First revision

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2. **STUDY DESIGN**
3. **VALIDITY OF THE FINDINGS**
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BASIC REPORTING

- Clear, unambiguous, professional English language used throughout.
- Intro & background to show context. Literature well referenced & relevant.
- Structure conforms to PeerJ standards, discipline norm, or improved for clarity.
- Is the review of broad and cross-disciplinary interest and within the scope of the journal?
- Has field been reviewed recently. It there a good reason for this review (different viewpoint, audience etc.)?
- Introduction adequately introduces the subject and makes audience and motivation clear.

STUDY DESIGN

- Article content is within the Aims and Scope of the journal.
- Rigorous investigation performed to a high technical & ethical standard.
- Methods described with sufficient detail & information to replicate.
- Is the Survey Methodology consistent with a comprehensive, unbiased coverage of the subject? If not, what is missing?
- Are sources adequately cited? Quoted or paraphrased as appropriate?
- Is the review organized logically into coherent paragraphs/subsections?

VALIDITY OF THE FINDINGS

- **Impact and novelty is not assessed.** Meaningful replication encouraged where rationale & benefit to literature is clearly stated.
- Conclusions are well stated, linked to original research question & limited to supporting results.
- Is there a well developed and supported argument that meets the goals set out in the Introduction?
- Does the Conclusion identify unresolved questions / gaps / future directions?

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Support criticisms with evidence from the text or from other sources	*Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.*
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Comment on language and grammar issues	*The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult. I suggest you have a colleague who is proficient in English and familiar with the subject matter review your manuscript, or contact a professional editing service.*
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Please provide constructive criticism, and avoid personal opinions	*I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC*
Comment on strengths (as well as weaknesses) of the manuscript	*I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.*

Common Insect Pests Homes and Heritage

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Insect pests represent a threat to the integrity of historic buildings and homes, causing a serious losses and irreversible damage. These pests can lead to extensive damage to organic materials, including wood, textiles, and paper. Beetles, termites, booklice, moths, and cockroaches are just some of the main insect pests that are frequently found in historic buildings and homes. Beetle species such as the furniture beetle and the Powder-post beetle are well recognised for their capacity to infest and feed on wood. Termite infestations can remind undetected and cause considerable damage that may even lead to the complete destruction of a building's structural integrity. Larvae moths are known to destroy textiles including carpets, furniture, clothes, and tapestries. Some wood-destroying species of cockroaches have the potential to harm historic buildings. Booklice have the ability to eat cellulose fibres found in archived papers and artefacts that are present in heritage buildings, causing deterioration and damage to documents over time. This paper reviews the literature and presents an overview of the major insect pests belonging to the four known orders Coleoptera, Blattodea, Lepidoptera, Zygentoma (Silver fish) and Psocoptera, which pose a threat to households, museums, depositories, libraries, and cultural heritage buildings. We also discuss their biology, their impact on human health, and the various potential approaches to identifying them.

Common Insect Pests Homes and Heritage

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Summary:

Insect pests represent a threat to the integrity of historic buildings and homes, causing a serious losses and irreversible damage. These pests can lead to extensive damage to organic materials, including wood, textiles, and paper. Beetles, termites, booklice, moths, and cockroaches are just some of the main insect pests that are frequently found in historic buildings and homes.

Beetle species such as the furniture beetle and the Powder-post beetle are well recognised for their capacity to infest and feed on wood. Termite infestations can remind undetected and cause considerable damage that may even lead to the complete destruction of a building's structural integrity. Larvae moths are known to destroy textiles including carpets, furniture, clothes, and tapestries. Some wood-destroying species of cockroaches have the potential to harm historic buildings. Booklice have the ability to eat cellulose fibres found in archived papers and artefacts that are present in heritage buildings, causing deterioration and damage to documents over time.

This paper reviews the literature and presents an overview of the major insect pests belonging to the four known orders Coleoptera, Blattodea, Lepidoptera, Zygentoma (Silver fish) and Psocoptera, which pose a threat to households, museums, depositories, libraries, and cultural heritage buildings. We also discuss their biology, their impact on human health, and the various potential approaches to identifying them.

Keywords:

Cultural heritage, museum, building, household, insect pests, beetles, Blattodea, termite, Coleoptera, Lepidoptera, Psocoptera, Zygentoma (Silver fish), human health, pest identification, cultural heritage.

Introduction

Historic buildings and their contents represent a huge cultural and national value for society, often embodying the history and distinctiveness of a location.[1] They may be constructed of or store a variety of materials including wood, textile, and paper.[2] For different reasons such as time, humidity, bacteria, and fungus, many of these historic buildings have been damaged over time.[3] Insect pests can be one of the causes of severe deterioration, particularly when all conditions are favourable.[4] Only 0.5% of the total number of known insect species are considered to be pests.[5]

Insect pests have been defined as any insect in the wrong place.[6] They have spread throughout the world as a result of globalisation, transportation, and international trade.[7], [8] Most household pests, such as fruit flies, cockroaches, moths, and mites invade our homes, often entering with infested commercial products. Currently, they have a cosmopolitan distribution,[9], [10] along with subterranean termites and wood-infesting beetles which share the same potential for widespread damage to houses, villages, towns, buildings, and other features. The human way of life creates favourable conditions for these kind of pests, which are closely related to human quality of life and health.[8], [11], [12]

Certain pests are known to destroy museum artefacts, historical books, museum, and may be found in buildings,[13], [14], [15], [16] inflicting damage through their consumption of a wide range of organic materials including wood, woollen fabrics, silk, leather, and paper.[13], [17], [18]

Economic losses caused by a single pest can reach up to 17 billion dollars per year.[19], [20] Despite the wide range of approaches to dealing with insect pests, the choice, effectiveness, and cost of them are problematic.[21], [22]

Although many studies have reported the infestation of historic buildings, museum objects, books, and collections with household pests and approaches to managing them [23],[16], [24], [25], [26], [27] to our knowledge a full review of these pests has not yet been conducted.

In this review, we will focus on the most major common pests threatening homes and historic buildings in Europe. The main insect species commonly observed in both heritage sites and human residences in France are shown in Table 1. We will look at their biology, the damage they cause, and their impact on human health, particularly insects in the order of the four major urban insect pests: Coleoptera, Blattodea (cockroaches, termites) Lepidoptera, Zygentoma "Silver fish" and Psocoptera (psoque). We will also discuss several promising approaches for pest identification and detection. Understanding domestic and cultural pests would contribute to more effective pest control programmes and reduce the threat to human life and heritage.

Survey Methodology

To ensure comprehensive and unbiased coverage of the literature, we implemented a multifaceted search strategy. This involved utilizing various reputable platforms including Web of Science, Google Scholar, Google Books, ResearchGate, PubMed, and other academic databases. Our search was tailored to encompass the specified orders: Coleoptera, Blattodea, Psocoptera, and Lepidoptera, as well as 'Historical building pest,' in combination with specific terms for each order. We meticulously scrutinized publications from these platforms, encompassing peer-reviewed articles, book chapters, and relevant case studies.

The inclusion criteria applied were as follows: publications had to focus on insects belonging to one of the four orders and have a documented impact on historical houses or museums. Studies that did not meet these criteria were excluded from our analysis.

Coleoptera

Coleoptera is another important pest that can have a negative influence on cultural heritage and human life.[28], [29] This order has the highest number of known species of any insect order,[30] and is divided into four suborders. Almost 90% of the family and species that have an impact on human existence are in the Polyphaga suborder.[31]

The principal beetle pests, which damage stored items, timber in buildings, packing cases, and furniture, belong to the families Ptinidae, Cerambycidae, Lyctidae, Curculionidae, Dermestidae and Bostrychidae.[32] Species such as *Attagenus unicolor* have been recognised as dangerous museum invaders. This insect, according to Back and Cotton (1938), attacks a wide range of animals, and feeds on grain products.[33] Other species, such as *Lyctus brunneus*, a tropical species that was first discovered in Venice in 1972, are known for their aggressiveness and proliferation (60–70 eggs per female).[34] *Stegobium panicum*, commonly known as biscuit beetles or herbarium beetles, and cigarette or tobacco, beetles (*Lasioderma serricorne*), eat dried fungus, paper, and adhesives.[35] are known to consume a variety of dried plant products, including biological specimens found in museum collections, as indicated by a study.[36]

Anobium punctatum, known as a bookworm, woodworm, or the common furniture beetle,[37] is the most common and damaging anobiid beetle in northern Europe and the UK.[38] It has been known to damage museums, cathedrals, castles, and other historical structures and grows in practically all native wild and cultivated wood species, as well as a few tropical kinds of wood.[39]

The most frequently observed species in both stored product and heritage buildings are classified into three categories: primary, secondary, and tertiary pests.[28], [37] The main families that have an impact on homes and historic buildings are listed below (Table 1).

Bostrichidae (the lesser grain borer). This family includes more than 700 species, most of which are wood borers**.** Powderpost beetles are named after the larvae and adults of the bostrichid beetles, which can transform bamboo and sapwood timber into a powdery frass. As a result of this, the forestry and lumber-dependent businesses have experienced enormous economic losses.[40] Larvae live in the sapwood and cambium of dead, injured, or newly cut and stored branches and trunks, which has aided the spread of foreign species from one country to another.[32]

The most common pest species, *Dinoderus minutus*, has a worldwide spread and poses a danger to maize and attacks bamboo-based structures and structures. Breeding sites include rattan goods and wooden container crates.[40], [41]

Lyctus linearis and *Lyctus brunneus* are worldwide xylophagous beetles that attack wood. They damage furniture, woodwork, and other materials. The entomologist P. Lesnes discovered these species in a collection of museum woodwork during his research.[42], [43]

In many parts of the world, particularly tropical and subtropical regions, *Rhyzopertha dominica* is a major pest of grain crops. This cosmopolitan, polyphagous insect pest can cause huge economic losses in stored goods.[44], [45], [46] This species has been found in botanic remains kept in the Liverpool Museum in the UK.[47] Another important species that damages furniture is *Bostrichus capucinus*, which can pierce lead plates with their powerful mandibles.[32]

Cerambycidae (longhorn beetles) or capricorn beetles. According to the literature, this family includes some of the world's most dangerous xylophagous species.[48] From an economic standpoint, it is one of the most significant groups of insects in the world, affecting forests, timber products, shade trees, and fruit and nut trees.[49] Most damage occurs in the larval stage and affects both softwoods and hardwoods.[50] *Hylotrupes bajulus* is one of the principal species in this family and is thought to be responsible for significant economic losses in wood and wood products.[51] This species poses a threat to historical furniture by attacking any wooden furniture, including antique clocks and carved wooden furniture, and it has been demonstrated that it prefers wood in long-term storage.[49], [51]

Silvanidae (sawtoothed grain beetle). *Oryzaephilus surinamensis* is a serious pest of stored goods[52] and a worldwide invader of packaged consumer foods. It enters through improperly sealed openings or tears in packaging and has a significant negative economic impact.[53], [54] It is listed as a very serious devastator, as it poses a threat to dates and other dried fruits.[55] Their rapid reproduction and profusion can cause them to invade many healthy spaces, such as packaging and stored empty bottles, leading to their presence when these are filled (Figure 01).

Curculionidae (weevils). This includes the most destructive tree-killing bark beetles in Europe, including *Scolytus multistriatus, Scolytus rugulosus* and *Ips typographus*, beetles from Cossoninae subfamily are a specialist group that generally develops in fresh to rotting wood,. *Amaurorhinus brewickianus* , *Pselactus spadix*, *Pseudophloeophagus truncorum*, . [56], [57]. These insects, through their feeding activities, caused the separation of certain artifact components on display at the museum. Causing significant ecological and economic damage.[58], [59], [60] The most destructive and widespread species, *Pentarthrum huttoni*, is found in historic buildings and human dwellings. It was first discovered in Austria and was responsible for the irreversible disintegration of 18th century wooden coffins.[61], [62] *Hexarthrum exiguum* has been identified as a harmful species from the external environment to historical goods made of wood.[63] It is known as the "pit-prop beetle" in Central Europe because it damages wet wood, primarily in mines but also in homes.[64] Species such as *Sitophilus granarius*, *Sitophilus oryzae*, and *Sitophilus zeamais*, colonise and destroy grain, and inflict significant losses on a global scale.[37] *Sitophilus granarius* is the most frequently discovered species in archaeological contexts and may be found in both tiny rural warehouses as well as huge storage silos.[65], [66]

Ptinidae. This family include both xylophagous insects and pests of stored goods (polyphagous insects) Table 2 represent the main insect species, particularly from this family, , and their respective distributions and potential damage.[32] Most insect species of the Anobiidae family are now included in the Ptinidae family. Some species of larvae lead to the deterioration of organic plant and animal matter. Some species consume dry excrement, others feed on animal corpses. *Ptinus sexpunctatus* , *Ptinus pyrenaeus and ptinus tectus* are examples of larvae that can be found in the nests of social hymenopterans, where they feed on their exuviae and organic waste (Figure 02).[67]

In 1941, the Department of Entomology at the British Museum highlighted 21 species identified as pests. The majority of them destroy stored goods of all kinds and belong to two sub-families, Gibbinae and Ptilininae, represented in the table below.[68] Woodborers such as *Anobium punctatum* (Coleoptera: Ptinidae, formerly Anobiidae), a widespread species, were common in furniture and historic buildings in the past, but with the rise of modern housing, they are now frequently found in museums and historic buildings. Wood-boring beetles have been found in wooden shipping crates and wooden pallets used to transport and protect works of art, which has resulted in infestation of these works with these pests as well as the contamination of museums. Three cases of infestation of newly manufactured picture frames in Austria between 2010 and 2015 and wooden pallets were all associated with the spread of various wood-boring beetles.[69], [70], [71] This pest is responsible for significant financial losses due to the irreversibly damage it causes.[39], [72] *Xestobium rufovillosum* ~~(xylophagous),~~ known as the death-watch beetle, is the largest species in terms of size. The larvae prefer aged oak timber rather than softwood and can damage wooden objects in museums and libraries if exposed to fungal decay.[73], [74], [75], [76] Infestation is favoured when humidity is high. In humid environments, fungus can soften the wood, which allows insect larvae to more easily tunnel through the wood while feeding on cellulose and hemicellulose.[77] *Oligomerus ptilinoides,* a species of beetle belonging to the Anobiidae family and native to the Mediterranean region, is renowned for its destructive impact on wood in some southern

European countries. It is particularly notorious for the extensive damage it inflicts on objects made from hardwood, such as furniture and works of art (Figure 03)[78].

Recently, *Gibbium psylloides,* which belongs to the Ptinidae family, was identified during a survey to determine the biodiversity of insect pests that infest the manuscript library of the Coptic Museum in Egypt.[79] *Lasioderma serricorne* (a polyphagous insect), known as the "cigarette beetle", is a serious pest of museums, books, and dried plants, in addition to being a pest of tobacco storage. Because of the harm it can do to dried herbarium specimens, this beetle is known as the "herbarium beetle" in hotter countries.[80], [81] Among the polyphagous insects, *Mezium affine* is known as the "spider beetle" because of its round body shape. The larvae feed on dried meat, dried mushrooms, seeds, wool, hair, feathers, leather, book bindings, insect collections, books, and all kinds of dried animal and plant specimens, which classifies them among the insects that threaten museums.[82] *Nicobium castaneum* poses a threat to all types of wood products, including composite wood, and typically destroys historical artefacts, eating old documents as well as every kind of paper, cardboard, parchment, and leather.[83] *Stegobium paniceum* (a polyphagous insect), is known as the "drugstore beetle" and damages dry plants, paper pulp, and starch-rich cardboard. It usually feeds on the bindings of old books that have been coated with starch glue, leaving tunnels.[36], [83], [84]

Dermestidae (hide and carpet beetles). Dermestid beetles can spread easily around the world as a result of international trade. The term "Dermestes" is derived from the Greek for "skin-eater".[85] They may also be found in a range of biological settings, including human residences, animal carcasses, and bird and spider nests. They have recently become prevalent pests in the burgeoning pet food sector in many wealthy countries.[86] Among the species of this family that are considered as pests of historic buildings and homes, are species from the genera *Anthrenus,* the larvae of which are harmful to different commodities of natural origin. Species from the genera *Anthrenus,* including *Anthrenus flavipes*, also known as the "carpet beetle", is a common pest that can cause damage to museums and households.[87],[88] It damages textiles, clothing, and items made of animal origin, such as wool, fur, feathers, and hide, in addition to carpet.[89] *Anthrenus verbasci* is a cosmopolitan species known as the "museum beetle" and has been detected on old books and the ethnographic textiles (Figure 04).[90], [91], [92] Also known as the "varied carpet beetle", it infests items such as carpets, woollen materials, silks, hides, furs, feathers, hair, horn, cereals, red pepper, fishmeal, and any processed animal or plant food. In common with other carpet beetles, this species will feed on cotton, linen, and synthetic fibres if they are contaminated with human excretions (blood, skin, hair).[93] Most species of the genera *Attagenus* species spread through infested bird nests, rodent carcasses, or dead birds,[10] such as *Attagenus pellio,* known as the "two-spot carpet beetle".[94] Another significant pests of organic artefacts in European museums are *Attagenus smirnovi,* also known as the "vodka beetle" or "carpet beetle" and *Trogoderma angustum* .[95], [96] *Attagenus unicolor,* known as the "black carpet beetle" is a household pest unique in its ability to digest complex proteins, and is widely recognised as a serious economic pest threatening stored products and museum collections.[97], [98].

Dermestes genus (Coleoptera: Dermestidae), can be serious pests threatening stored animal products, such as food, silkworm cocoons, leather and other textile items, and museum collections. Both the adult and larval stages are scavengers that favour dry, protein-rich organic matter.[99], [100], [101] The genus includes species that are of forensic interest, such as *Dermestes haemorrhoidalis, Dermestes ater, Dermestes frischii, Dermestes lardarius.*[101], [102], [103]

Trogoderma is one of the largest genera, containing approximately 130 described species and widely distributed.[104] This genera includes the khapra beetle, *Trogoderma granarium,* originating from India.[85] This is an extremely destructive species that is classified as a quarantine pest in the United States. The warehouse beetle *Trogoderma variable* is the most prevalent stored-product insect that is extremely fertile, a strong flyer, and can be found in and around processing facilities and storage warehouses.[105] It is one of the most frequent and devastating dermestid species.[106] It is uncertain whether the larger cabinet beetle *Trogoderma inclusum* is currently in Europe or the USA (Figure 05) .[107]

Biology

The biology of beetles is diverse, due to the high species number, although there are many common characteristics. Anatomically adult beetles (Coleoptera) have stiffened fore wings known as "elytra" covering the abdomen and separating them from other insects.[108] For some families, such as blister and false blister beetles, the body and elytra are soft.[109] The head contain the mouthparts that are adapted for biting or chewing [85]. There are has four stages in the lifecycle of beetles, and complete metamorphosis begins with the egg, through to larva, pupa and, finally, adult.[110]

Eggs are placed individually or in clusters on or in soil, living or dead plant debris, textiles, water, carrion, and, in rare cases, living animals. They hatch as vigorous larvae containing simple eyes (ocelli) and chewing, mandibulate mouthparts, and an abdomen segmented into between eight and ten parts. Most beetle larvae moult at least three times before becoming pupae.[31] Beetle larvae are often responsible for the most damage to different materials.[109]

In the UK, for example, adult *Anobium punctatum* beetles emerge between April and July and survive for 20–30 days. Females deposit their eggs in rough wood, end grain, cracks and crevices, as well as old flight holes. The eggs hatch within 15–25 days. Excreta (frass) is abundant in the larval tunnels, which is a gritty texture and has a barley-grain form. When the larvae are fully developed, the pupal chamber expands. After two to three weeks, depending on the family to which it belongs, the adults emerge, leaving a distinctive circular exit hole in the case of Ptinidae family and an oval-shaped hole in the case of the Cerambycidae family.[69]

Damage and impact on human health

In addition to the significant economic losses that affect a wide range of products, buildings and industry,[111], [112], [113] these pests also affect human health. Coleoptera do not threaten human life, but some beetle species may impact human health, such as the beetles of genera *Anthrenus, Attagenus, Dermestes*, and *Trogoderma* known as “carpet beetles” which can cause a cutaneous pruritic papulovesicular reaction due to the hairs (hastae) on the larval surface, which can lead to an allergic effect.[114], [115] In Malaysia, a case of Canthariasis intoxication of a one-year-old infant was thought to be due to *Lasioderma serricorne* larvae.[116] The dermestid beetle is known to infest human remains and can cause damage to bones and other tissue.[101] Other cases of allergies in wool workers and museum staff have been reported as being caused by Dermestid beetles.[94] One study has shown that Dermestids can produce chemical allergens.[86] Moreover, beetles such as *Anobium punctatum* play host to *Pyemotes ventricosus* mites, small arthropods that are tissue-juice feeders responsible for intensely pruritic erythematous maculopapular lesions with central micropustules.[117], [118], [119], [120] Where the volume of

Pyemotes exceeds the available supply of food, they have been known to occasionally bite mammals, including humans, causing dermatitis followed by a "comet sign" lymphangitis, as was the case of one Caucasian woman.[121], [122]

Other research suggests the possibility of isolating probiotic bacteria from the faeces of storage food insects such as *Tribolium castaneum,* and using it as a model system for screening.[123] Beetles can have a profound impact on human food supplies. One of the major concerns is their ability to attack grain reserves, leading to potential famine, particularly in communities which are heavily dependent on grains as their main source of sustenance.[124], [125], [126] When they infest stored grains, they consume and contaminate the food, resulting in substantial losses of crops and reducing the available food for human consumption. Moreover, the damage caused by beetles can compromise the quality and nutritional value of the grains, making them unsuitable for human consumption even if they are not entirely consumed.[127]

Blattodea

The Blattodea order includes both termites and cockroaches. Their existence goes back more than 300 million years,[128] with more than seven thousand species of blattodea,[129] including 3015 species of termites and around 4700 species of cockroaches.[130], [131], [132] Termites have evolved from "wood-eating cockroaches".[133]

Cockroaches are distinguished by the following characteristics: an oval-shaped body that is more or less dorsoventrally compressed, with the head partially or completely concealed by the pronotum. They possess long and filamentous antennae, and their forewings, when present, are typically hardened and leathery in texture.[134] They are classified into five families including the most primitive family, Cryptocercidae,[135] which shares several important traits with termites[136] and contains a worldwide xylophagous species with fewer than ten species.[137], [138] These five families include the Blattidae family, with more than 650 species and the Blattellidae family, with almost a thousand species .[139] Most species have a preference for inhabiting warm tropical and subtropical zones[132] The Polyphagidae family includes the smallest outdoor wood cockroach.

Cockroaches are one of the most common insects, with a high presence in cities. One percent of cockroaches, about 40 species, are considered to be pests.[140] Four to five species are significant as pests on a worldwide scale, classified as group I, based on their global distribution, significant economic impact, and potential medical significance. The remaining species are minor pests or have only local significance.[141] The most common significant cockroach pests include *Blattella germanica,* known as the German cockroach, which has been labelled as a museum pest due to its link to a case where it damaged museum artefacts, representing an example of the distinctive "herding" social structure that cockroaches have.[142] Transportation and international trade have favoured the spread of the German cockroach and it is now widespread throughout the world.[143] They are often observed in kitchens and bathrooms.[144] The *Periplaneta americana* cockroach, known as the American cockroach, is a tropical species that can be found around the world, particularly in ports.[145] This species is found mostly in the basements and ground floors of buildings. A comparative study between museums in Southeast Asia and North America revealed that this species is more commonly found in Asia than in America. In Asia, it is known to feed on starchy materials, sugary or fermented foods, as well as leather and parchment.[146], [147] *Supella longipalpa,* known as the brown-banded cockroach, is a household cockroaches that is spreading worldwide and has recently been found in buildings including hospitals, especially in urban areas. It is also referred to as the furniture cockroach.[147], [148] Research suggests that it has been a peridomestic pest for thousands of years.[149] *Blatta orientalis* or the Oriental cockroach represents the biggest cockroach pest in the United Kingdom. It lives in households and industrial buildings and has spread throughout the world.[150] These species are classified in third place as a common pest in textile museums.[151] Wood cockroaches include many species from the genera *Parcoblatta,* commonly found in the USA and other regions.[152] They consume and need a lot of moisture to survive, thus they are generally found among leaf debris and rotting wood. Wood cockroaches are occasionally found in moist basements, garages, woodsheds, and on decks under trees.[153]

Termites are small and can be white, brown or black. Commonly known as "white ants", with four wings of equal size, hence the name Isoptera,[154] termites have an almost worldwide distribution.[155] There are three main types of termites according to their preferred habitat: damp wood termites, which live in extremely moist wood but do not require mud or soil to survive, drywood termites, which prefer dry wood but do not require a close proximity to soil, and subterranean termites, which prefer to eat soft woods.[156] These are classified as posing the most serious problems to cultural wooden artefacts.[157]

Drywood termites as well as subterranean termites, are frequently found in museums in colder regions, and any of them can seriously harm priceless artefacts.[158], [159] In Australia, subterranean termites represent a major threat to the house building industry, due to their capability to damage the contents, fabric, and other materials used in the building of any type of house, including wood. Subterranean termites are like advanced cancer; once discovered it is too late to repair the destroyed structure.[160] There are 28 species of termites around the globe that are regarded as invasive. According to the literature, all pest species are wood eating and nest in food stuffs, and have a fast reproductive cycle. Most species belong to the Kalotermitidae and Rhinotermitidae families.[159] In South America, termite have been reported as structural or agricultural pests causing major damage.[161]

In Indonesia, historical buildings and cultural items are frequently infested by two termite species: *Coptotermes gestroi* and *Nasutitermes matangensis.*[162] The *Reticulitermes* species is widespread throughout the world and six species are the most prevalent in Europe. They are *R. santonensis* in western France, *R. grassei* in southwestern France, northwestern and southern Spain and Portugal, *R. banyulensis* in northeastern Spain, the central area of the Iberian Peninsula and southwestern France, *R. balkanensis* in the Balkans and *R. santonensis* in Northern Italy and Southeastern France.[163] The only two termite species were known to exist in Italy prior to the end of the 20th century were *Reticulitermes lucifugus* and *Kalotermes flavicollis*. Recently, the first report of *Reticulitermes lucifugus corsicus* was made in northern Italy.[164]

Biology

Termites and cockroaches are both part of the same order of insects known as Blattodea. While they may look very different on the surface, they share many similarities in terms of their biology and behaviour,[146] both being hemimetabolous insects.[165] Their development cycle consists of several stages, including the egg, nymph, and adult stages. Females are ovoviviparous (Figure 06).[166]

Cockroaches have a varied diet and are omnivorous scavengers, eating many organic decaying materials such as birds. Most species have smooth, flattened bodies that enable them to fit into small spaces, and they tend to live in crevices.[166] After adult cockroaches mate, the female lays an average of between five and 40 eggs, depending on the species of cockroach. The eggs are covered with an ootheca, a protective egg case.[167] The female deposits the case in a secret location and uses her saliva to adhere it to a surface. Within a month, immature cockroaches will emerge in warm environments. Cockroach juveniles moult between seven and eight times before they reach adulthood.[168], [169], [170] The time for a nymph to achieve adult stage depends on the species, with an average of between 126 and 365 days, when all the conditions for development are met.[171]

Both nymph and adult cockroaches have a mouth part containing strong tooth mandibles which are well developed for biting and chewing. In most cases, the adults have two pair of wings known as the "tegmina."[31]

Termite development includes an incomplete metamorphosis with a caste, such as nymphs, pseudergates, workers, soldiers, and several types of reproductive termites. Before becoming productive workers, nymphs hatch from eggs and moult at least three times.[141], [172], [173]

Damage and impact on human health

Termites and cockroaches are related to each other into the Blattodea order. Many species are among the top decomposers of dead wood and pests on the planet. They are valued for their ecological and economic contributions both locally and internationally. They are crucial to the health of many ecosystems, and the decomposition of dead wood has measurable effects on the climate.[165], [174]

Less than one percent of cockroaches species are regarded as pests,[175] because of their invasive behaviour toward homes, buildings, and other environments, infesting food, clothing, and the surfaces they crawl on. According to recent research, it is believed that cockroaches and humans started living together when people began building dwellings.[176] Their presence can have a significant economic impact on properties and communities. While the exact financial cost of these infestations is difficult to assess, there are several ways in which they can affect property values and local economies.[177]

Cockroaches may be implicated in the spread of nosocomial infections, which are the main causes of morbidity in immunocompromised patients.[178], [179] Several recent studies have demonstrated the capacity of cockroaches to transmit fungi such as *Candida spp., Aspergillus spp.,*[180], [181] and bacteria including *Salmonella, E. coli* , *Klebsiella, Pseudomonas*, *Staphylococcus, Enterobacter, Streptococcus, Serratia, Bacillus*, and *Proteus.*[182], [183], [184], [185] In the 1950s, one research study indicated the correlation between cockroach infestations and hepatitis A.[186], [187] Intestinal protozoa and helminth parasites such as *Entamoeba coli* and *Entamoeba histolytica/dispar* cysts, as well as *Enterobius vermicularis*, *Trichuris trichiura*, *Taenia spp*, and *Ascaris lumbri coidesova* cysts were isolated in 2008 in both the bodies and guts of cockroach species *Blattella germanica*, *Periplaneta brunnea* and *Pycnoscelus surinamensis.*[188] Another study showed the presence of protozoa *Blastocystis homnisis* responsible for digestive symptoms in the *Periplaneta americana* cockroach species.[189] Other experimental studies have demonstrated the vectorial potential of cockroaches. Finally, cockroach infestations can cause psychological issues.[145], [190]

Many other medically relevant pathogenic agents have been isolated in cockroaches from their body surfaces and in their excrement, in infectious environments such as homes, hospitals, and industrial settings.[134], [182], [191] In 1964, cockroaches were linked for the first time to allergic reactions.[192], [193] Cockroach infestations may cause asthma, rhinitis, eczema and other allergic diseases, especially given that they are a source of inhalant allergens.[194], [195], [196]

The fact that cockroaches have been used in traditional Chinese medicine for over 300 years to treat pain, gastrointestinal ulcers and even chronic heart failure is interesting.[197], [198] Research studies have shown that the oligosaccharides from the *Periplaneta americana* cockroach species have an anti-inflammatory effect.[199]

Termites represent the most troublesome pests for both plants and building, and are responsible for more than 40 billion dollars in economic losses every year.[167] Americans spend more than $11 billion each year on preventing, treating and repairing termite damage.[200] Despite the fact that termites cause enormous economic losses, they perform work as ecosystem engineers, influencing the distribution and aggregation of phosphorus in the soil and increasing water infiltration.[154], [201] Studies have shown that termites are highly rich in proteins, vitamins and calories and their use in the medical field has been reported to treat various diseases such as asthma and bronchitis. Other investigations found that termite water extract might reduce HIV-1 viral activity.[202]

Lepidoptera (moths and Butterflies)

The Lepidoptera order represents some of the most abundant, ubiquitous, and economically significant insects, with over 120 families and around 160 000 known species, representing one of the major orders of Holometabola.[141] This order is not typically associated with significant damage to historical artefacts and buildings. It include both butterflies which are helpful insects (silkworms) and moths which are harmful (crop pests). [203], [204] Few species within this order can cause problems and pose a threat to cultural artefacts, historical buildings, and valuable collections. Several mummies and human remains have been found with moths and other arthropods.[205]

Tineola bisselliella, a webbing cloth moth, and *Tinea pellionella*, a case-bearing clothes moth (Order Lepidoptera) are the most significant pest with a cosmopolitan distribution. In the second degree is the pale-backed cloth moth known as *Monopis crocicapitella,* the brown house moth, *Hofmannophila pseudospretella,* the white-shouldered house moth, *Endrosis sarcitrella,* and the Indian meal moth, *Plodia interpunctella*.[28], [206]

The webbing cloth moth known as *Tineola bisselliella* is responsible for significant economic losses around the world. Their larvae feed on wool, feathers, hair and fur, causing damage to homes, clothes, and cultural items.[207] Research indicates that it may originate from central and southern Africa. It represent the most significant and prevalent cloth moth on the planet and belongs to the family Tineidae within the superfamily Tineoidea.[208] Classified as a museum insect pest and found all over the world,[209] harm caused by this species was reported in a biological collection for the first time in Mexico.[210]

Tinea pellionella, also known as the case-bearing cloth moth, has been present in Britain for over a thousand years. Birds' nests and animal carcasses represent their natural habitat.[28]

Lepidoptera biology

Adult females lay their eggs separately or in groups, attached to the surface with an adhesive..[211] At around ten days, the eggs hatch and larvae emerge. There are usually five or six larval instars which develop into the pupae stage. The larvae stage can last for 30 months, moderated by the environment conditions (food, temperature, humidity).[212] The larvae stop feeding and usually spin a tough, spindle-shaped, silken cocoon in which to pupate... Adults lack functional mouthparts and , their purpose being to reproduce and lay eggs (Figure 07). [213].

Damage and impact on human health

Moths are responsible for serious and irreversible damage to fabric, furnishings, textiles, artworks, and other manmade items (using materials of both animal and plant origin)One study has shown that damage caused by cloth moths is more serious than that caused by beetles.[214], [215] The damage can reach stored products, domestic items, and museum artefacts.[209] Moth species have been reported to infest stored animal products, and losses of up to 50% of product have been reported.[216]

Many museum pests have been reported as destroying artefacts made of wood, fabric, fur, feathers, felt, and other animal or plant materials at three major museums in Vienna, including the *Tineola bisselliella* butterfly, which has been classed as a species of museum pest.[217] According to the literature, the larvae of the brown house moth *Hofmannophila pseudospretella* occasionally eat the glue from moist books, which causes the condition of the books to deteriorate.[28]

Species in the Lepidoptera order do not generally have a direct impact on human health, unlike some other insects. However, it has previously been shown that insects like moth and butterflies can exacerbate the symptoms of bronchial asthma. It has been proven in asthmatic Japanese patients, where immunology exams showed the presence of antibodies against midges and moths.[218] Other cases have reported allergic skin and respiratory reactions caused by bee moths.[219]

Zygentoma (Silverfish)

Silverfish present a significant pest issue, particularly for museums, libraries, and buildings, as they have a tendency to feed on various materials such as paper, cotton, starch, and cereals.[220] These urban pests are commonly found in close proximity to humans and tend to reside areas such as bathrooms, basements, and attics. [221] They have been documented for over 400 million years and are classified within the primitive, wingless order Zygentoma [222], comprised five families, including the Lepismatidae, Nicoletiidae and Lepidotrichidae. The genus Ctenolepisma is the most diverse in the Lepismatidae family. [223] Over the ten last year's *Ctenolepisma longicaudatum* as known the long-tailed silverfish or giant silverfish represent a threat to libraries, archives, and museums in Europe [224]. Due to its potential to damage valuable and irreplaceable items such as graphic collections, photographs, paper-based modern art, historic documents, and books. [225]This species is particularly troublesome in modern buildings , where it can reach high densities and spread between rooms and apartments.[226] *Lepisma saccharina* a silverfish species that is commonly found in human habitats.[227]According to a survey assessing the prevalence of silverfish in 65 Spanish homes, 42% of the structures inspected were found to be infested with *Lepisma saccharina* species, including at least one species from the *Ctenolepisma* genus [228]majority of the time four species of silverfish are found within buildings: *Lepisma quadriseriata*, *L. saccharina, Thermobia domestica*, and *Ctenolepisma longicaudatum* [229], [230]

Damage and impact on human health

Silverfish are seen by homeowners as a nuisance and may have indirect impact on human life, in both economic and medical field. [231] Researchers conducted a study of insect abundance using traps placed in various museums during the COVID-19 pandemic in Vienna. The results show an increase in the number of common silverfish (*Lepisma saccharina*), as well as *Ctenolepisma longicaudatum* and *C. calvum* in some museums. Although other insects were also found, their numbers did not increase significantly. [232]Research has shown that household dust harbours substantial levels of antigens originating from silverfish. In the early 21st century, a study suggested that silverfish could be a significant source of indoor inhalant allergens. Following this, scientists isolated a specific component from silverfish and examined its ability to trigger allergic reactions in patients.[233] Scientists have isolated a specific component, rLep s 1, from silverfish and have demonstrated its ability to elicit hypersensitivity reactions through various routes of exposure, including inhalation, ingestion, and parenteral administration. [234] Based on these results, further research has demonstrated IgE sensitisation to Lepisma saccharina (silverfish) in children with respiratory allergies. The study revealed a high frequency of IgE binding to specific proteins in the silverfish extract.

Psocoptera

the name “Psocoptera” is derived from the Greek “psochein”, which means “crushing” and pteron which means “wing”. They are terrestrial insects with small, soft bodies, less than 6 mm in length.[235]

According to fossil records, they originally emerged in the Permian era, hundreds of millions of years ago,[236] and live mainly on vegetation and on edaphic material. All stages feed on microflora, algae, and fungi.[237] Flakes of skin from humans and their pets are consumed by some Psocids.[31] They can be found in mammalian or bird nests, particularly some species of the Proquillidae family,[235] which live in bird nests and feed on dead skin cells without harming the bird. Some species eat the eggs of dead insects (scavengers), while others feed on starchy items such as books, bindings, and wallpaper paste.[31]

Psocids (Psocoptera) are pests that have a negative impact on grains and other amylaceous products. They can grow in a wide range of cereal products, and multiply quickly, especially when they are subjected to a humid conditions which encourages the development of fungus, the primary food source.[238], [239] They infest domestic homes, stores of raw materials, manufacturing plants, and historical documents in museums.[240] Their common names “bark lice” and “booklice” are related to their tendency to infest books. The World Catalogue of Insects lists over a thousand known species[241] and 35 families around the world. Studies are very sparse in European countries such as Bulgaria,[242], the Republic of Belarus,[243] and the Republic of Malta.[244]

Most species associated with human habitats belong to the suborders Trogiomorpha and Troctomorpha. Species such as *Lepinotus reticulatus, Liposcelis bostrychophila, Cerobasis annulate* and *Cerobasis guestfalica* are abundant, especially when conditions are favourable,[237], [244], [245] such as humid rooms following water damage, basements, wet walls, and room partitions, where they can find optimal conditions for development.[246] Libraries, bookshops, and paper stores are other common habitats for these insects.[247]

Psocids are spread around the world, due to transport and trade in commercial goods, and the geographical origin of several domestic species is unknown. *Dorypteryx domestica,* a species of *Psocidae*, has been described in human habits in Africa, North America and at least 16 European countries.[248] Since the 20th century, *Psocoptera* and several species of the family Liposcelididae have been considered as a threat to human life and stored products, as they cause severe germ damage and weight loss in stored grain.[249] Nearly a hundred species of psocids have been documented as infesting stored products, with four of them, *Liposcelis bostrychophila, L. decolor, L. entomophila,* and *L. paeta*, causing substantial economic losses worldwide.[239]

Biology

Psocids have a tropism to wet areas. A temperature of 22 °C to 33 °C, with 70%–80% relative humidity, is ideal for their growth and multiplication. While a low temperature of 2 °C is undesirable for adult survival, the eggs may survive and hatch as soon as temperature and humidity conditions become favourable.[28], [30]

Psocids exhibit a variety of reproductive patterns, with females depositing between 50 and 100 eggs during their lifetime. However, some psocids, such as Archipsocopsis and Phallocaecilius, are viviparous. Eggs can be placed alone or in clusters and the entire embryonic development takes place within the mother's ovary (Figure 08).[250], [250], [251]

Typically, nymphal development covers six nymphal instars before reaching adulthood. Egg hatching takes between one and four weeks, and a nymph emerges in the first stage of development. The psocids have no pupal stage and are the stages are occasionally reduced to five, four, or even three. Under optimum conditions, the pest's life cycle is completed in 21 days .[245]

Parthenogenesis is known to occur in about 15 families of the three Psocoptera suborders.[252]The literature reveals that psocid infestations increase in warmer climates, a fact demonstrated by the installation of thirty thousand insect traps in English heritage properties.[253]

Damage and impact on human health: allergies and Rickettsia

The economic impact of Psocids on stored products has been estimated as weight loss of between 5% and 10%.[239] Psocids, like other insects, have been linked to cases of dust allergies in people.[254] There is no evidence in the scientific literature on their role as pathogen vectors. However, many studies have demonstrated the presence of *Rickettsia* and suggest that they play a role in the early development of the oocyte.[255], [256] Others have suggested that *Rickettsia* is an obligate symbiont of *L. bostrychophila*.[257], [258], [259]

Their existence in household dust and museums exacerbates symptoms of dust allergies (conjunctivitis, rhinitis, and dermatitis).[260], [261], [262], [263] This was demonstrated in a description of a patient who began working at an antique bookstore[247] and developed an allergy.

Approaches used for pest identification

The identification of insect pests belonging to the orders Coleoptera (beetles), Blattodea (cockroaches and termites), Psocoptera (booklice), and Lepidoptera (moths and butterflies) is a key step towards protecting historic buildings and artefacts as well as towards successful pest management.[28], [264] Using various types of dichotomous keys, such as Gorham 1991 for cockroaches, Coleoptera, and mites [37], and those developed by Bordereau et al., 2003 and Bouillon et Mathot (1965) for termites, we ensure accurate and precise identification of these species [172], [265]. The morphological identification approach may differ depending on the order. Identification of Blattodea species (cockroaches and termites) uses a combination of criteria including the morphology of different parts of the insect such as the shape, the size of the head, pronotum, abdominal segment, legs, wings and, in some cases, the mandibule.[155], [172], [190] Genitalia and intestinal segment dissection can provide information about species identification.[266], [267] Identification of Lepidoptera species in adults can be based on Hind wing veins M2 and M3, antennal flagellum, male maxillary palpus, and the male abdominal segment, sometimes requiring the dissolution of soft tissues and dissection of the abdomen so that the structure of the genitalia can be examined.[268], [269] Identification of Coleoptera represents a challenging task due to the diverse range of their life stages.[270] The identification of Coleoptera (beetles) often involves the use of morphometric and genitalia criteria. Identification of larvae includes the number of abdominal segments, overall body coloration, body shape, and the structure of the head capsule.[271], [272] Psocoptera identification involves morphometric measurements including head length, post clypeus distance, head width, the distance between the sides of the head, and the quotient of head length and head width.[259] , and commonly conducted using microscopic examination of certain internal organs [273]

Molecular biology has opened the way for various alternative approaches to arthropod identification, based on DNA sequences such as DNA barcoding, which helps with the determination and classification of different species,[274] PCR amplification, and DNA sequencing using various markers such as *COI*, *COII*, *16s rRNA*, *ITS 2* and *cytochrome b* [275].

The proteomic tool MALDI-TOF MS has been applied successfully to arthropod species identification of hematophagous arthropods such as fleas, lice, mosquitoes, ticks, bed bugs, and

Phlebotomine sand flies.[276] The use of this tool has recently proven successful in identifying termite species collected from diverse origins.[154]

Conclusion

Many of these insect pests play essential roles in nature. They act as “cleaners” by feeding on corpses, dead wood, and debris, while also serving as crucial links in the food chain for other insects and animals, such as termites. However, when they invade our homes and target our belongings and food, they become unwelcome pests. Human activities, particularly international trade, have led to the widespread distribution of these insects, and this trend is unlikely to change. Wherever humans go, these insects can be found.

Though these insects do not transmit diseases, they still affect human health through allergies and direct or indirect dermatological reactions, including skin irritations caused by their bristles and parasitic infestations like *Pyemotes* and *Sclerodermus*. Additionally, their effect on stored food can lead to potential food shortages, raising concerns around human nutrition.

To strike a balance in the ecosystem and to minimise the negative impacts on human health and well-being, it is crucial to implement effective pest management strategies. Further research is needed to better understand their biology, behaviour, and interactions. These insights could help to develop sustainable solutions to our coexistence with these insects while ensuring our environment and our resources are protected.

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Figure 01: Wood-Boring Beetle (Coleoptera)*: Oligomerus ptilinoides* larvae (A), Adult (B), *Oligomerus ptilinoides* adult in a natural environment, showcasing the damage caused by larvae through small, irregularly shaped holes in the surface of wooden furniture (C).

Figure 02: Coleoptera (a) Dorsal view of adult *Oryzaephilus surinamensis*, (b) Red circle indicating an *Oryzaephilus surinamensis* trapped inside a bottle, (c) Dorsal view of adult *Tribolium castaneum*, (d) Ventral view of adult *Tribolium castaneum*.

Figure 03: (a) Woodborers (Coleoptera: Ptinidae, formerly Anobiidae) adult *Anobium punctatum,* (b) adult *Attagenus smirnovi.*

Figure 04: Carpet Beetle (Coleoptera) *Anthrenus verbasci* larvae (a), Adult (b), Electron Microscope Demonstrations of Larval Hairs (setae) look like arrows due to their pointed and barbed appearance (c, d).

Figure 05: (A) Larvae of carpet beetles *Attagenus* sp, (B) Ventral and dorsal views of the adult Drugstore Beetle, *Stegobium paniceum*, (C) Adult *Bostrychus capucinus*, (D) Adult Brown Carpet Beetle, *Mezzium affine*, observed in its natural environment.

Figure 06-A: Blattodea (a) Adult *Blatta orientalis*, (c) Ootheca containing the eggs of *Blatta orientalis*, (d) *Blatta orientalis* observed in its natural habitat.

Figure 06-B: (a) Adult *Blattella germanica*, (c) Ootheca containing the eggs of *Blattella germanica,* (d) Blattella germanica observed near water canal conduits in its natural habitat.

Figure 07: Common Clothes Moth (Lepidoptera)*Tineola bisselliella* (a) Profil view of (c) Dorsal view (e) Cocoon of the larva.

Figure 08: Psocoptera Species *Liposcelis sp*. Adults (A) and *Liposcelis* in Natural Habitat (B).

Table 1: Table representing Ptinidae species, their distribution, and associated damage.

Table 2: Insects commonly observed in both heritage sites and human residences.

Author contributions

Conceived and designed the experiments: PP, JMB. Took pictures: JMB, FF. Acquired funding: PP. Project administration: PP, JMB. Supervision: PP. Drafted the paper: BH, JMB. Critically reviewed the paper: PP, JMB, BH, FF. All authors reviewed and approved the final version.

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Competing interests

The authors declare no competing interests.

Figure 1

Psocoptera Species *Lipocelis sp*

Psocoptera Species *Lipocelis sp*. Adults (A) and *Lipocelis* in Natural Habitat (B).

Figure 2

Wood-Boring Beetle (Coleoptera)

Oligomerus ptilinoides larvae (A), Adult (B), *Oligomerus ptilinoides* adult in a natural environment, showcasing the damage caused by larvae through small, irregularly shaped holes in the surface of wooden furniture (C).

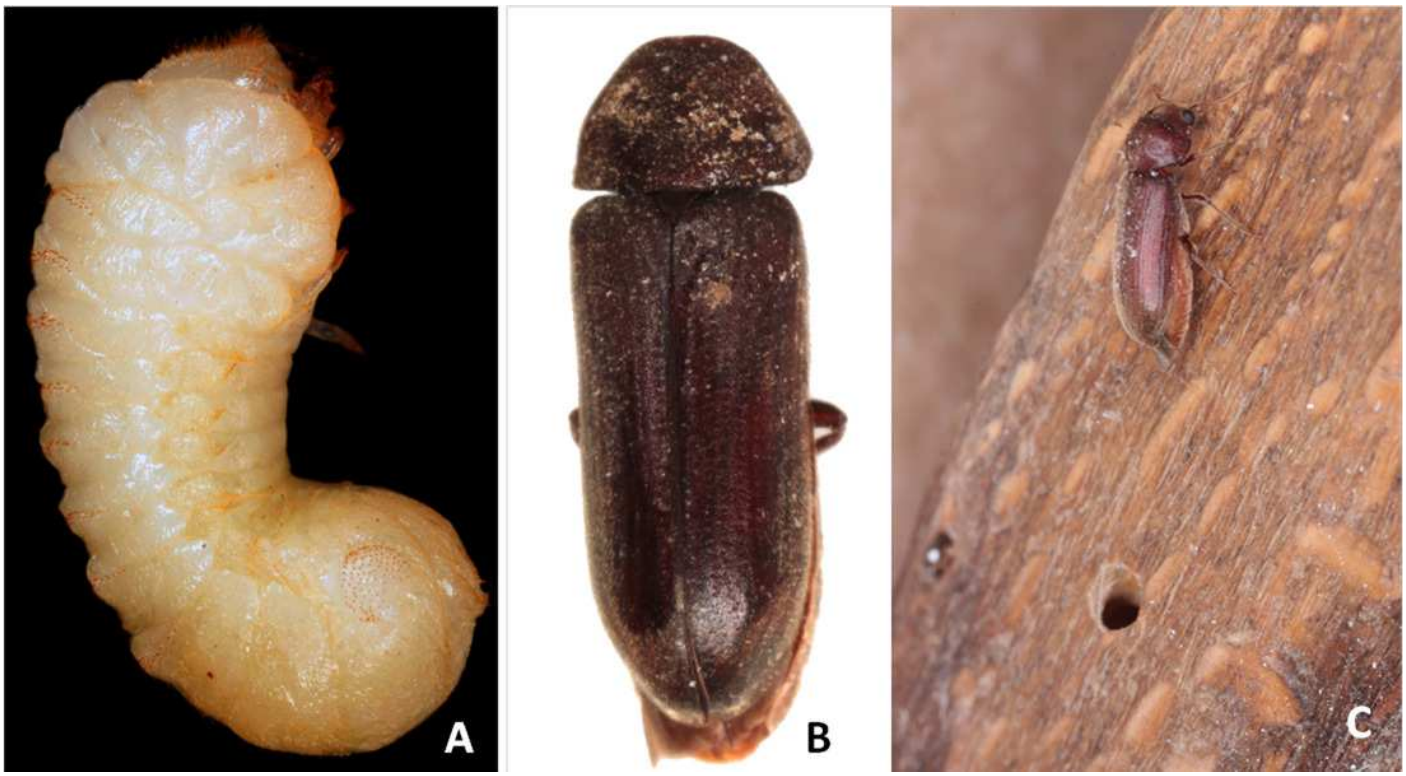

Figure 3

Coleoptera

Coleoptera (a) Dorsal view of adult *Oryzaephilus surinamensis*, (b) Red circle indicating an *Oryzaephilus surinamensis* trapped inside a bottle, (c) Dorsal view of adult *Tribolium castaneum*, (d) Ventral view of adult *Tribolium castaneum*. Coleoptera (a) Dorsal view of adult *Oryzaephilus surinamensis*, (b) Red circle indicating an *Oryzaephilus surinamensis* trapped inside a bottle, (c) Dorsal view of adult *Tribolium castaneum*, (d) Ventral view of adult *Tribolium castaneum*.

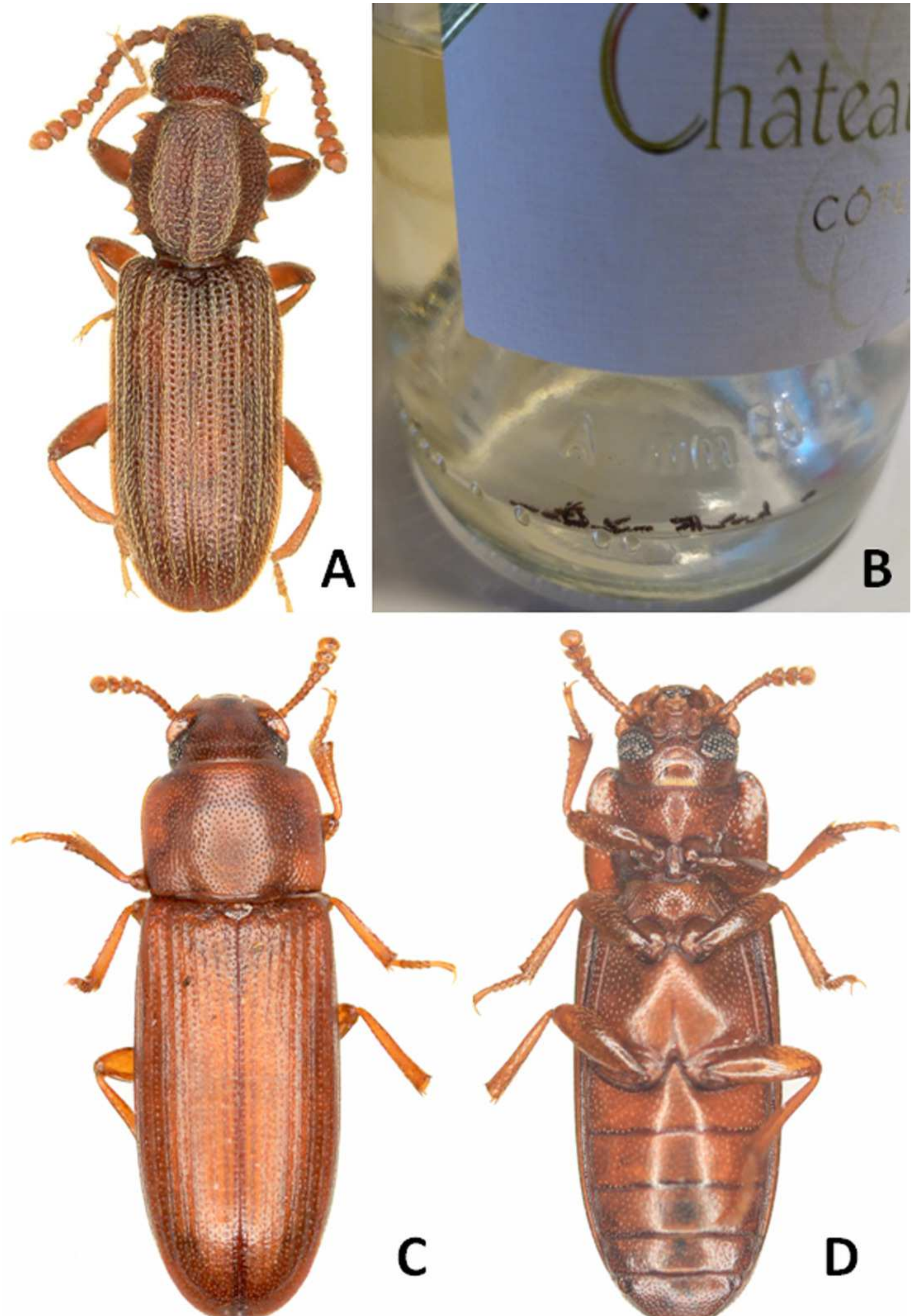
A
B
C
D

Figure 4

Wood-Boring Beetle (Coleoptera)

(a) Woodborers (Coleoptera: Ptinidae, formerly Anobiidae) adult *Anobium punctatum,* (b) adult *Attagenus smirnovi*

Figure 5

Carpet Beetle (Coleoptera)

Antrenus verbasci larvae (a), Adult (b), Electron Microscope Demonstrations of Larval Hairs (setae) look like arrows due to their pointed and barbed appearance (c, d).

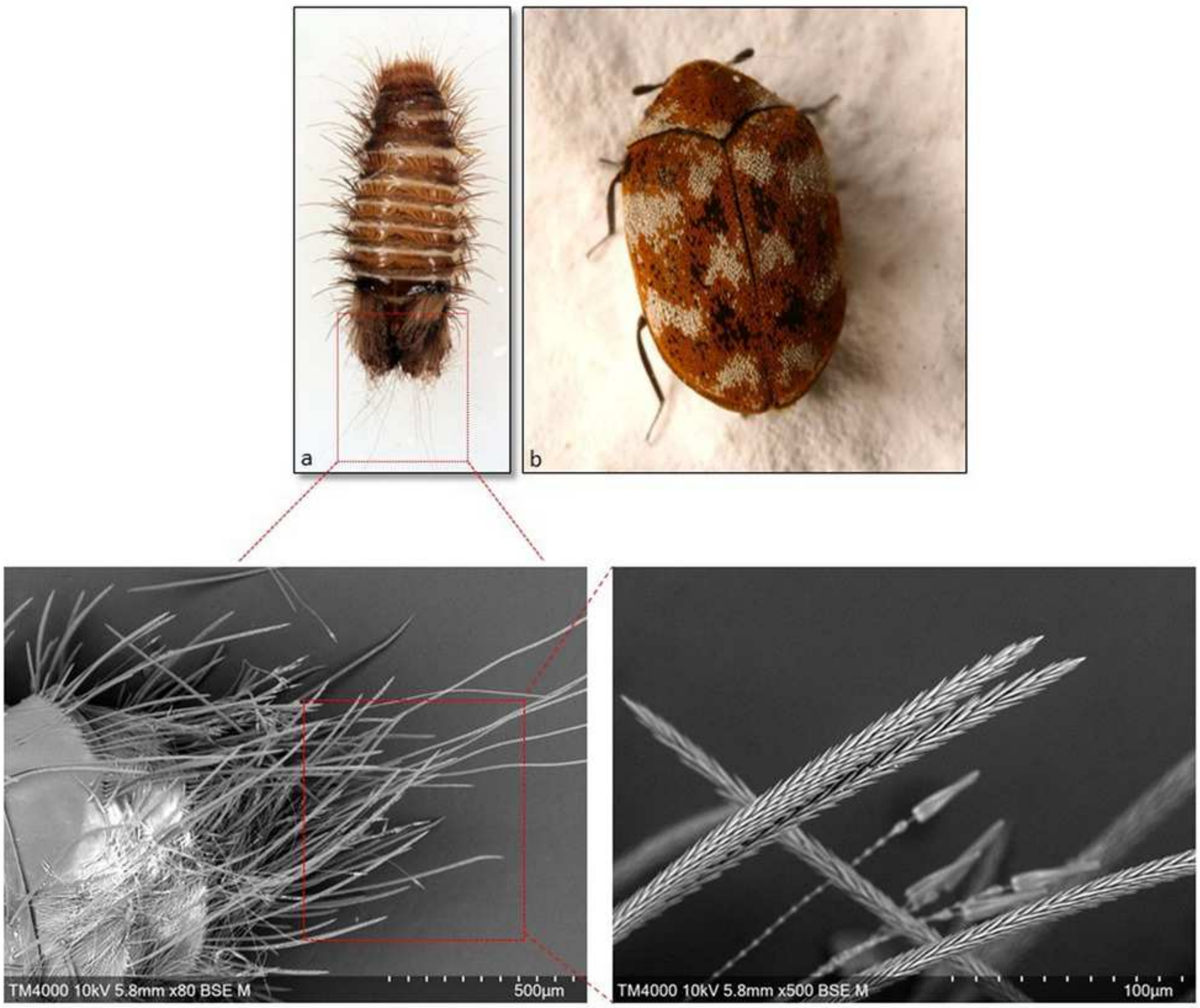

Figure 6

Adults and larvea beetle

(A) Larvae of carpet beetles *Attagenus* sp, (B) Ventral and dorsal views of the adult Drugstore Beetle, *Stegobium paniceum*, (C) Adult *Bostrychus capucinus*, (D) Adult Brown Carpet Beetle, *Mezzium affine*, observed in its natural environment.

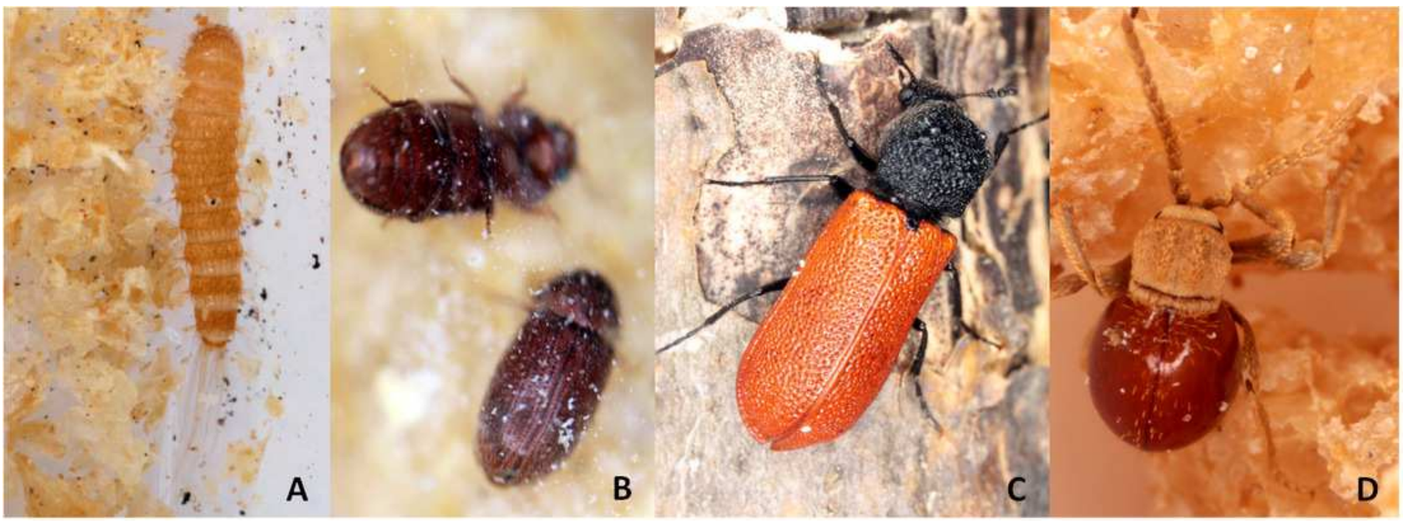

Figure 7

Blattodea

A (a) Adult *Blatta orientalis*, A(c) Ootheca containing the eggs of *Blatta orientalis*, A(d) *Blatta orientalis* observed in its natural habitat. B (a) Adult *Blattella germanica*, B(c) Ootheca containing the eggs of *Blattella germanica, B*(d) Blattella germanica observed near water canal conduits in its natural habitat

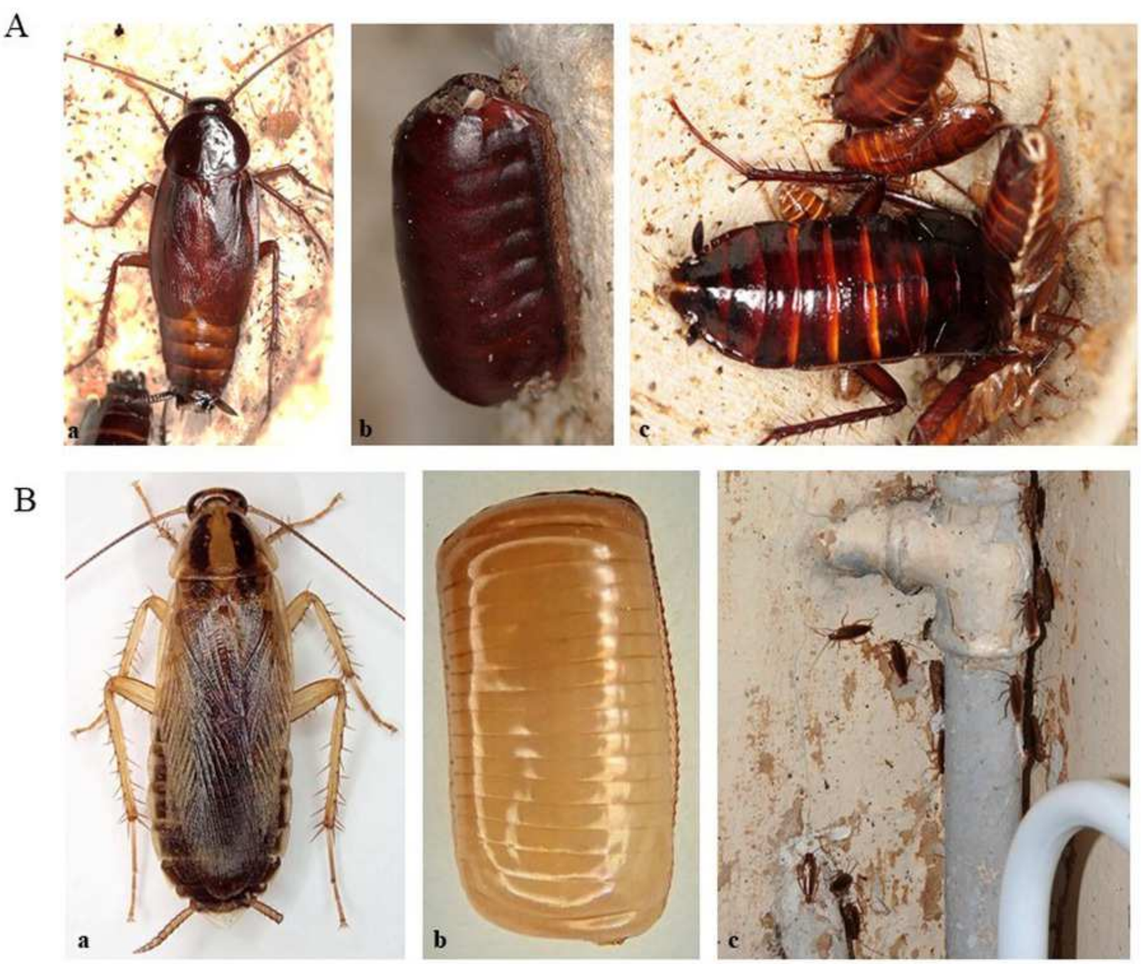

Figure 8

Common Clothes Moth (Lepidoptera)

(A) Adult *Tineola bisselliella.* (B) Larva., (C) Cocoon of the larva, (D) Larva emerging from its cocoon within a fabric.

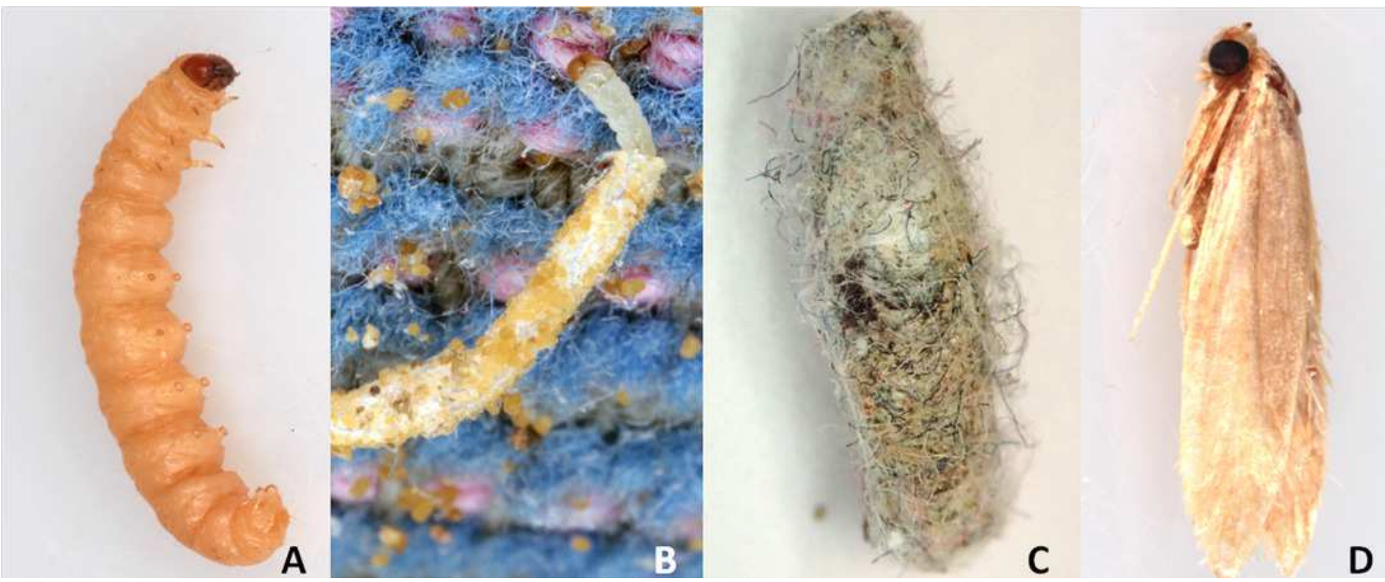

Table 1(on next page)

Table 1. Insects commonly observed in both heritage sites and human residences in France.

Insects commonly observed in both heritage sites and human residences in France.

In red, the most common and hazardous species

In blue, species of lesser significance for the heritage domain.

In black, rarer species that may be present in heritage sites.

Species	Order	Family
***Adistemia watsoni* (Wollaston, 1871)**	Coleoptera	Lathridiidae
***Ahasverus advena* (Waltl, 1834)**	Coleoptera	Silvanidae
***Alphitobius diaperinus* (Panzer, 1797)**	Coleoptera	Tenebrionidae
***Alphitobius laevigatus* (Fabricius, 1781)**	Coleoptera	Tenebrionidae
***Anobium punctatum* (De Gere, 1774)**	Coleoptera	Ptinidae
***Anthrenus flavipes* (LeConte,1854)**	Coleoptera	Dermestidae
***Anthrenus museorum* (Linnaeus, 1761)**	Coleoptera	Dermestidae
***Anthrenus pimpinellae* (Fabricius, 1775)**	Coleoptera	Dermestidae
***Anthrenus scrophulariae* (Linnaeus, 1758)**	Coleoptera	Dermestidae
***Anthrenus verbasci* (Linnaeus, 1767)**	Coleoptera	Dermestidae
***Attagenus bifasciatus* (Olivier 1790)**	Coleoptera	Dermestidae
***Attagenus brunneus* Faldermann, 1835**	Coleoptera	Dermestidae
***Attagenus cyphonoides* Reitter, 1881**	Coleoptera	Dermestidae
***Attagenus fasciatus* (Thunberg, 1795)**	Coleoptera	Dermestidae
***Attagenus pellio* (Linnaeus, 1758)**	Coleoptera	Dermestidae
***Attagenus smirnovi* Zhantiev, 1973**	Coleoptera	Dermestidae
***Attagenus unicolor* (Brahm 1791)**	Coleoptera	Dermestidae
***Blatta orientalis* (Linnaeus, 1758)**	Dictyoptera	Blattidae
***Blattella germanica* (Linnaeus, 1767)**	Dictyoptera	Blattelidae
***Bostrichus capucinus* (Linnaeus, 1758)**	Coleoptera	Bostrichidae
***Carpophilus hemipterus* (Linnaeus, 1758)**	Coleoptera	Nitidulidae
***Carpophilus ligneus* Murray, 1864**	Coleoptera	Nitidulidae
***Carpophilus obsoletus* Erichson, 1843**	Coleoptera	Nitidulidae
***Cartodere constricta* (Gyllenhal, 1827)**	Coleoptera	Lathridiidae
***Corticaria elongata* (Gyllenhal, 1827)**	Coleoptera	Lathridiidae
***Cryptolestes ferrugineus* (Stephens, 1831)**	Coleoptera	Laemophloeidae
***Cryptophagus cellaris* (Scopoli, 1763)**	Coleoptera	Cryptophagidae
***Ctenolespisma lineata* (Fabricius, 1775)**	Zygentoma	Lepismatidae
***Ctenolespisma longicaudatum* Escherich, 1905**	Zygentoma	Lepismatidae

Dermestes ater **(DeGeer, 1774)**	Coleoptera	Dermestidae
Dermestes bicolor **(Fabricius, 1781)**	Coleoptera	Dermestidae
Dermestes carnivorus (Fabricius, 1775)	Coleoptera	Dermestidae
Dermestes frischii Kugelann, 1792	Coleoptera	Dermestidae
Dermestes haemorrhoidalis **(Küster, 1852)**	Coleoptera	Dermestidae
Dermestes lardarius Linnaeus, 1758	Coleoptera	Dermestidae
Dermestes maculatus De Geer, 1774	Coleoptera	Dermestidae
Dermestes murinus **(Linnaeus, 1758)**	Coleoptera	Dermestidae
Dermestes mustelinus **(Erichson, 1846)**	Coleoptera	Dermestidae
Dermestes peruvianus **(Laporte de Castelnau, 1840)**	Coleoptera	Dermestidae
Dermestes undulatus **Brahm, 1790**	Coleoptera	Dermestidae
Dienerella argus **(Reitter, 1884)**	Coleoptera	Lathridiidae
Dinoderus minutus **(Fabricius, 1775)**	Coleoptera	Bostrichidae
Dorypteryx domestica **(Smithers, 1958)**	Psocoptera	Psyllipsocidae
Dorypteryx longipennis Smithers, 1991	Psocoptera	Psyllipsocidae
Ernobius mollis (Linnaeus, 1758)	Coleoptera	Ptinidae
Gibbium psylloides **(Czempinski, 1778)**	Coleoptera	Ptinidae
Hexarthrum exiguum **(Boheman, 1838)**	Coleoptera	Curculionidae
Hylotrupes bajulus **(Linneaus, 1758)**	Coleoptera	Cerambycidae
Kalotermes flavicollis **(Fabricius, 1793)**	Isoptera	Kalotermitidae
Lasioderma serricorne **(Fabricius, 1792)**	Coleoptera	Ptinidae
Lepisma saccharina (Linnaeus, 1758)	Zygentoma	Lepismatidae
Liposcelis corrodens (Heymons, 1909)	Psocoptera	Liposcelididae
Liposcelis decolor (Pearman, 1925)	Psocoptera	Liposcelididae
Litargus balteatus **LeConte, 1856**	Coleoptera	Mycetophagidae
Lyctus brunneus (Stephens, 1830)	Coleoptera	Bostrichidae
Lyctus linearis (Goeze, 1777)	Coleoptera	Bostrichidae
Megatoma undata **(Linnaeus, 1758)**	Coleoptera	Dermestidae
Mezium affine (Boieldieu, 1856)	Coleoptera	Ptinidae
Necrobia ruficollis **(Fabricius, 1775)**	Coleoptera	Cleridae
Necrobia rufipes (De Geer, 1775)	Coleoptera	Cleridae
Necrobia rufipes **(DeGeer, 1775)**	Coleoptera	Cleridae
Nicobium castaneum (Olivier, 1790)	Coleoptera	Ptinidae
Niptus hololeucus (Faldermann, 1835)	Coleoptera	Ptinidae
Oligomerus ptilinoides (Wollaston, 1854)	Coleoptera	Ptinidae
Oryzaephilus mercator **(Fauvel, 1889)**	Coleoptera	Silvanidae
Oryzaephilus surinamensis **(Linnaeus, 1758)**	Coleoptera	Silvanidae
Palorus depressus **(Fabricius, 1790)**	Coleoptera	Tenebrionidae
Pentharthrum huttoni **Wollaston, 1854**	Coleoptera	Curculionidae
Phradonoma villosulum **(Dufschmid, 1825)**	Coleoptera	Dermestidae
Plodia interpunctella (Hübner, 1813)	Lepidoptera	Pyralidae
Priobium carpini **(Herbst, 1793)**	Coleoptera	Ptinidae

***Psyllipsocus ramburii* Sélys-Longchamp, 1872**	Psocoptera	Psyllipsocidae
***Ptilinus pectinicornis* (Linnaeus, 1758)**	Coleoptera	Ptinidae
***Ptinus fur* Linnaeus, 1758**	Coleoptera	Ptinidae
***Ptinus latro* Fabricius, 1175**	Coleoptera	Ptinidae
***Ptinus variegatus* Rossi, 1792**	Coleoptera	Ptinidae
***Reesa vespulae* (Milliron, 1939)**	Coleoptera	Dermestidae
***Rhyzopertha dominica* (Fabricius, 1792)**	Coleoptera	Bostrichidae
***Sefrania bleusei* (Pic, 1899)**	Coleoptera	Dermestidae
***Silvanus bidentatus* (Linnaeus, 1792)**	Coleoptera	Silvanidae
***Sitophilus oryzae* (Linnaeus, 1763)**	Coleoptera	Dryophthoridae
***Sitophilus zeamais* (Motschulsky, 1855)**	Coleoptera	Dryophthoridae
***Stegobium paniceum* (Linnaeus, 1758)**	Coleoptera	Ptinidae
***Supella longipalpa* (Fabricius, 1798)**	Dictyoptera	Blatellidae
***Tenebrio molitor* Linnaeus, 1758**	Coleoptera	Tenebrionidae
***Tenebrio obscurus* Fabricius, 1792**	Coleoptera	Tenebrionidae
Thermobia domestica **(Packard, 1837)**	Zygentoma	Lepismatidae
***Thylodrias contractus* (Motschulsky, 1839)**	Coleoptera	Dermestidae
***Thyphea stercorea* (Linnaeus, 1758)**	Coleoptera	Mycetophagidae
***Tinea pellionella* (Linnaeus, 1758)**	Lepidoptera	Tineidae
***Tineola bisselliella* (Hummel, 1823)**	Lepidoptera	Tineidae
***Tribolium castaneum* (Herbst, 1797)**	Coleoptera	Tenebrionidae
***Tribolium confusum* Jacquelin du Val, 1861**	Coleoptera	Tenebrionidae
***Trichoferus holosericeus* (Rossi, 1790)**	Coleoptera	Cerambycidae
***Trogium pulsatorium* (Linnaeus, 1758)**	Psocoptera	Trogiidae
***Trogoderma augustum* (Solier, 1849)**	Coleoptera	Dermestidae
***Trogoderma glabrum* (Herbst, 1783)**	Coleoptera	Dermestidae
***Trogoderma granarium* Everts, 1898**	Coleoptera	Dermestidae
***Trogoderma inclusum* LeConte, 1854**	Coleoptera	Dermestidae
***Trogoderma megatomoides* Reitter, 1881**	Coleoptera	Dermestidae
***Trogoderma versicolor* (Creutzer, 1799)**	Coleoptera	Dermestidae
***Trogoxylon impressum* (Comolli, 1837)**	Coleoptera	Bostrichidae
***Xestobium rufovillosum* (De Geer, 1774)**	Coleoptera	Ptinidae

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Table 2(on next page)

Table 2. Coleoptera species commonly observed in both heritage sites and human residences

Coleoptera species commonly observed in both heritage sites and human residences

Species	Distribution	Damage
Mezium affine	Europe, North Africa.	House, warehouses, granaries, decaying animal and vegetable debris, dead insects.
Mezium americanum	Cosmopolitan.	Dwellings, dried animal products, warehouses, mills, infested cayenne pepper, opium, grain, obacco.
Gibbium psylloides	Cosmopolitan	Houses, hotels, warehouses, mills, granaries, stored seeds, woollen materials
Gibbium boieldieui	Europe, Persia, Russia, Malay archipelago	Houses feeding on bread, cheese, and moulds
Gibbium aequinoctiale	Nearly cosmopolitan	Houses feeding on bread, cheese, and moulds
Sphaericus pinguis	South Europe, North Africa, California	Herbarium pest living in red pepper
Tipnus unicolor	Europe, Canada Transcaucasia.	Houses, Warehouses, old wood, birds' nests
Niptus hololeucus	Nearly cosmopolitan but absent in the tropics.	Houses, Warehouses, dried organic materials, dead insects, clothing soiled by grease.
Trigonogenius globulus	Europe, Africa, North and South America, Tasmania	Houses, warehouses, granaries, and in cotton, flour, and corn mills
Pseudeurostus hilleri	Japan, Great Britain, Canada	Warehouses, granaries
Ptinus (Cyphoderes) japonicus	Japan, India, Russia	Infests and damages flour made of *Amorphophallus koniac,* used for food in Japan
Ptinus (Cyphoderes) raptor	Europe, Russia, Canada, USA	Stored grain in warehouses
Ptinus (Bruchoptinus) rufipes	Europe	Dead wood, a pest of stored products
Ptinus (Tectoptinus) exulans	Europe, Australia, Asia, Tasmania	Pest of stored products
Ptinus (Tectoptinus) tectus	Cosmopolitan	Houses, granaries, warehouses, dried organic materials, dried leaves, and flowers,
Ptinus hirtellus	Cosmopolitan	Scavengers damaging books, feathers, hides, dried mushrooms, drugs, and roots, stored products (sugar, dried fruit)
Ptinus latro	Nearly cosmopolitan	Houses, warehouses, stored products
Ptinus (Ptinus) fur	Cosmopolitan	Omnivorous feeder, dried and decaying animal and vegetable matter, feathers and animal hides, stored products
Ptinus pusillus	Europe	Stored products
Ptinus subpilosus	Europe	Houses, wood, and ants' nests

Ptinus bicinctus	Europe, North Africa, North America	Warehouses, dwellings, old wooden items, stored products
Ptinus villiger	Europe, Asia, and North America.	Houses, warehouses, stored products.