Insect damage as a function of climate

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Abstract

Successful insect development is dependent on a number of factors. The availability, quality and quantity of suitable food is a primary one, but other factors such as light, access to undisturbed areas, proximity to other insects of the same species, are others. Fundamental to insect growth, however, are environmental factors of temperature, relative humidity and moisture content of food materials. When a combination of favourable factors leads to increased insect development there is a co-related increase in the damage to materials through eating, despoiling, burrowing and other activities.

Museums and other institutions holding historic and artistic collections have seen a rapid increase in insect damage in the last ten years. Some of the increased attack is due to the banning of powerful pesticides, but other factors have increased the number and variety of insect pests attacking collections. External warming of the environment, through global warming and high internal temperatures in buildings, have energized insect pests to eat and breed faster, thus increasing their propensity to cause more collateral damage. Additionally, the higher ambient temperatures have allowed warm and hot climate insect pests to migrate and thrive in countries and buildings formerly too cold for them to survive.

The changing internal and external climate with increasing temperatures, and its effect on relative humidities and the moisture content in organic material, requires a review of Integrated Pest Management policies in museums to accommodate current changes and future predictions.

Introduction

Insects are small and secretive. They are usually to be found in tiny microclimates such as under skirtings, behind backboards and embedded in material. The microclimate will not be identical to the environmental conditions measured in the room or building, which if satisfactory, can lead to complacency that insects are not present.

Insects are cold blooded invertebrates; therefore their energy requirements to live, eat and breed are acquired from external heat sources and from metabolising food. Their moisture requirements are also normally satisfied from the food they eat through the metabolism of the food to generate water, though some will drink liquid water. Most insects prefer conditions of higher temperatures (above 25°C) and higher relative humidities (above 70%RH), although some can tolerate different conditions [2].

The surface area of an insect varies with the square of its radius, while its volume varies with the cube of its radius. Small insects have a very high surface area to body volume and therefore an intimate relationship with their environment, in terms of heat and moisture loss or gain.

Most insect pests in temperate climates have optimum development at temperatures between 20°C and 35°C. At temperatures below 15°C mating is limited, and movement such as flying becomes sluggish. Above 35°C some insects can cool themselves for short periods by evaporating water from their bodies, but in the longer term can die from desiccation. Some insects such as cockroaches, can acclimatise themselves to different temperature norms, but are then killed if subjected to other conditions.

Moisture requirements for insects are satisfied in a number of ways. Some insects, such as silverfish *Lepisma saccharina)* and furniture beetle *(Anobium punctatum)* obtain their moisture from the food they eat. They therefore require that the food has a suitably high moisture content and this is related to the ambient relative humidity of the surrounding environment and other mechanisms to dampen the food source. A few pest insects such as Australian spider beetle *(Ptinus tectus)* and some cockroaches *(Blatta spp)* require liquid water to survive. A small number of insect pests such as the webbing clothes moth *(Tineola bisselliella)* and biscuit beetle (*stegobium paniceum*) can exist at low relative humidities in water-free areas by processing their foods to produce metabolic water.

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HIGH AMBIENT TEMPERATURES

The historic and artistic collections in the UK and elsewhere are subject to higher ambient temperatures than they were twenty years ago. With global warming, annual temperatures are up to 2-3°C higher than in 1980. For example, the 1990's was the warmest decade in the UK since records began [3], and in some areas such as the south west of England, winter frosts are now a rarity. The result of this is that many insect pests are not killed or culled by cold winter conditions, but can survive and breed throughout the year [4]. In some insects, the temporary cessation of growth known as 'diapause' which often helps the insect through the cold months, is bypassed completely in warm conditions, while in others where a different mechanism such as day length triggers the diapause, it may continue to occur.

Indoors, comfort conditions have gradually been raised over the last few decades. In the UK in the 1970's, there was legislation to limit the upper temperature in government buildings to a maximum of 19°C. Now, comfort conditions are normally 22°C or above. Centrally heated galleries and collection storage areas now have high ambient temperatures all year round [5].

Additional heat sources such as conservation heating and dehumidifiers, and solar gain are often present in galleries and storage areas, raising the ambient temperature which is already higher than in previous years from the global warming effect.

EFFECTS OF HIGH AMBIENT TEMPERATURES

Insects live at temperatures that are very close to their surroundings [6]. Higher long-term temperatures cause the following trends:

- higher energy levels.

  For most insect pests, temperatures above 15°C up to 35°C cause increasing energy levels that lead to greater mobility, higher feeding rate, higher reproduction rates, greater egg production and lower mortality. These factors can be subdivided as follows:

- greater mobility.

  For insects to fly, they normally need high body temperatures. The furniture beetle *(Anobium punctatum)* does not fly readily at temperatures below 25°C and death watch beetle *(Xestobium rufovillosum)* needs temperatures in excess of 27°C to fly. Flying obviously increases the spread of insect attack to other areas.

  In general, lower temperatures below 25°C, limits the flying and thus the spread of insect pest adults. Temperatures in this range also limit the mobility of larvae and thus the spread of an infestation outside a localized area.

- increased egg laying.

  Insects such as the webbing clothes moth (*Tineola bisselliella*) produce more eggs at higher temperatures. In experiments at 80%RH *Tineola* females laid about 80 eggs at 25°C, but up to 100 eggs at 30°C. Even though eggs can still hatch at 35°C, males quickly (within 2 days) become sterile and all stages are killed in four hours at 41°C [7]. Similar results are seen with a number of other pest insects, with egg production peaking at about 30°C and then dropping off rapidly.

  At low temperatures, below about 15°C, reproduction and egg-laying is greatly reduced for many insects and for *Tineola* stops completely below 10°C, even though the insect can still survive.

- fast development times.

  The incubation time of eggs of silverfish (*Lepisma saccharina*) ranges from over 40 days at 22°C to under 20 days at 32°C. However, adult's lives are shortened by higher temperatures, so they may live 31/2 years at 27°C; 2 years at 29°C but only 11/2 years at 32°C. Other insects show similar trends but often around a different norm, thus the furniture beetle (*Anobium punctatum*) develops best at about 22°C and stops at about 28°C.

  Webbing clothes moth (*Tineola bisselliella*) was formerly considered to have an annual life cycle, but in recent years, two or even three generations a year have been observed in some indoor UK locations. Similarly, some woodborers such as furniture beetle (*Anobium punctatum*) and death watch beetle (*Xestobium rufovillosum*) appear to be completing their larval stages in appreciably shorter time than in former years.

  Very high temperatures above about 40°C will kill most insects at all stages within a few hours [8].

- introduction of new 'warm weather' pests [9].

  With higher outside and indoor temperatures, insect pests acclimatised to warmer conditions can thrive in formerly inhospitable locations. The mosquito that can carry malaria now breeds in north Wales and termites had established themselves in the South West of England – though they are now eradicated. Indoors, the brown carpet beetle *(Attagenus smirnovii*) originally from Kenya, is now resident in many London museums, and the Guernsey carpet beetle (*Anthrenus sarnicus*) is relentlessly moving northward towards Scotland. The varied carpet beetle (*Anthrenus verbasci*) was considered to be the major pest of woolen textiles in Britain 30+ years ago, and webbing clothes moth was not considered to be a pest. Now that situation is reversed [10], though the reason may be due to other factors such as the use of pervasive insecticides such as dieldrin, used in the 1960's in sheep dips.

- other effects.

  There may be a number of other temperature effects, that affect the development of certain insects, such as the spread of sex pheromone attractants.

Effects of low ambient temperatures

Temperatures below accepted human comfort levels of 20-25°C, increasingly affect insect's metabolism, slowing down movement, feeding and reproduction [11]. In many pest insects that are acclimatised to human comfort conditions within buildings, reproduction stops below 15°C and movement virtually ceases below 10°C. Insects in various life stages can survive at these low temperatures. Many lower their internal water content before entering hibernation and generate glycerol in the haemolymph to act as an anti-freeze during these diapausal states. Exceptionally, some insect larvae can freeze solid for short periods without harm.

Temperatures below -10°C will eventually kill all stages of most insects. It is generally accepted that the following temperatures and times will kill all stages:

-18°C to – 20°C	will kill in 10-14 days
-25°C	will kill in 7 days
-30°C	will kill in 3 days

This effect is used as one of the principal methods of pest control in many museums [12].

Effects of varying ambient relative humidities

Insects have high moisture contents and owing to their size, have very high surface area to volume ration, so they can readily lose moisture through evaporation. All insects have a waxy layer on the external cuticle which waterproofs it from loss of body moisture. However, they still lose water through respiration and defecation [13].

Water is obtained by insects in three main ways – by drinking water, as some beetles such as the Australian spider beetle (*Ptinus tectus*) can do, by ingestion of food with a high moisture content, which is the principal mechanism, or occasionally from the metabolism of dry food to produce chemical water.

Some insects can absorb moisture directly from the air. The firebrat (Thermobia), for instance, can accomplish this at RH's down to 45%. But most insects rely on the relationship between high relative humidities and high moisture contents in associated materials. Most insect pests therefore prefer areas of high humidity. The eggs and young larvae of furniture beetle (*Anobium punctatum*) do not survive when the moisture content of the wood is below about 12%, which corresponds to an equilibrium relative humidity above 65%. Some insects, including the webbing clothes moths, can survive at low ambient RH's as they can manufacture water by the metabolisation of the wool on which their larvae feed.

Effects of climate on pest control treatments

It is commonly known by pest control technicians that treatments are often not effective at low temperatures (below 20°C) [14]. This is because the low temperature reduces insect activity, so they are less likely to encounter the insecticide and their metabolism is lowered, so they will take longer to die.

High temperatures are known to increase the success of insecticidal treatments including fumigation and space spraying, as the insect's metabolism and activity is increased. Higher temperatures though, will break down chemical insecticides faster. Anoxic 'fumigation', now extensively used in museums, is very temperature dependent and is found to be relatively ineffective at temperatures below 15°C [15].

Conclusion

Temperature and relative humidity effects on insect activity are critical to their development and success. Higher ambient temperatures generally increase insect activity and the number of species able to exist in an internal and external environment [16]. Survival parameters for many insect pest species have been studied and are well understood. However, there is much less information about some of the more recently introduced pests, such as the brown carpet beetle. Knowledge of insect biology can be used to provide optimum conditions for the preservation of vulnerable material from insect attack. Furthermore, the information can be used to enhance the efficacy of pest control treatments.

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