galford (1969) outlined methods for rearing 10 species in the subfamily Cerambycinae on artificial diets. These diets contain ground host plant tissue added to enhance larval acceptance. The red oak borer and locust borer were successfully reared on artificial diets by Galford (1974) and Wollerman et al. (1969). Attempts to rear the OHB on artificial media have been unsuccessful (Gosswald 1939). The current laboratory rearing methods are based on

studies by Berry (1972). This method involves the impregnation of pine blocks, under pressure, with solution of peptone and yeast extract.

A general review of the nutritional requirements of immature insects is presented by Scriber and Slansky (1981) and Chapman (1979). Studies by Becker (1943 1949 1963), Rasmussen (1957), Cymorek (1968) and Durr (1956) outlined the basic requirements for developing OHB larvae. Durr (1956) reported that larvae require the following constituents in various degrees: cellulose, hemicellulose, pentosans, protein (organic nitrogen), lignin, moisture, oils, fats and resins. According to Becker (1949 1963) and Durr (1954) susceptibility of seasoned softwood to attack by larvae is dependent on the protein content found in the sapwood. Rasmussen (1957) showed that additions of peptone and yeast extract to wooden blocks accelerated larval growth.

Mating Behavior

A thorough review of the extensive literature on insect courtship behavior and fecundity was presented by Engelmann (1970) and Matthews and Matthews (1978). Courtship display and related mating behavior are determined by internal and external environmental stimuli (Chapman 1979). Internal stimuli center around the development and maturation of the gonads, while external stimuli include such factors as temperature, light, humidity and density of related species (Matthews and Matthews 1978). Wilson (1975) described three common functions of courtship: to stimulate and maneuver females into copulation; to

facilitate species and sexual identification and to facilitate the meeting of solitary individuals. Courtship behavior and subsequent oviposition in Hymenoptera, Diptera, Coleoptera, Hemiptera, Homoptera, and Lepidoptera were reviewed by Leonard and Ringo (1978), Wong and Nakahara (1978), Lew and Ball (1980), Mau and Mitchell (1978), Kumar and Saxena (1978), and Howell et al. (1978). Beeson and Bhatia (1939) and Linsley (1959 1961) reviewed the life history and sexual behavior of the Cerambycidae. Comparative studies of 16 species of Cerambycidae have been published by Michelsen (1963).

Chemical attractants play the predominant role in bringing together the sexes in the class Insecta (Chapman 1979, Engelmann 1970, Matthews and Matthews 1978, Wilson 1975). However, Matthews and Matthews (1978) stated that once together tactile sensory reception is also important. Location of mates is aided by olfactory organs found primarily on the antennae (Chapman 1979, Linsley 1959 1961). It is common in many orders of insects for males to emerge first and congregate near the female emergence site (Matthews and Matthews 1978). This particular courtship behavior has been reported in male cerambycids (Linsley 1961, Michelsen 1966).

Once paired mate selection consists of two major types of competition, intersexual and intrasexual selection (Parker 1970 1978). Intersexual (epigamic) selection depends upon choices made between opposite sexes and requires elaborate prescribed rituals to bring about mating. Intrasexual selection involves interactions between males, and occasionally females, and is based on aggressive exclusion among members of the courting sex (Matthews and Matthews 1978, Wilson 1975).

Intrasexual selection is the dominant theme in many of the subfamilies of Cerambycidae (Michelsen 1966). Durr (1956) reported intrasexual selection between both male and female OHB.

According to Matthews and Matthews (1978) and Engelmann (1970) a great diversity of stimuli influence the oviposition behavior of mated females. Oviposition behavior involves a chain of responses resulting in the selection of an oviposition site and assessment of its suitability. Females have been observed stroking, tapping, licking and probing the substrate previous to oviposition (Michelsen 1966, Linsley 1961). Site selection by the OHB female is influenced by α and β terpines and various chemical components in the frass (Becker 1963, Evans and Higgs 1977). Studies by Donley (1978) showed that the mated red oak borer female would search, probe, and tap the substrate with her ovipositor, before egg deposition.

The most important factor influencing egg production is nutrition. Chapman (1979) reported that many insects require a proteinaceous meal prior to oviposition. However, insects with short adult life spans may never eat and oviposition occurs immediately after mating. In this case, procurement and storage of nutrients by the larval stage is an important factor in egg maturation and production.

Ecological Energetics

The goal of nutritional ecology is to understand how insects transduce the stored energy of their food into specific growth and biomass. According to Grodzinski et al. (1975) and Brody (1945)

bioenergetics is defined as the study of energy transformations in living organisms. Price (1975) uses the term ecological energetics to describe the nutritional interaction between a species and its host. There are several approaches to the study of bioenergetics. The first is the molecular biochemical approach, and is concerned with cellular and sub-cellular interactions. Another approach deals with the individuals and is referred to as the physiological approach. A third is the ecological energetics, and is restricted to the study of energy transformation under field conditions (Grodzinski et al. 1975). The majority of insect bioenergetic studies deal with the ecological approach rather than the molecular or physiological approaches. In most areas of insect ecology the opportunities for contributing to this field of energetics are enormous.

Techniques and methods for determining insect energy budgets have received attention from several authors (Grodzinski et al. 1975, Parra and Kogan 1981, Waldbauer 1964 1968, Lawton 1970, McCullough 1975, Wightman 1981). Waldbauer (1964 1968) developed a standard set of ecological indices. His studies made possible comparative energetic studies between stages and species of insects.

The most common techniques used for studies of ecological energetics are gravimetric, colorimetric, and radioisotopic. The colorimetric method involves the incorporation of non-digestible dyes in the insect food (McGinnis and Kasting 1964). Radioisotopic methods include the use of radioisotopes such as cesium 137 (Crossley 1966), sucrose-U^{14}C (Kasting and McGinnis 1965), or sodium 22 (Buscarlet 1974). Waldbauer (1968) established a quantitative nutritional approach to

the gravimetric technique. This technique is most widely used in energetic studies and consists of measuring the amount of food consumed, digested, assimilated, excreted, metabolized and converted into biomass. The availability of electronic microbalances and advanced respirometers have helped make this technique popular (Scriber and Slansky 1981, Bailey 1976, Kogan and Cope 1974). Waldbauer (1968) defined his ecological indices as non-dimensional ratios of various parameters of energy flow in a community. These parameters are computed on the basis of fresh animal weight and dry weight of food consumed. Waldbauer's (1968) energy indices have undergone several modifications (Grodzinski et al. 1975, Woodring et al. 1979, Scriber and Slansky 1981, McCullough 1975) but still represent 5 basic ratios: consumption index, relative growth rate, efficiency of conversion of digested food, efficiency of conversion of ingested food, and the approximate digestibility of the food. Formulas for the computation of these parameters are presented by Waldbauer (1968), Scriber and Slansky (1981), Grodzinski et al. (1975), and McCullough (1975).

Parra and Kogan (1981) and McGinnis and Kasting (1964) conducted comparative analysis between the gravimetric and radioisotopic and colorimetric and gravimetric methods, respectively. Their findings showed that gravimetry is the most reliable and inexpensive technique to use in energetic studies.

Ecological performance values are used as tools to improve our understanding of nutritional and insect ecology. Scriber and Slansky (1981) noted that indices will vary with instar, with food quality, temperature, humidity, density, and body size. Energy budgets based

on ecological indices have been developed for a large number of insects (Barlow 1979, White and Sinha 1981, Campbell and Sinha 1978, King et al. 1981, Woodring et al. 1979, Van Hook and Dodson 1974, Ikeda 1979, Hespenhide 1976, Reichle 1967). The majority of these studies deal with phytophagous Lepidoptera and granivorous insects (Campbell and Sinha 1978, Singh et al. 1976, Campbell et al. 1976).

There is a paucity of information on the bioenergetics of wood-feeding Coleoptera, perhaps due to their long life cycles (2 to 3 yrs) and cryptic mode of feeding. Van Hook and Dodson (1974) developed an energy budget for the yellow-poplar weevil, Odontopus calceatus (Say). Consumption and utilization studies of the cerambycid Phymatodes maaki (Kraatz) were undertaken by Ikeda (1979). A partial energy budget was developed by Williams (1977) for Xyletinus peltatus (Harris), a wood destroying Anobiid. Becker and Damaschke (1963) studied OHB respiration and reported that increases in larval weight were correlated with decreases of O_2 consumption. The influence of various temperature regimes on the consumption of O_2 was not studied.

Section III

THE NORTH AMERICAN BIOTYPE OF THE OLD HOUSE BORER, *HYLOTRUPES BAJULUS* (L.) (COLEOPTERA: CERAMBYCIDAE)

INTRODUCTION

The old house borer (OHB), Hylotrupes bajulus (L.), is an important structural insect pest in eastern and southeastern United States. This cerambycid, native to the Atlas Mountains of Northern Africa, has been introduced into all major continents (Becker 1979). The OHB was first reported in N. A. over 200 years ago, and now occurs in the Atlantic seaboard and Gulf Coast states (Moore 1978).

OHB biology and life history in England were reviewed by Hickin (1975) and Parkin (1934); in Germany by Cymorek (1968) and Becker (1942a); in Denmark by Rasmussen (1961), and in South Africa by Durr (1954 1956), and Tooke and Scott (1944). In these countries the OHB is considered an established pest, capable of surviving under natural conditions in unprocessed wood. The life history and habits of the South African and northern European populations vary considerably. Durr (1956) reported female OHB in South Africa to be more fecund than those in Europe. Variations in adult, larval and egg, size and longevity have also been noted between OHB populations on the different continents (Becker 1942a, Weidner 1936, Durr 1956). These individual populations or biotypes have evolved through the introduction into areas and subsequent isolation by geographic barriers (Becker 1979). González et al. (1979) and Eastop (1973) define biotypes as populations, of similar genetic composition, which vary in biological functions such as behavior, host preference, morphology, or reproductive potential. Durr (1954) noted that the variations between European and South African biotypes are the result of more favorable environmental conditions in South Africa.

The biology and pest status of the OHB in N. A. were reviewed by Moore (1978), McIntyre and St. George (1961), St. George et al. (1957) and Snyder (1955). However, the biological data found in these reports were based primarily on data originating from South Africa, Europe, and on field observations in the U.S. Cannon (1979) reported that the biology and life history of the OHB under N. A. environmental conditions differs considerably from both the South African and European biotypes.

The objective of the research presented here was to describe and compare the biology and habits of the OHB in N. A. with data from Europe and South Africa. Results of this research will allow for a precise understanding of the presence and status of a N. A. population of the OHB.

MATERIALS AND METHODS

A laboratory colony of OHB's was established and maintained from adults and larvae collected throughout Virginia's 3 geographic regions (Coastal, Piedmont, Mountain). This colony is considered representative of the N. A. OHB population because of Virginia's midpoint location in the distribution of the OHB in eastern U.S.

Adult OHB were confined in 1ℓ, clear plastic containers during their lifetime. Each container was maintained at room temperature (22.1° ± 2°C and 60-80% RH) and provided with oviposition sites consisting of pine (Pinus spp.) blocks and filter paper. Eggs were removed from containers daily, counted and incubated in 30 ml plastic cups under similar environmental conditions until eclosion. Larvae were

reared to adults in blocks of southern yellow pine (Pinus spp.) (50 x 25 x 15 cm), placed in temperature-humidity controlled chambers (30° ± 1°C and 65-75% RH). The laboratory colony was maintained using methods described by Berry (1972).

Parameters used to describe the N. A. population include the length and width of adults and eggs, longevity of adults, larvae, pupae and eggs, and the adult female fecundity. These parameters were compared with published data from Europe and South Africa.

In this study, longevity of adults was measured in days from the time of emergence to the time of death. Egg longevity was measured in days from deposition to eclosion. Larval longevity was based on homeowner survey data (Cannon and Robinson 1982a) and is expressed as a range of developmental time in years. Pupal longevity was defined as the time between the prepupal molt and emergence of the adult. Oviposition period was defined as the time from deposition of the first egg batch to the time the last egg batch was deposited. Adult length was measured along the dorsal surface, from the mandibles to the last visible segment of the body; width was measured across the humeral region of the elytra. Measurements were made with a vernier micrometer. Eggs and larvae were measured with a microscope ocular micrometer. Egg length was measured from end to end and width recorded across the blunt pole of the egg. Larvae were measured from the mandibles to the end of the last abdominal segment. First-instar larvae were weighed in groups of ten on a Mettler balance. Fecundity was considered to be the total number of eggs oviposited by a female during her life span. Egg viability was calculated as a percentage of egg hatch based on total fecundity.

RESULTS AND DISCUSSION

Adults. The N. A. OHB adults ranged from 6.5 to 25.5 mm in length and 2.6 to 6.4 mm in width. Longevity ranged from 4 to 24 days. These data are within the ranges reported for the European and South African OHB biotypes (Table I). N. A. females were equal in size to South African females (16.9 ± 0.5 vs 17.1 mm), but males were slightly larger (12.2 ± 0.5 vs 11.4 mm). More accurate statistical comparisons among the N. A., European and South African biotypes are not possible because of the lack of sufficient data, and because available data do not include sample size and variation. N. A. female OHB were consistently larger in size and shorter lived than males. These findings are in agreement with observations made by Durr (1956) and Hickin (1975).

The most striking difference noted among biotypes was the large number of eggs oviposited by the N. A. females ($\bar{x}$ = 165.1 range 46-334) (Table I). The average number of eggs per female in South Africa and Europe was 119.4 and 105.2, respectively. A possible explanation for the high fecundity of N. A. females may lie in the fact that the OHB is found predominantly in new homes ($\bar{x}$ = 6.1 ± 1.0) in N. A. Becker (1949) and Durr (1956) showed that the nutritional content of wood is a limiting factor in OHB growth and development. New wood (i.e., $\leq$ 10 yrs) contains a higher proportion of available protein and vitamins. Larvae feeding in wood of higher nutritional value would be expected to produce larger adults. Becker (1942b) showed a positive correlation between size of adult females and egg production. In Europe the OHB is found predominantly in old homes ($\geq$ 10 yrs) (Schuch 1937) and

because of the lower nutritional value of this wood, larvae would expect to take longer to develop and produce smaller adults. In South Africa, Durr (1956) reported that the OHB is found primarily in new wood, and that females are more fecund than those found in Europe. N. A. females deposited more egg batches (4.3 vs 2.5) over a longer period of time (5.2 vs 3.9 days) when compared to the South African biotype. Corresponding data are not available for the European biotype.

Eggs. Eggs of N. A. females ranged from 1.6 to 2.1 mm in length and 0.41 to 0.51 mm in width (Table II). They were slightly smaller than eggs from the South African biotypes, and within the range recorded for the European biotype. Under similar environmental conditions (20-25°C and 60-75% RH) the incubation period for eggs of N. A. females was 8.5 days which is considerably shorter than South African (14) and European (9-12) biotypes, respectively. There was little difference in the eclosion rates (85.2% vs 83.2%) between eggs from N. A. and South Africa, respectively.

Larvae. The length, head capsule width, and weight of first instar larvae are presented in Table II. The N. A. larvae weighed less than larvae of similar age in South Africa (0.18 vs 0.22 mg, respectively). This is not unexpected, since similar differences were noted in the comparison between eggs of these two biotypes. The developmental period of OHB larvae, under environmental conditions in N. A., was observed to range from 1-11 years ($\bar{x}$ = 6.1 ± 1.0) (Cannon and Robinson 1982a) (Table II). This period is longer than the 1-5 year ($\bar{x}$ = 3.21) developmental period reported in South Africa (Durr 1956) and is comparable in range to the 3-11 year period reported in Europe (Weidner 1936).

Cannon and Robinson (1981) reported that OHB larvae are most efficient in utilizing wood for growth and development at temperatures and relative humidities of 20-30°C and 60-80%, respectively. Rasmussen (1967), and Cannon and Robinson (1981) showed that the larval developmental period is shortened or extended depending on the range and stability of temperature, relative humidity, and nutritional content of wood. The environmental conditions for developing larvae in N. A., South Africa and Europe are similar with mean summer temperatures ranging from 60-80°F and relative humidity of 50-70%. However, the microhabitat in which larvae are found may differ resulting in a reduction or extension of the development period.

Pupae. There was little variation in the longevity of the pupal stage (Table II). The European biotype recorded the shortest developmental period (14-21 days) and the South African biotype the longest (29-44 days). Pupae of the N. A. biotype require a developmental period of 21.7 ± 3.2 days.

CONCLUSION

The biological data appears to indicate the existence of a N. A. biotype of the OHB. This biotype was described from field collected and laboratory reared specimens. An accurate biological data base is now available for evaluating this insect pest. These data, along with data on larval feeding (Cannon and Robinson 1981) and distribution (Cannon and Robinson 1982a) will be useful in developing recommendations for OHB control.

Table I. Descriptive data on biotypes of the old house borer, Hylotrupes bajulus (L.).

Life Stage		Location		
		North America	South Africa	Northern Europe
		$\bar{X}$ ± S.E.	$\bar{X}$	$\bar{X}$
ADULT FEMALE	Length (mm)	16.9 ± 0.5[1]	17.1[3]	NA*
	Width (mm)	5.0 ± 0.1	NA	
ADULT MALE	Length (mm)	12.2 ± 0.5	11.4	NA
	Width (mm)	3.8 ± 0.1	NA	
ADULT LONGEVITY (DAYS)	Female	9.9 ± 1.1[2]	8.9[4]	8.0
	Male	15.5 ± 1.4	16.4[5]	16.0
FECUNDITY		165.1 ± 15.5	119.4[6]	105.2
MEAN NO. EGG BATCHES/FEMALE		4.3 ± 0.3	2.5	2-8
OVIPOSITION PERIOD (DAYS)		5.2 ± 0.5	3.9	12

[1]based on 50 adult females and 50 adult males

[2]based on 25 adult females and 17 adult males at room temp. (22.1°C 2° and 60-70% RH)

[3]based on 210 adult males and females

[4]based on 104 females at room temp. (23°C and 61% RH)

[5]based on 145 males at room temp. (23°C and 61% RH)

[6]based on 152 females

NA = data not available

* (adults were reported to range in size from 7-24 mm) in Northern Europe

Table II. Descriptive data on biotypes of the old house borer, Hylotrupes bajulus (L.).

Life Stage	Location		
	North America $\bar{X} \pm$ S.E.	South Africa $\bar{X}$	Northern Europe $\bar{X}$
EGG:			
Length (mm)	1.9 ± 0.002[1]	2.03[2]	1.2 - 2.0
Width (mm)	0.45 ± 0.001	0.58	0.5
Incubation Period (Days)	8.5 ± 0.3	14.0	9-12
Eclosion Rate (%)	85.2 ± 0.5	83.2	NA
1ST-INSTAR LARVA:			
Length (mm)	1.7 ± 0.004[3]	NA	NA
Width (mm)	0.19 ± 0.001	NA	NA
Weight (mg)	0.183[4]	0.222	NA
LARVAL DEVELOPMENTAL PERIOD (YEARS)	6.1 ± 1.0[5]	3.21	3-11 (Range)
PUPAL PERIOD (DAYS)	21.7 ± 3.2[6]	29-44	14-21

[1]based on 50 eggs at room temp. (22.1°C ± 2 and 60-70% RH)

[2]based on 40 eggs at room temp. (23°C and 69% RH)

[3]based on 50 1st instar larvae

[4]based on 5 reps. of 10 larvae each

[5]based on survey data of 32 infested homes throughout Va.

[6]based on 8 pupae, room temp. 22.1°C ± 2° and 60-70% RH

NA = data not available

Section IV

LABORATORY STUDIES OF THE NORTH AMERICAN AND EUROPEAN BIOTYPES OF THE OLD HOUSE BORER, *HYLOTRUPES BAJULUS* (L.) (COLEOPTERA: CERAMBYCIDAE)

INTRODUCTION

Many insect species have been studied and found to consist of a complex of biotypes (Eastop 1973, Claridge and den Hollander 1980). González et al. (1979) and Eastop (1973) define biotype as individuals consisting of equal genotype. The delineation of biotypes is based on a variety of different studies such as electrophoresis, host plant preference, feeding and behavior, life history and reproductive potential (González et al. 1979, Berlocher 1979). Other biotypes have been characterized based on developmental rates, morphology and color. The most common origin of biotypes is the introduction into an area and subsequent isolation by geographic barriers.

The old house borer (OHB), Hylotrupes bajulus (L.), has been introduced into every major continent (Becker 1979) and the term biotype may be applicable to several of these isolated populations. Durr (1954 1956) showed that distinct biological variation existed between the South African and European populations of the OHB. Cannon and Robinson (1982b) examined field and laboratory data and established the presence of the N. A. biotype of the OHB. In their study the N. A. biotype was described and compared to the South African and European biotypes. Parameters utilized in the description included growth and developmental analysis of all life stages and female reproductive potential.

Cannon and Robinson (1982b), and Durr (1954 1956) attributed the biological variation among OHB populations to bioclimatic differences

found on each continent. However, these studies did not elaborate on the degree of genetic variation among the biotypes.

The objective of the study presented here were to examine the inherent variability between the N. A. and European biotypes of the OHB. Comparative studies were conducted between biotypes at constant temperature, humidity, and under similar nutritional conditions. Results should indicate whether there is a genetic basis for the observed biological variation noted between these populations under natural conditions.

MATERIAL AND METHODS

Adult OHB used in this study were taken from laboratory colonies of the N. A. and European biotype (Cannon 1979). The N. A. biotype was established from adults and larvae collected in Virginia and surrounding mid-Atlantic states. The European biotype colony was established with specimens from West Germany. Handling and mating of adults and laboratory rearing of larvae were carried out using methods described by Berry (1972).

Parameters used to delineate biotypes included measurements of egg length, width, viability, and incubation period; adult length, width, longevity and fecundity; larval (first-instar) length, weight and head capsule width, and larval developmental period; and pupal longevity. All developmental stages were reared in constant temperature-humidity chambers maintained at 28-30°C ± 1°C and 65-70% RH. Comparative analysis was conducted using a Model I ANOVA; $P<0.05$.

Egg length was measured from end to end and width across the blunt pole of the egg. Measurements were made with an ocular micrometer. Egg longevity was measured in days from deposition to eclosion. Egg viability was calculated as a percentage of egg hatch based on total fecundity. Adult length was measured along the dorsal surface, from the mandibles to the last visible segment of the body, width was measured across the humeral region of the elytra. Measurements were with a vernier micrometer. Adult longevity was measured in days from the time of emergence to the time of death. Fecundity was considered to be the total number of eggs oviposited by a female during her life span. First-instar larvae were measured from the mandible to the last abdominal segment, head capsule measurements were taken across the ventral articulation points on the larval head. Larval longevity was based on the time (months) required to reach the pupation weight of 200 mg. Pupal longevity was defined as the time (days) spent in both the prepupal and pupal stages and measured from the prepupal molt to the adult stage.

RESULTS AND DISCUSSION

The biological variation noted between populations on each continent was not expressed when reared under similar environmental conditions. The absence of any significant variation between biotypes indicates that this species has undergone little genetic change since its separation over 200 years ago.

Length and width comparisons between adults from the two biotypes were not significantly different (Table III). Females from both biotypes were consistently larger and shorter lived than males. This size and longevity data are in agreement with studies by Durr (1956) and Becker (1943), who found females to be larger in size and shorter lived than males. Adult female longevity was not significantly different between the biotypes. Males of the European biotype lived considerably longer (18.0 ± 4.2 days) than N. A. males (14.9 ± 6.9 days) but this difference was not significant ($P<0.05$, ANOVA; Table III).

Egg length, width, incubation period and viability were not significantly different between biotypes (Table IV). A similar trend of non-significance was noted in female fecundity (Table IV). Under natural conditions N. A. females were considerably more fecund ($\bar{x}$ = 165.1 eggs) than the European females ($\bar{x}$ = 105.2) (Cannon and Robinson 1982b). In this study the N. A. females oviposited fewer eggs ($\bar{x}$ = 126.9 ± 55.9) when compared to the European ($\bar{x}$ = 161.3 ± 72.6) but they were not found to be significantly different.

Analysis of first-instar larvae showed no significant variation in length, head capsule width and weight (Table V). Larvae of each biotype developed at similar rates, requiring 18-20 months to reach a pupation weight in the range of 190-220 mg.

The pupation rate was similar between N. A. biotypes and European biotypes (49.7 and 55.8%, respectively) and no significant difference was noted in the prepupal and pupal developmental rates (Table V).

CONCLUSION

This study examined two biotypes of the OHB from different bioclimatic regions. These biotypes were established based on biological variation in life history and reproductive potential (Cannon and Robinson 1982b). The results show that under similar and constant environmental conditions there is no significant difference between these two populations and it is assumed that these biotypes have undergone little genetic change since their separation over 200 years ago.

Mayr (1973) reported that many species express a wide variety of non-genetic biological variation resulting from interactions of the genotype and environment. This is apparently the case with the OHB as noted in the biological variation among field populations (Cannon and Robinson 1982b, Durr 1956). This developmental flexibility seen in the OHB allows the species to cope with changing conditions by producing populations suited for new environments. The advantage of this wide variation lies in the ability of the species to exploit marginal habitats and various subniches. The developmental flexibility of the OHB has lead to the production of different biotypes under different environmental conditions. This is in agreement with Eastop (1973) who found biotypes to be temporally unstable, numerically infinite, and difficult to detect morphologically.

Future laboratory studies involving biotype comparisons should measure the response under a range of environmental conditions. Studies by Eubank et al. (1973) showed that moderate fluctuations around optimal temperatures produce relatively little change in developmental

time while large fluctuations can produce significant accelerations or retardation of development. Similar studies (Sharpe and Hu 1980) have shown that biotypes exhibit developmental differences at the extremes rather than within the mid-temperature region. Sharpe and Hu (1980) classified these populations as thermal biotypes and characterized them by thermodynamic characteristics of certain underlying enzymes.

Table III. Comparisons between adults of old house borer, Hylotrupes bajulus (L.) biotypes.

Biotype	North American $\bar{X}$ ± S.D.	European $\bar{X}$ ± S.D.
ADULT FEATURE		
Female:[1]		
Length (mm)	16.1 ± 1.3 (a)[3]	15.7 ± 1.0 (a)
Width (mm)	5.1 ± 0.55 (a)	5.1 ± 0.44 (a)
Longevity (days)	8.9 ± 3.4 (a)	8.5 ± 4.4 (a)
Male:[2]		
Length (mm)	14.9 ± 1.1 (a)	14.9 ± 2.2 (a)
Width (mm)	4.8 ± 0.45 (a)	4.9 ± 0.52 (a)
Longevity (days)	14.9 ± 6.9 (a)	18.0 ± 4.2 (a)

[1]based on 23 N.A. females/11 European females

[2]based on 9 N.A. males/4 European males

[3]means in the same row followed by a different letter are significantly different $P<0.05$, ANOVA

Table IV. Comparisons between eggs of old house borer, Hylotrupes bajulus (L.) biotypes.

Biotype	North American $\bar{X}$ ± S.D.	European $\bar{X}$ ± S.D.
ONTOGENIC FEATURE		
Egg:		
Length (mm)[1]	2.2 ± 0.11 (a)[6]	2.4 ± 0.66 (a)
Width (mm)[2]	0.46 ± 0.03 (a)	0.47 ± 0.04 (a)
Number/female[3]	126.9 ± 55.9 (a)	161.3 ± 72.6 (a)
Incubation time (days)[4]	9.4 ± 2.4 (a)	7.5 ± 2.8 (a)
Percentage hatch[5]	68.9% ± 23.8 (a)	69.1% ± 31.3 (a)

[1]based on 50 eggs each biotype

[2]based on 50 eggs each biotype

[3]based on 17 N.A. females/8 European females

[4]based on 205 eggs N.A./170 eggs European biotype

[5]based on 205 eggs N.A./170 eggs European biotype

[6]means in a row followed by a different letter are significantly different $P<0.05$, ANOVA

Table V. Comparisons between first-instar larvae and pupae of old house borer, Hylotrupes bajulus (L.) biotypes.

Biotype	North American $\bar{X}$ ± S.D.	European $\bar{X}$ ± S.D.
ONTOGENIC FEATURE		
Larva:		
Length (mm)[1]	1.7 ± 0.13 (a)[5]	2.2 ± 0.45 (a)
Head capsule (mm)	0.37 ± 0.02 (a)	0.33 ± 0.11 (a)
Weight (mg)[2]	0.23 ± 0.09 (a)	0.29 ± 0.07 (a)
Prepupa:		
Female longevity (days)[3]	9.6 ± 3.4 (a)	9.1 ± 2.9 (a)
Male longevity (days)[4]	11.6 ± 3.6 (a)	7.5 ± 3.5 (a)
Pupa:		
Female longevity (days)	18.4 ± 2.6 (a)	16.2 ± 6.2 (a)
Male longevity (days)	18.1 ± 3.8 (a)	10.0 ± 8.5 (a)

[1]based on 50 larvae each biotype

[2]based on 5 reps. of 10 larvae each biotype

[3]based on 23 N.A. females/11 European females

[4]based on 9 N.A. males/4 European males

[5]means in a row followed by a different letter are significantly different $P < 0.05$, ANOVA

Section V

AN ARTIFICIAL DIET FOR THE LABORATORY REARING OF THE OLD HOUSE BORER, *HYLOTRUPES BAJULUS* (L.) (COLEOPTERA: CERAMBYCIDAE)

INTRODUCTION

Larvae of the old house borer (OHB), Hylotrupes bajulus (L.), tunnel in seasoned softwoods used in the construction of houses and other wooden structures. This cerambycid is native to the Atlas Mountains of Northern Africa, but has been introduced into all major continents (Becker 1979).

The larval stages of the OHB may take from 3 to 11 years to develop. During this long feeding period larvae seldom break the wood surface, making early detection of this pest difficult. Larval feeding and development are affected by temperature, relative humidity (RH) and the nutritional content of wood (Cannon and Robinson 1981). Optimal conditions for larval development are temperatures from 20°-30°C, RH 70-80%, and new wood (< 10 yrs. old). Under these ideal conditions larvae can complete their development in 2 to 3 years.

Reducing the larval developmental period, through improved rearing methods, would greatly facilitate studies of OHB behavior, life history and control. Becker (1943 1963), Rasmussen (1957), Cymorek (1968) and White (1962) showed that additions of peptone and yeast extract to pine blocks used to rear larvae greatly reduced the larval developmental period. Gösswald (1939) reported similar reductions in larval development through additions of diatase to pine blocks. Berry (1972) successfully reared the OHB from egg to adult in 12 to 14 months using nutrient fortified pine blocks. Although successful in reducing the larval rearing time, Berry's (1972) method did not allow for the direct observation of developing larvae, or for the synchronization of adult emergence. Another disadvantage of rearing OHB larvae in pine

blocks is the high larval mortality (20%) from the constant handling and transfer of larvae.

The purpose of the study presented here was to develop an artificial diet for mass rearing OHB larvae. A suitable artificial diet will reduce rearing time, reduce larval mortality, and allow for the observation of larval and adult habits and behavior. Other advantages of an artificial diet include studies on nutrition, physiology, and control of the OHB.

MATERIALS AND METHODS

The artificial diets tested were based on modifications of diets developed for other wood-feeding Coleoptera (Gardiner 1970, Payne et al. 1975). Diets were evaluated on the basis of monthly survival, and growth rates of larvae. The composition of the final diet is given in Table VI. This oligidic diet is formulated with additions of ground southern yellow pine (Pinus spp.), cellulose, bacto-peptone, yeast extract and cholestrol. Southern yellow pine was split into small pieces and ground in a Wiley laboratory mill (Model 4) equipped with a 2mm screen.

Fromulation of the artificial diet involved the following steps. Agar and distilled water were placed in a 1ℓ pyrex beaker and the solution slowly boiled. Sorbic acid and methyl hydroxybenzoate were dissolved in warm 95% ethyl alcohol, then added to the agar and water solution. The remaining ingredients (Table VI) were placed in a blender and mixed thoroughly. This mixture was transferred to a 4ℓ stainless steel beaker, the hot agar-water mixture added, and the entire mixture blended

with a spatula until it reached a uniform consistency. After preparation, diets were immediately pressed into 4.5 cm clear plastic dishes (27.5 ml) and stored, uncovered, at 45-50°C for 1-2 hrs. or until a crust formed on the diet surface.

Recently hatched OHB larvae were selected from a laboratory colony maintained at the VPI & SU insectary (Cannon 1979). Ten larvae per dish were placed, head first, into 6-mm deep holes, pressed into the diet surface. Dishes were placed in constant temperature-humidity chambers (27° ± 3°C and 70-80%) and larval survival and growth recorded every 30 days.

After 6 to 8 months fully-developed larvae (180 - 300 mg) were transferred to an environmental chamber maintained at 5-10°C for 8 weeks to induce pupation (Becker 1949). Adult emergence occurred 4 to 8 weeks after returning larvae to the constant temperature-humidity chambers. Observations of larval, pupal and adult longevity and fecundity were recorded and compared to conventional rearing methods.

RESULTS AND DISCUSSION

In a comparison between diet-reared larvae and larvae reared in nutrient fortified wood there was no significant difference in the percentage survival after one month (Table VII). The low survival rates for larvae in wood are in agreement with the 44.5% survival rate reported by Howick (1972). Low survival rates of diet-reared larvae, after one month, were attributed to high moisture content and possible overcrowding. When diets were dried for longer periods (2-4 hrs 50°C) and fewer larvae placed on each diet (i.e., 5 per diet) survival rates at one

month were increased by 20-25%. Diet-reared larvae had a significantly higher survival rate after 6 months when compared to larvae reared in pine blocks. The artificial diet apparently provided a suitable physical and nutritional environment for established larvae.

Growth and development of larvae on artificial diets were significantly greater when compared to those in fortified wood (Table VIII). Larvae feeding on artificial diets reached their pupation weight in 6-8 months of feeding. Behavior of the diet reared larvae appeared unaltered and larvae pupated normally. The pupation rate (52.1%) and period (30-60 days) compare favorably to pupation rates and periods of pupae in nutrient fortified wood (Berry 1972).

A comparison of fecundity and eclosion rates (Table IX) showed no significant differences between the two rearing methods. The significant difference in egg length and width is attributed to variability within individual adults as reported by Durr (1956). Longevity of diet reared male and female adult OHB (16.1 and 9.3 days, respectively) was not significantly different between the two rearing methods. The development from egg to adult by OHB on the artificial diet ranged from 9-11 months with a 50-60% survival rate. Conventional rearing methods (Berry 1972, Howick 1972) reported a 12 to 14 month egg to adult period with a 30-40% survival rate.

CONCLUSION

This study showed that an artificial diet can be used to rear the OHB. An oligidic diet was prepared with ground host tissue (southern yellow pine), cellulose, agar and various other nutrients required by

this species. This diet reduced the rearing time, decreased mortality over conventional rearing methods and allowed for the direct observations of larval behavior and habits.

Table VI. Composition of the artificial diet for laboratory rearing of Hylotrupes bajulus (L.), the old house borer.

Ingredients	Quantity[1]
Agar	20
Water	300 (ml)
Alphacel	75
Sawdust, yellow pine	75
Wheat germ	23
Sucrose	26
Casein, vitamin free	26
Salts, Wesson's	8
Ascorbic acid	3
Choline chloride	1
Vanderzant's vitamin mixture	8
Bacto-yeast extract	6
Bacto-peptone	6
Cholestrol	3
Methyl hydroxybenzoate	2
Sorbic acid	2

[1]Expressed in grams unless otherwise noted.

Table VII. Comparison between survival rates of old house borer larvae on diets and wood.

Rearing Medium	% Survival[1] (1 month) $\bar{X}$ ± S.E.	% Survival[2] (6 months) $\bar{X}$ ± S.E.
diet	62.8_a ± 4.24	82.6_a ± 4.24
wood	59.4_a ± 3.34	57.0_b ± 6.80

Means followed by different letters are significantly different $P<0.05$, ANOVA.

[1]Based on 100 1st instar larvae, 10/diet.

[2]Based on total larvae surviving after 1 month.

Table VIII. Comparison between larval development of old house borer on diets and wood.[1]

Rearing Medium	Weight (mg) $\bar{X}$ ± S.E.	Length (mm) $\bar{X}$ ± S.E.	Head Capsule Width (mm) $\bar{X}$ ± S.E.
diet	195.2_a ± 11.3	17.9_a ± 0.04	1.44_a ± 0.01
wood	28.7_b ± 3.1	9.4_b ± 0.37	0.91_b ± 0.03

Means followed by different letters are significantly different $P<0.05$, ANOVA.

[1]Based on 30 (six month old) larvae.

Table IX. Comparison between eggs of old house borer females reared on diets and wood.

Rearing Medium	Fecundity[1] $\bar{X}$ ± S.E.	Eclosion Rate $\bar{X}$ ± S.E.	Length (mm)[2] $\bar{X}$ ± S.E.	Width (mm) $\bar{X}$ ± S.E.
diet	158.8_a ± 14.4	86.5_a ± 1.9	2.1_a ± 0.01	$.48_a$ ± 0.003
wood	161.3_a ± 14.8	79.1_a ± 6.4	2.4_b ± 0.14	$.41_b$ ± 0.008

Means followed by different letters are significantly different $P<0.05$, ANOVA.

[1]Based on 30 adult females.

[2]Based on 50 eggs.

Section VI

EGG PRODUCTION AND MATING BEHAVIOR OF THE OLD HOUSE BORER, *HYLOTRUPES BAJULUS* (L.) (COLEOPTERA: CERAMBYCIDAE)

INTRODUCTION

The old house borer (OHB), Hylotrupes bajulus (L.), is a structural insect pest of worldwide importance (Becker 1979). Despite the pest status of this wood-infesting beetle, little is known about its fecundity and mating behavior. Investigations by White (1954 1959) indicated that OHB females need mate only once to lay their full complement of eggs. Fecundity and egg viability data were not considered. Durr (1956) studied adult mating behavior and found that both sexes of OHB attack each other before mating.

Information on mating frequency, fecundity, egg viability and mating behavior of the OHB is needed to better understand the life history of this insect. The objective of this research is to obtain data on these factors.

MATERIALS AND METHODS

OHB adults used in this study were selected from a laboratory colony maintained at VPI&SU (Cannon 1979). Observations on mating behavior were made in an aquarium (30 x 20 x 20 cm), under fluorescent light (970 lux), at temperatures (T) of 27 to 30°C, and a relative humidity (RH) of 50-70%. No provisions were made for adult feeding (Durr 1956). Each observation period lasted 4 hours, after which the adult beetles were isolated in separate containers for 24 hours. The following day adults were placed back into the aquarium for further observation. Three oviposition sites, consisting of blocks of southern yellow pine (5.0 x 2.5 x 1.5 cm) and pieces of filter paper, were placed in the mating arena. Numbered tags, glued to the dorsum of the thorax,

were used to identify the 1 to 3 day old adults used in each mating regime. Eggs from mated females were incubated in controlled environment chambers (30° ± 1°C; RH 75-80%).

Two mating regimes, single and multiple, were used in this study. Single matings involved the simultaneous placement of 1 virgin male and 6 virgin females into the mating arena. Immediately after the first copulation, females were removed and isolated in 1 qt. clear plastic containers provided with oviposition sites. The females were held in containers for the remainder of their life. This mating regime was repeated 5 times. Adult longevity, length of time in copula, oviposition period, fecundity, and egg viability were recorded for each adult female within each repetition. Details of male and female mating behavior were recorded on tape.

Multiple matings (i.e., random mating) involved the simultaneous placement of 3 virgin males and 3 virgin females into the mating arena. Adults were observed for a 4 hour observation period as previously described. Records of the adult longevity, length of time in copula, frequency of copulation, oviposition period, fecundity, and egg viability were made. Five repetitions of this regime were conducted and male and female mating behaviors recorded on tape. At the conclusion of the experiments the tapes were transcribed and comparisons between mating regimes analyzed using student t-Test and model 1 ANOVA; $P<0.05$.

In these experiments the oviposition period was defined as the time from deposition of the first egg batch to the time the last egg batch was deposited. Longevity of adults was measured from the time of emergence to the time of death. The time in copula was defined as

the period in which the copulatory organs were visibly joined together. Fecundity was considered to be the total number of eggs oviposited by females during their life span and egg viability was calculated as a percentage of egg hatch based on total fecundity.

RESULTS AND DISCUSSION

There have been few detailed studies of adult behavior involving members of the subfamily Cerambycinae. A general description of the behavior of cerambycids is provided by Linsley (1961).

In this study, females allowed to mate randomly (i.e., multiple mating regime) mated an average of 6.8 (± 0.65) times. This is in contrast to the single mating regime in which females mated only once. Under the multiple mating regime females remained receptive to males during their entire adult life and mated between the deposition of egg batches. Males, in the multiple mating regime, were observed to actively compete for females. Aggressive interactions between males were observed frequently. This behavior involved the violent dislodging of copulating males from the backs of females and fighting behavior often followed resulting in the loss of one or more appendages. Bouts were intense and continued even after copulation. Inseminating males frequently remained mounted presumably to guard the ovipositing female. This particular behavior was reported by Parker (1970) in dipterans known to exhibit sperm displacement. The complex sexual behavior observed in OHB adults has been reported in other longhorned beetles (Michelson 1966).

Under both mating regimes males appeared to recognize and locate females at a short distance through antennal contact. Apparently chemical attractants play only a minor part in bringing together potential mating pairs at short distances. Females, in both regimes, generally were not receptive to advancing males, and usually avoided contact by moving away. However, the males would actively pursue the females and mount them dorso-ventrally. Females kicked and attempted to dislodge males during this initial precopulatory period but males calmed females by tapping and stroking the anterior-dorsal surface of the females' elytra, with the maxillae. Females were never observed to pursue males and no aggression was noted among rival females, even in the single mating regime. This differs from the observations of Durr (1956).

In a comparison between mating regimes (Table X) adults in the multiple mating regime were in copula for a longer period of time (194 vs 186 sec.). This was probably due to the competition among males for females since rival males were not always successful in dislodging mating males. Adult longevity and oviposition periods were significantly shorter under the multiple mating regime (9.3 ± 0.52 and 3.07 ± 0.39 days, respectively) (Table X). Apparently multiple matings reduce the oviposition period, and with the increased activity of mating, competition and oviposition, a significant reduction in adult life span was observed.

Under the multiple mating regime females laid significantly fewer egg batches (3.93 vs 4.52) (Table XI). However, there was no significant difference in the total fecundity (Table XI), indicating that

these egg batches contained more eggs. Similarly no significant difference in egg viability was observed between the two regimes (Table XI). These data suggest that females may be capable of altering the number of eggs per batch and that this behavior may be related to mating frequency.

Table XII provides data on the effects of mating sequence of females which mated with a single male. No significant differences in the number of egg batches, fecundity or egg viability were observed when comparing females mated first to those which mated last. This indicates that males can mate at least six times (and probably more) without a reduction in their ability to transfer a viable spermatophore. It also shows that females receive enough sperm from one mating to fertilize their entire egg complement.

CONCLUSION

These experiments have shown that adult OHB exhibit mating behavior similar to that of other cerambycids. Aggressive behaviors between males displayed in the multiple mating regime play an important role in the mating process. Male aggressive and guarding behaviors undoubtedly help to reduce the occurrence and success of inseminations by other males. This in turn would reduce the chances of sperm competition and increase fitness.

The practical implications of these data indicate that under conditions of large and widespread infestations, where mass emergence and multiple matings are probable, adult females will oviposit larger batches of eggs in shorter periods of time, without subsequent

reduction in viability. Under conditions of small and localized infestations and few adults emerging (probable single matings) males are capable of inseminating several females without reduction in the transfer of a viable spermatophore. Under these conditions females would live longer, oviposit over a longer period of time but the egg batches would be smaller. The number of matings, however, does not appear to be an important factor with regard to fecundity since a full complement of eggs can be deposited regardless of mating frequency. The advantage of multiple matings lies with females releasing their egg batches over a shorter period of time. Because of the unpredictable environmental conditions into which adults emerge, multiple matings by females has a distinct survival advantage over single matings.

Table X. Comparison of single and multiple matings of Hylotrupes bajulus (L.).

Mating Regimes	Length of Copulation (sec.) $\bar{X}$ ± S.E.	Adult Female Longevity (Days) $\bar{X}$ ± S.E.	Oviposition Period (Days) $\bar{X}$ ± S.E.
Single[1]	186_a ± 27	12.7_a ± 0.63	5.45_a ± 0.56
Multiple[2]	194_a ± 16	9.3_b ± 0.52	3.07_b ± 0.39

[1]N = 29 adult females.

[2]N = 14 adult females.

[a]Means in columns followed by different letters are significantly different. $P<0.05$ Student t-Test.

Table XI. Comparison of single and multiple matings of Hylotrupes bajulus (L.).

Mating Regimes	No. Egg Batches $\bar{X}$ ± S.E.	No. Eggs $\bar{X}$ ± S.E.	Egg Viability[3] $\bar{X}$ ± S.E.
Single[1]	4.52_a ± 0.42	195.8_a ± 15.3	85.2_a ± 0.45
Multiple[2]	3.93_b ± 0.42	195.3_a ± 14.8	85.7_a ± 1.33

[1]N = 29 adult females.

[2]N = 14 adult females.

[3]$\bar{X}$ ± S.E. expressed as %.

[a]Means in columns followed by different letters are significantly different. $P<0.05$ Student t-Test.

Table XII. Fecundity of single-mated Hylotrupes bajulus (L.) females.

Female Position in Mating Sequence[1]	No. Egg Batches $\bar{X}$ ± S.E.	No. Eggs $\bar{X}$ ± S.E.	Egg Viability[2] $\bar{X}$ ± S.E.
Female 1	3.8_a ± 1.5	204.8_a ± 62.8	81.3_a ± 8.5
Female 2	3.2_a ± 0.8	158.4_a ± 19.3	90.8_a ± 2.7
Female 3	4.3_a ± 0.9	194.8_a ± 37.2	87.0_a ± 3.2
Female 4	4.8_a ± 0.9	188.6_a ± 23.1	90.3_a ± 3.4
Female 5	4.8_a ± 0.9	219.4_a ± 41.2	83.5_a ± 6.6
Female 6	6.2_a ± 0.9	208.8_a ± 39.2	81.6_a ± 6.4

[1] 5 reps. of 6 females each.

[2] $\bar{X}$ ± S.E. expressed as percentage.

[a] Means in columns followed by different letters are significantly different $P<0.05$, ANOVA.

Section VII

WOOD UTILIZATION AND METABOLIC EFFICIENCIES OF OLD HOUSE BORER LARVAE, *HYLOTRUPES BAJULUS* (L.) (COLEOPTERA: CERAMBYCIDAE)

INTRODUCTION

Larvae of the old house borer (OHB), Hylotrupes bajulus (L.), play an important role in the destruction of seasoned softwood used in buildings and other structures. According to Becker (1979) the OHB is found on every major continent, and is considered a major structural insect pest. The OHB was introduced into the U.S. over 200 years ago and is second to the subterranean termite in its ability to damage buildings and structures (St. George et al. 1957). In spite of the damage caused by this pest, little information is available on its biology other than studies of the life history and distribution.

The information available on the quantitative aspects of larval feeding is limited. Larvae of this cerambycid may take from 2 to 11 years to become full grown, depending on the temperature, relative humidity and the nutritional content of wood. Wood consumption and utilization were studied by Becker (1963) and Rasmussen (1967) and their work showed that larvae utilize only a small portion of the carbohydrates available in their food. The influence of changing temperature on wood utilization and oxygen consumption by OHB larvae has not been considered.

The purpose of this study was to quantify wood consumption, utilization, larval growth and respiration in three size classes of OHB larvae under different temperatures at a constant relative humidity. Results of this study provide information on the ecology of this wood-feeding Coleoptera as well as practical information on how the energy pattern of larvae vary under different temperatures.

MATERIALS AND METHODS

The OHB larvae used in this study were selected from the VPI&SU laboratory colony (Cannon 1979). Studies were conducted in environmental chambers maintained at constant temperatures of 15°, 20°, 25°, 30° and 35°C. This regime represents the approximate range of temperatures normally encountered by OHB larvae infesting wooden structures along the Eastern coast of N. A. (Moore 1978, St. George et al. 1957). Relative humidity (RH) was maintained in the range of 70-80% with KOH solutions (Solomon 1951).

The larvae used in this study were divided into three distinct weight classes since the number of larval instars of the OHB have not been accurately determined (Rasmussen 1967). Seventy-five larvae were equally divided among the three weight classes: small, 63.6 to 74.3 mg; medium, 134.8 to 155.2 mg; and large, 235.2 to 245.9 mg. Five replicates of each weight class were conducted at each temperature. Initial mean weights were not significantly different within each class and temperature (ANOVA; $P<0.05$).

Wooden blocks (5.0 x 2.5 x 1.5 cm), cut from outer sapwood portions of southern yellow pine (Pinus spp.), were used for larval feeding. Holes (3-7 mm) were drilled in the end of each block, to provide an access for larvae, and the blocks were oven dried at 100°C 24 hr and the dry weight recorded. All blocks were then stored for 15-30 days at 30° ± 1°C and 70-80% RH to equilibrate their moisture content.

Larvae were transferred into blocks and each block placed in a separate aluminum tray to retain ejected frass and to prevent cross feeding by adjacent larvae. After a 21 day feeding period, all blocks were removed from the environmental chambers and the final weight of each larva recorded. Frass was scraped from the feeding galleries, oven dried (100°C, 24 hr) and the dry weight recorded. Since the majority of OHB feces is undigested food (Durr 1956) no attempt was made to separate uneaten scrapings from frass pellets. Dry weight measurements of remaining blocks were also made to determine the amount of unconsumed wood. The amount of wood consumed per larva was calculated as the difference between the initial and final dry weight of a block. All weight determinations were made on a Mettler RH-20 balance.

The wood consumption index (CI), growth rate (GR) and utilization index (ECI) were measured by the gravimetric techniques established by Waldbauer (1968). The following ecological parameters were computed on the basis of live larval weight and dry weight of food consumed.

Wood Consumption Index $CI = \frac{C}{WT \cdot T}$

C = total dry weight (mg) of wood eaten

WT = average weight (mg) of larvae during feeding period

(i.e., $\frac{\text{Initial wt. + final wt.}}{2}$)

T = duration (days) of feeding period

Relative Growth Rate $GR = \frac{G}{WT \cdot T}$

G = weight (mg) gain or loss during feeding period

Efficiency of conversion of ingested food to body substance

$ECI = \frac{GR}{CI}$

Hourly respiration rates for each of the surviving OHB larvae were determined at the temperature in which the larvae had been held during the study. Respiration rates were determined in a Gilson-Differential Respirometer (Model IGRP-14) equipped with 25 ml reaction vessels. An equilibrium period of 1 hr was followed by a 2-3 hr determination period. The reaction vessels contained 0.2 ml KOH solution to absorb CO_2 and maintain RH.

RESULTS AND DISCUSSION

Temperature exerted a significant influence on the metabolic activities of OHB larvae. The temperature effect was reflected in the ecological performance values as shown below.

Consumption Index. Significant reduction in the consumption index (CI) were observed for all larval classes at temperatures of 15° and 35° (Table XIII). These values were lowest for large larvae (0.55 and 0.042 mg/mg/day, respectively) and highest for small larvae (0.318 and 0.103 mg/mg/day, respectively). Consumption indices for larvae in the 20° to 30°C range, within each class, were not significantly different except for medium larvae at 20°C.

These data are in partial agreement with Becker (1949), Cymorek (1968) and Rasmussen (1967) who reported that optimal feeding occurs in the temperature range of 28-30°C. These results indicate that OHB larval CI are not significantly reduced in the temperature range of 20°-30° but that feeding activity is significantly inhibited at temperatures below 20° and above 30°. Wood consumption data are in agreement with

previously published work (Cannon and Robinson 1981) and are provided to show the destructive potential of OHB larvae within each weight class and temperature.

Growth Rate. Table XIV provides data on the mean weight gain or loss and the growth rate (GR) of OHB larvae. Weight gains and GR values among small larvae were not significantly different, despite a significant reduction in the CI at temperatures of 15° and 35°C as noted in Table XV. At 15° and 35°C the small larvae converted small amounts of wood to body weight more effectively than medium and large larvae under similar conditions. Reichle (1967) provided a possible explanation for this. He found that energy metabolism does not vary directly with simple body weight but varies with the metabolically-effective body weight. Larval growth experiments by Rasmussen (1967) also support this finding. He reported that small larvae gain weight faster than medium and large larvae. This phenomenon was attributed to the presence of a higher concentration of digestive enzymes in the small OHB larvae. In this study results indicate that small OHB larvae are metabolically more efficient than medium and large larvae.

Growth rates by medium and large larvae in the 20° to 30°C range were not significantly different. Negative GR values were recorded for both medium and large larvae at 15° and 35°. These data relate well to the low CI recorded for larvae under these conditions.

Efficiency of Utilization. The relationship between weight gain and food consumption provides a measure of food utilization and is also referred to as the efficiency of conversion of ingested food to body

weight (ECI). Waldbauer (1968) stated that the ECI is an overall measure of an insect's ability to utilize for growth the food which it ingests. Table XV shows that the potential for this species to consume wood and convert it to biomass (weight gain) is reduced in most cases at temperatures below and above 20° and 30°C, respectively. The ECI of small larvae was not significantly different except for those held at 35°C. The high ECI (11.76%) of small larvae at 35°C reflects the overall lower energy demands of these larvae. Medium and large larvae recorded negative ECI's at 15° and 35°C indicating that their low CI was inadequate in providing sufficient energy for their metabolic needs under these conditions. There was no significant difference in ECI for medium and large larvae at other temperatures.

Respiration Rate. Respiration is a measure of metabolic activity and a good indicator of larval activity and physiological state. The respiration rates (µl. O_2/mg dw/hr) for OHB larvae at each temperature are given in Fig. 1. Small OHB larvae had the highest respiration rates. The small larvae at 35°C recorded lower O_2 consumption than larvae at 30° and 25°C, indicating lower activity and lower energy demands, possibly due to heat stupor. The overall higher respiration rates of small OHB larvae may be due to the observed phenomenon that metabolic rates (per unit weight) tend to decrease as body size increases (Reichle 1967). Another factor affecting respiration rates is the presence of fat reserves. Scriber and Slansky (1981) stated that fat reserves (metabolically less active tissue) frequently increase in later instars and contribute to a decline in relative respiration rates.

Respiration rates for medium and large larvae increased with increasing temperature (Fig. 1). Low and high respiration rates at 15° and 35°C for these larger larvae relate well to the low consumption and low growth at these temperatures. These results are not in agreement with those by Becker and Damaschke (1963) who reported that respiration in larger larvae decreased with increasing temperature. However, their studies did conclude that more work was needed in this area.

CONCLUSION

These results determined gravimetrically are in close agreement with those obtained for other wood feeding Coleoptera having a similar life history. As a general rule, slow growth is associated with low CI and low ECI in wood chewers which require more than one year to develop. The CI for OHB larvae, which require 2 to 11 years to develop, ranged from 0.042 to 0.600 mg/mg/day. Temperature was a major factor in determining the CI. These CI values are low when compared to leaf feeding Coleoptera (0.97 mg/mg/day) with univoltine life cycles (Van Hook and Dodson 1974).

The GR values for OHB larvae in the temperature range of 20°-30°C varied from 0.0053 to 0.0018 mg/mg/day. These values are similar to those reported by Ikeda (1979) (0.0124 - 0.0323 mg/mg/day) from another wood boring cerambycid. The lowest growth rates are reported for tree-foliage-chewing Coleoptera with values ranging from 0.001 to 0.11 mg/mg/day (Scriber and Slansky 1981).

Wood utilization is affected by factors which influence the amount of energy devoted to the maintenance of physiological functions

and the support of activity. In this study the ECI was influenced by the temperature at which the larvae were held. Temperature played a significant role in the amount of wood utilized for growth and that which was metabolized for maintenance purposes. Except for small larvae, the highest ECI values were reported at the 20° and 25°C temperatures.

The respiration rates provided a measure of larval activity and physiological state. In this study the effects of temperature were reflected in low and high respiration values for medium and large larvae at 15° and 35°C. From this study it can be concluded that developmental rates of OHB larvae are affected by temperature and that medium and large larvae are affected to a greater extent by changes in temperature than small larvae.

Table XIII. Mean larval wood consumption and consumption index (CI) for 21 days at constant temperature and RH.

Temp. Regime (°C)	No. Larvae Surviving	Mean (Dry) Weight Wood Consumed (mg)	CI mg/mg/day
		SMALL LARVAE	
15	5	418.0	0.318 a*
20	4	725.0	0.455 b
25	4	762.5	0.523 b
30	4	925.0	0.600 b
35	4	150.0	0.103 c
		MEDIUM LARVAE	
15	5	246.0	0.082 a
20	5	990.0	0.336 b
25	4	1575.0	0.513 c
30	4	1625.0	0.483 c
35	5	222.0	0.079 a
		LARGE LARVAE	
15	5	246.0	0.055 a
20	5	1600.0	0.300 b
25	4	1750.0	0.350 b
30	4	1175.0	0.243 b
35	4	182.0	0.042 a

*Means followed by different letters in each column are significantly different; Duncan's Multiple Range; $P<0.05$.

Table XIV. Mean larval weight gain or loss and relative growth rate (GR) for 21 days at constant temperature and RH.

Temp. Regime (°C)	No. Larvae Surviving	Mean Weight Gain or Loss (mg)	GR mg/mg/day
		SMALL LARVAE	
15	5	8.32	0.0054 a*
20	4	14.13	0.0093 a
25	4	17.55	0.0118 a
30	4	18.33	0.0095 a
35	4	14.20	0.0085 a
		MEDIUM LARVAE	
15	5	-7.60	-0.0010 a
20	5	25.86	0.0088 b
25	4	16.48	0.0055 b
30	4	14.30	0.0053 b
35	5	-6.70	-0.0028 a
		LARGE LARVAE	
15	5	-31.32	-0.0068 a
20	5	58.60	0.0110 b
25	4	31.83	0.0063 b
30	4	33.20	0.0065 b
35	4	-42.50	-0.0098 a

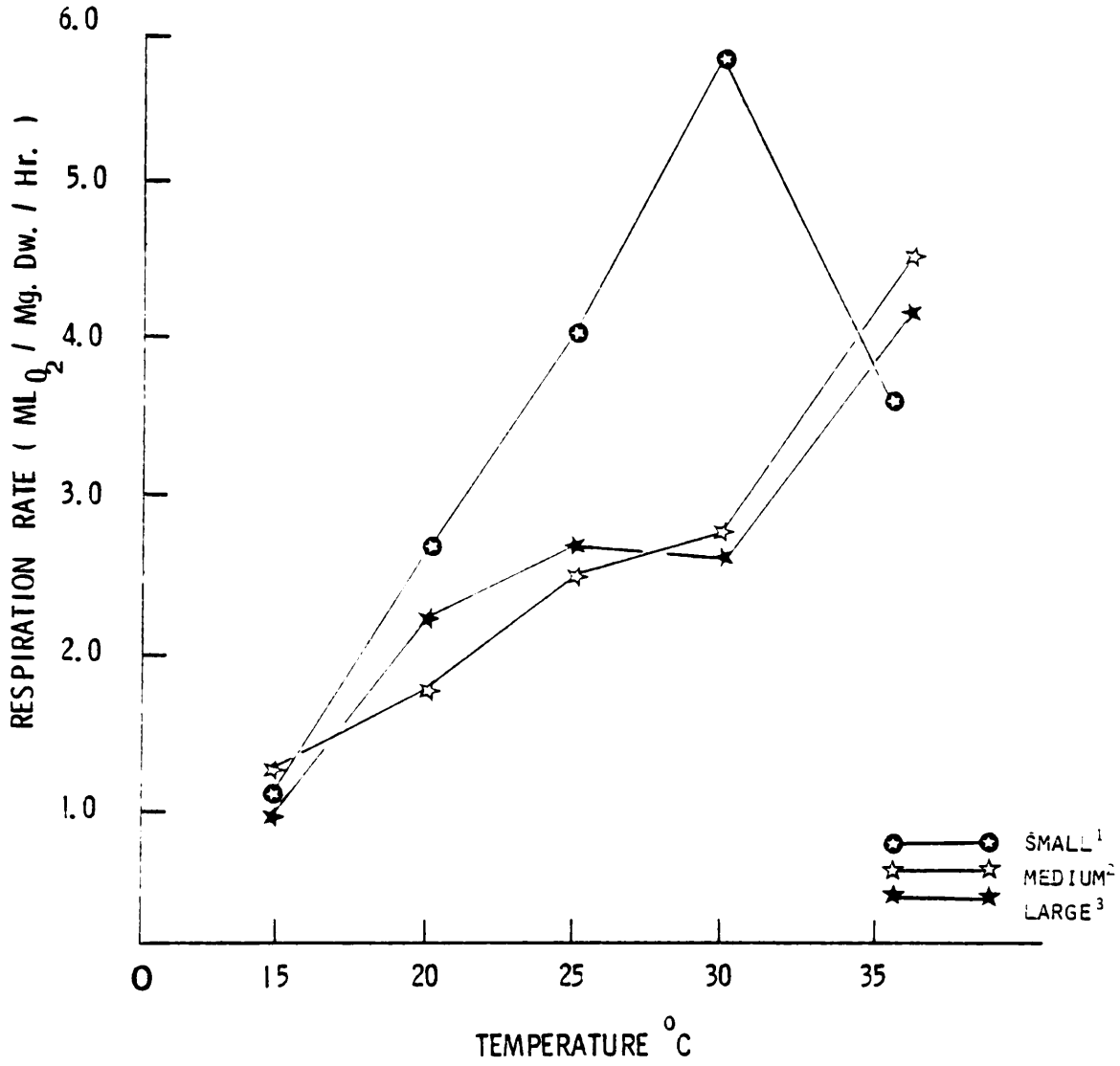
*Means followed by different letters in each column are significantly different; Duncan's Multiple Range; $P<0.05$.

Table XV. Efficiency of conversion of ingested wood (ECI) by old house borer larvae for 21 days at constant temperature and RH.

Temp. Regime (°C)	No. Larvae Surviving	ECI Mean %
	SMALL LARVAE	
15	5	1.81 a*
20	4	1.92 a
25	4	2.37 a
30	4	1.63 a
35	4	11.76 b
	MEDIUM LARVAE	
15	5	-2.32 a
20	4	2.93 b
25	4	1.00 b
30	4	0.95 b
35	5	-8.14 a
	LARGE LARVAE	
15	5	-17.76 a
20	4	3.56 b
25	4	1.60 b
30	4	2.84 b
35	3	-23.48 a

*Means followed by different letters in each column are significantly different; Duncan's Multiple Range; $P<0.05$.

Fig. 1. Mean Respiration Rates of H. bajulus Larvae at 5 Constant Temperatures and R H



[1]N = 5, 4, 4, 4, 4 at each temperature, respectively.
[2]N = 5, 4, 4, 4, 5 at each temperature, respectively.
[3]N = 5, 4, 4, 4, 3 at each temperature, respectively.

Section VIII

SUMMARY

The old house borer has been present in the U.S. for over 200 years. During this time limited biological studies have been conducted. The biological data contained in these studies are based on casual field observations and reports from Europe and South Africa. The data presented here represent the first attempt in the U.S. to colonize and study the OHB under field and laboratory conditions.

It is evident from this research that the OHB exhibits an extreme amount of biological plasticity. A North American biotype of the OHB was established through comparisons among populations on each continent. Laboratory and field observations compiled over several years form the foundation of the N. A. biotype. The delineation of the N. A. biotype is based on female fecundity and variation in the developmental rates of all life stages.

The apparent differences noted in fecundity and developmental rates among biotypes prompted further laboratory investigations. Attempts were made to measure the degree of genetic divergence between the N. A. and European biotype. When these biotypes were reared under identical conditions the biological variation reported under field conditions was not seen. Results indicate that this species has undergone little genetic divergence and that differences between biotypes have originated from interactions of the genotype and environment. This high degree of biological flexibility allows the OHB to inhabit marginal habitats and explains its present world-wide distribution.

An oligidic diet was developed for laboratory rearing of the OHB. This diet was concocted in an attempt to reduce larval mortality,

attributed to handling and to reduce the larval developmental period. The diet was composed of ground host tissue (southern yellow pine), cellulose, agar and various nutrients required by this species. OHB were reared from egg to adult in 9-11 months with a decrease in overall mortality. No significant variation was noted in the morphology of diet reared adults, larvae, pupae or eggs when compared with conventional rearing methods. Behavior appeared normal. Diets allowed for the direct observation of developing larvae and for improved synchronization of adult emergence. Nutritional requirements can now be monitored through the development of meridic and holidic diets.

Experiments on the mating behavior and egg production of the OHB showed that total fecundity was not influenced by the actual number of matings. However, when females are allowed to mate randomly they oviposit larger batches of eggs in shorter periods of time. The importance of this finding lies in the fact that females often emerge into unpredictable environments (attics and basements). Under elevated temperature conditions the female longevity is reduced 2 or 3 days. The female, by releasing her full complement of eggs in a short period of time, assures the establishment of her progeny. This study also noted the presence of intrasexual mating behavior between males of this species. These aggressive displays play an important role in mating. Male aggressive and guarding behaviors undoubtedly help to reduce the occurrence and success of inseminations by other males. This in turn would reduce the chance of sperm competition and increase fitness.

The studies of wood utilization and conversion efficiency indicate that larvae can withstand a wide range of thermal conditions

(20° - 30°C) with no significant reduction in the ecological parameters measured. However, consumption, growth, utilization and respiration are significantly altered above and below a threshold temperature of 20° and 30°C. It appears that small OHB larvae are not affected to the same degree by environmental change as medium and large larvae. These findings support earlier statements relating to the high degree of biological flexibility inherent in this species.

In conclusion the status of the OHB as a serious structural pest in the eastern U.S. is not likely to change. Recent studies (Cannon and Robinson 1982a) show that the OHB can survive and reproduce outside of man-made structures. The ability of the OHB to live in unprocessed lumber in conjunction with interstate movement of construction materials provides the opportunity for this pest to extend its range. Various aspects of this study show that the OHB exhibits a high reproductive rate and a wide range of biological flexibility. Recent advances in home insulation resulting in air-tight homes and poor ventilation increase the chance that wood will remain suitable for larval feeding and development. The softwood timber used in construction of modern buildings contains a high percentage of sapwood providing an excellent food source for developing larvae. The results of this study provide an accurate data base from which to develop management programs and for the purpose of educating homeowners, Cooperative Extension personnel and professional pest control operators.

The results of this research indicate that future work is needed on the OHB in N. A. Biotype analysis should focus on the response of

larvae to extremes in temperatures. Artificial diets of the meridic type should be investigated. Results would allow for a precise understanding of the nutritional requirements of the species. Future research on adult mating behavior should involve male to male interactions and investigate the presence of sex pheromones. Utilization studies concentrating on cellulose digestion throughout a range of temperatures would aid in understanding the physiological response of OHB larvae occurring within their microhabitat.

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VITA

Kevin F. Cannon was born May 24, 1952, in Bethesda, Maryland. He is the son of Vincent P. Cannon and Margaret A. Cannon. He attended St. Jude's Elementary School in Rockville, Maryland and graduated from Robert E. Peary High School in June, 1971. He began undergraduate studies at Frostburg State College in the same year. In 1976, he received a Bachelor of Science degree in Biology. He began graduate studies at Virginia Polytechnic Institute and State University, Blacksburg, Virginia, in 1976, working towards a Master of Science degree in Entomology. On September 9, 1978 he was happily married to Nancy Diane Prichard of Baltimore, Maryland.

Mr. Cannon received a Master of Science degree in June, 1979 from the Department of Entomology. Immediately following graduation he began studies towards a Ph.D. degree also in Entomology.

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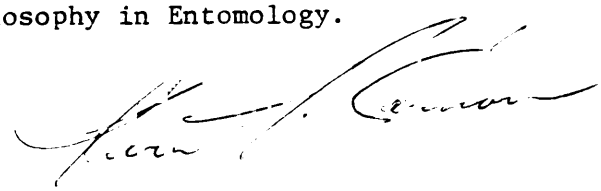

LIFE HISTORY STUDIES OF THE OLD HOUSE BORER, *Hylotrupes bajulus* (L.), (COLEOPTERA: CERAMBYCIDAE)

by

Kevin Francis Cannon

(ABSTRACT)

A North American biotype of the old house borer, *Hylotrupes bajulus* (L.) was established from field and laboratory data. This biotype is based on differences in size and longevity of the life stages and on adult fecundity. N. A. females were observed to oviposit a mean of 165.1 ± 15.5 eggs in comparison to 119.4 (South African) and 105.2 (European). Oviposition period was 5.2 ± 0.5 days for the N. A. biotype and 3.9 and 12 days for the South African and European, respectively. Eggs of the N. A. biotype were smaller than those of the South African and incubation period (8.5 ± 0.3) shorter than both South African (14.0) and European (9-12). Development and comparisons of the pupal and larval stages are presented and discussed.

Comparisons of the N. A. and European biotypes under similar temperature, humidity and nutritional conditions found no significant differences between biotypes. These results indicate that the biotypes have undergone little genetic change since their separation over 200 years ago. The old house borer is quite responsive to environmental conditions and the biological variation noted in field populations is attributed to non-genetic modifications of the phenotype. The high degree of biological flexibility noted in this species allows the OHB

to inhabit marginal habitats and explains its present world-wide distribution.

The OHB was successfully reared from egg to adult in 9-11 months on an artificial diet. An oligidic diet was developed and was composed of ground host tissue (southern yellow pine, Pinus spp.), purified cellulose, agar, and basic nutrients. This diet provided an adequate physical and nutritional environment as noted in the reduction in larval mortality and developmental period when compared to conventional rearing methods. Comparative nutritional, physiological and behavioral studies are now possible between larvae feeding on artificial diets and conventional wooden blocks.

Observations of the adult mating behavior, fecundity, oviposition period and egg viability were reported under two mating regimes: single and multiple. Fecundity and egg viability were not significantly different between regimes. However, the number of egg batches, length of oviposition period and the longevity of adult females were significantly different. Adult behavior between regimes was not noticeably different. Males actively compete for females when other males are present and aggressive interactions are common. The practical and evolutionary significance of single and multiple matings is discussed.

Consumption, growth, utilization and respiration by three weight classes of old house borer larvae, under 5 constant temperatures and relative humidity were studied. Wood consumption in all larval weight classes was greatest in the temperature range of 20° to 30°C and significantly reduced below and above these temperatures. Growth rates for small larvae were not significantly different among temperatures.

Medium and large larvae recorded negative growth rates at 15° and 35°C. Wood utilization was greatest at temperatures of 20° and 25°C. Respiration rates were highest for small larvae. Small larvae were apparently more efficient at converting wood ingested to biomass at all temperatures.