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Examination of Civil Forensic Entomology Through Case Studies

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Submitted by

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Brief History of Forensic Entomology

Forensic entomology utilizes scientific knowledge relating to insect biology, ecology, behavior, and distribution to form logical conclusions regarding evidence in legal cases. In the context of human history, forensic entomology is an extremely new field of study. In fact, the majority of advancements in the field have occurred since the 1980s. However, the first documented case involving forensic entomology came from 13th century China. It was recorded by lawyer and death investigator Sung Tz'u in the text *Hsi Yuan Lu* (The Washing Away of Wrongs). Tz'u described a situation in which a man was stabbed to death near a rice field by some sort of sharp object. The following day, Tz'u told all the workers to place their tools on the floor for examination. While no evidence was visible to the naked eye, flies were attracted to one man's sickle, presumably by the smell of blood. The owner of the sickle quickly confessed to the murder based on this evidence (retold in Benecke, 2001).

Even though we have such an early record of forensic entomology, the field progressed extremely slowly following the account by Sung Tz'u. In fact, virtually no other documented cases dealing with the use of insects as evidence can be found until the 19th century. However, several important discoveries were made between Sung Tz'u and the 19th century relating to the biology of insects that provided the groundwork upon which the field of forensic entomology has been built.

The most notable of these early discoveries came in 1667 when the Italian physician Francesco Redi tested the idea that maggots formed spontaneously on meat (called spontaneous generation, or abiogenesis) (Habermehl, 1994), which was a common belief at the time. Redi established that, contrary to popular opinion, maggots do not form spontaneously but are instead deposited by adult flies as eggs which then hatch into larvae. This discovery made it possible to

begin study and understand flies as natural organisms, instead of seeing them as mystical creatures which spontaneously appear. Viewing insects as natural organisms is critical to properly study them and be able to justify using what we see regarding them as evidence.

The first modern case in which insects were used to determine the time since death, also called the post mortem interval (PMI), came from France in 1855. A physician named Bergeret used insects to try and calculate the time since death for a child's body based on what he thought was true about insect life cycles. Bergeret thought that a full year was required for fly metamorphosis to occur. He therefore believed that fly eggs would be laid in the summer, they would hatch the following spring, pupate, and then finally emerge as an adult during the summer a full year after being laid. Based on this timeline, he concluded that the presence of larvae or pupae on a body would indicate the body died at the earliest the previous summer. He used this reasoning to determine the likely time of death of a mummified infant found behind a chimney (Benecke, 2001).

Unfortunately, the conclusions Bergeret arrived at in regards to the PMI of this infant were likely inaccurate, as forensically important flies can actually complete their lifecycle in a matter of weeks, as opposed to the full year he believed. The flaw in his logic reflected an incorrect understanding of insect biology and a lack of research in this area. However, it should be noted that even though his understanding of fly biology was inaccurate, the thought processes he used are often employed today during criminal investigations. For example, "if fly larvae take X number of days to mature on a body after death, and I found mature fly larvae on a body, then death must have occurred at least X number of days ago." Luckily, the entomological evidence in this case was only a small part of the forensic evidence he obtained (Benecke, 2001).

Another important moment in the history of forensic entomology came in 1894 when Jean Pierre Mégnin published his book titled *La Faune de Cadavers* (The Fauna of Cadavers) (Mégnin, 1894). In this book, Mégnin proposed that bodies would experience eight successional waves of insect activity during decomposition if freely exposed to the environment. He also discussed which insects would be found in these waves, and how to identify them. Mégnin even included 19 case studies illustrating the principles he outlined. This book provided a basic framework against which evidence found at a crime scene could be compared. It also raised awareness of the topic of forensic entomology and started to increase the perception that insects at crime scenes could be use as physical evidence. Mégnin is often considered to be the father of forensic entomology for this work (Benecke, 2001).

Wars have also had a large impact on our basic understanding of entomology. In particular, World Wars I and II provided motivation for studies of entomology in the effort to combat insect-borne diseases and develop better methods of pest control. Immediately after the World Wars, entomological research continued in the context of pest control and insecticide development. This research led to an increase in the basic information available regarding insect biology and ecology, and did a great deal to advance the field of entomology. (Benecke, 2001)

Forensic entomology has quickly advanced within the last 30-40 years as more research has been conducted on forensically important insects and as forensic entomology has gained mainstream acceptance. Today, it is widely understood that insects can provide reliable and valuable evidence in criminal and civil cases, and entomological evidence is widely accepted in the judicial systems of many countries. In recent years, the number of studies and the available information have increased exponentially, allowing for much better collection, analysis, and interpretation of entomological evidence. Organizations such as North American Forensic

Entomology Association (NAFEA), American Board of Forensic Entomologists (ABFE), and the European Association for Forensic Entomology (EAFE) have been formed within recent years to promote forensic entomology and ensure the continued advancement of this field of forensics (Rivers and Dahlem, 2014).

Today, forensic entomology is often used in cases involving criminal activity, in particular homicides or other cases involving human bodies. Insects are most often used to estimate the PMI, but may also be used as evidence in cases of neglect, for example when myiasis is found in elderly patients (Rivers and Dahlem, 2014). Many people are familiar with forensic entomology as it relates to criminal investigations. There are many publications regarding the identification and biology of forensically important insects, techniques for determining postmortem intervals, legal considerations, best practices, and recommendations for how to remain an efficient, ethical, and objective investigator in criminal cases (Haskel and Williams, 2008). Many case studies detailing cases of criminal forensic entomology are also available.

While criminal forensic entomology is the best known branch of forensic entomology, cases involving civil law may also involve entomological evidence. For example, entomological investigations are often needed in cases when insects are involved in product contamination complaints, pest control disputes, or stored product pest infestations, among many other topics. However, at this point, the field of civil forensic entomology has largely been neglected in the literature. The majority of textbooks examining forensic entomology gloss over the topic of civil forensics, and at best provide an brief overview with few references (see Gennard, 2012; Rivers and Dahlem, 2014 for examples).

Criminal vs. Civil Forensic Science

Forensic science deals with the application of science to law and legal cases, and is broadly defined as, “the use of scientific knowledge and technologies in civil and criminal matters, including case resolution, enforcement of laws and national security” (Rivers and Dahlem, 2014). Forensic entomology is a specific subcategory of forensic science concerned with the study of insects and insect related evidence in legal cases (Catts and Goeff 1992).

The general field of forensic science is typically broken into two broad categories: criminal forensics and civil forensics. These branches of forensics are related to two different bodies of law; criminal law and civil law, respectively. As implied by the name, criminal law relates to crime and punishing law breakers. Criminal law is enforced by the state, and cases are brought against an individual by the state or government. Civil law covers a wide variety of situations, but is defined as cases brought by private parties against other private parties without the involvement of the state. Civil cases can involve divorce, malpractice accusations, personal injury, product contamination, loss due to negligence, and many other issues. These two bodies of law have some other significant differences relating to the parties involved, the pleadings of the parties involved, the burden of proof, and the outcomes. It is important to understand these differences when considering the context into which forensic science fits. A summary of the main differences can be found in Table 1 (information summarized from Bevans, 2008).

Perhaps the most important difference between criminal and civil cases lies in the burden of proof. In criminal law, it must be determined beyond a reasonable doubt that a defendant is guilty. However, in a civil case, it must only be established that the preponderance of the evidence points to one side or the other. In other words, the plaintiff must show that their accusation is more likely true than not. Some have defined “preponderance of the evidence” as

meaning the plaintiff must establish the facts to 51% confidence. Another way to look at it is that in a civil case, the jury or judge must determine who has presented a more believable version of the facts. In some civil cases, clear and convincing evidence may be required, which is a higher burden of proof than preponderance of the evidence, but still lower than is required for criminal cases. This can occur if the result of the damages awarded will have a substantial impact on the lives of those involved (e.g. accusations of fraud).

	Criminal Cases	Civil Cases
Parties Involved	**Government** (or State) and **defendant** (person or organization being accused)	**Plaintiff** (person or organization who brings a civil suit) and **defendant** (person or organization being sued)
Possible Pleadings	Government issues accusation in the form of **complaint, information, or indictment**. Defendant pleads **guilty or not guilty.**	Plaintiff files a **complaint/petition**. Defendant responds with an **answer/ reply**.
Burden of Proof	**Beyond a reasonable doubt**. Jurors (or judge) must determine that there is no reasonable reason to doubt that the accused is guilty.	**Preponderance of the evidence** (occasionally clear and convincing evidence needed). Jurors (or judge) must determine which side has presented a more believable version of facts.
Outcome	Determination of **guilt or innocence**. If it is determined the defendant is guilty, a s**entence** will be imposed.	Determination of **liability**. If it is found that one party is liable to the other, **damages** (monetary compensation) will be awarded. No damages may also be awarded if it is determined neither party is liable.

Table 1: Summary of some key differences between criminal and civil cases.

Because the burden of proof in a civil case is lower, the testimony of a forensic scientist can greatly influence the conclusions in favor of one party or another. For example, a plaintiff may accuse a company of selling product contaminated with a live insect. The plaintiff may have pictures or video showing the insect on the product, or perhaps the testimony of others who claim they saw the live insect on the product. However, if an entomologist can provide a report explaining that it would be biologically impossible for an insect to survive under the conditions

inside the product, and that therefore the insect was introduced into the product after it was opened, this could tip the scales away from the plaintiff's claim and prevent the company from being found liable for the contamination.

Civil forensic entomology is differentiated from criminal forensic entomology in a number of other important ways. For example, civil entomology cases tend to be much more variable in the types of cases, scenarios, and the species involved. In criminal forensics, there is a subset of species (e.g. blow flies, dermestid beetles) which are commonly found, and which have been studied extensively in the context of forensic entomology. Most criminal forensic cases are likely to involve these species, and statistically reproducible information is often used. However, many civil cases are unique situations, and no base research has been conducted to help in gathering or interpreting the evidence specific to any particular case. Information will instead come from general research, which was not necessarily intended to apply to the specific context.

In criminal cases, recommendations and best practices are widely available (Haskell and Williams, 2008) to guide evidence collection and handling. No such guidelines exist for civil forensics, with the possible exception of stored product pests. In fact, the evidence collected in civil cases is rarely consistent or high quality. In many cases, only one specimen is available, and these specimens are often crushed, thrown away after being photographed, or otherwise damaged. This variability makes it extremely difficult to gather complete information, and in many situations the questions asked will be unanswerable due to lack of proper protocols or evidence collection and handling. Unlike in criminal forensics, which typically follows the scientific method closely, civil forensics are often less "scientific" and more based upon logical conclusions and piecing together available information (pg. 5-7 of Rivers and Dalhem, 2014).

Although many case studies have been published relating to criminal forensic entomology, very few are available relating to civil forensic entomology. In his book *Maggots, Murder, and Men*, Dr. Zakaria Erzinçlioglu described a few cases where he had been asked to comment on cases involving insects in civil cases (Erzinçlioglu, 2000). In addition, one case study was found which used entomological evidence to determine the origin of imported cannabis plants (Crosby and Watt, 1986). While this case is in the realm of criminal forensic entomology due to the classification of the cannabis plant, the principles are very similar to what could be used for civil cases relating to questions regarding the origin of food contamination, for example. This case is also significantly different than the majority of criminal forensics in that it did not involve homicide or any of the typical insects used for forensic entomology (e.g. blow flies). To help fill this gap in the literature, the following case studies are intended to add examples of how forensic entomology can be used in civil contexts.

Civil Forensic Case Studies

These case studies were conducted during employment at a research laboratory that is a division of a pest management company. Samples and cases are typically obtained from commercial companies who are paying customers of the pest management company. Purchasing the pest management services allows customers to use the services of the laboratory when needed for pest identification and forensic support. For the purposes of this paper, “customer” refers to companies that pay for pest management from the parent pest company, and “clients” refers to customers who have submitted a sample to the laboratory. To protect confidentiality, case studies are written with all reference to the names of the clients and other parties removed, and some details may be omitted if they will reveal the identity of those involved.

These case studies illustrate the types of cases that may be seen and techniques used to process samples. Techniques include insect identifications, literature searches, critical thinking, photography of samples, microscopy, and analytical chemistry. These case studies typically involve insects or other arthropods, but some cases involving other pest species or non-animals are also included to illustrate civil forensic principles. Pictures of the samples are included when available.

The Raisin Ant

This particular case involved a situation with a food manufacturing company that packages dried fruit and nuts and ships these products to a number of different countries. The manufacturer is located on the west coast of the United States. They contacted us asking if we could help them determine how an ant may have gotten into a package of raisins they sold. The raisins were grown, processed, and packaged in the US and shipped to Japan for sale at a retail location. They also wanted information on how they could prevent this from occurring in the future.

The information the manufacturer provided was that a large (1.1cm long), dead ant was found in a package of raisins after a consumer purchased the package at a grocery store in Japan. After eating the majority of the raisins, the consumer found the insect inside the package, and proceeded to return the raisins to the store. The store reported the contamination to the distributor, who complained to the manufacturer of the raisins. This situation caused significant tension between the manufacturer and the distributor in Japan. The distributor was one of the largest customers of the manufacturer, and was threatening to stop purchasing their products since they appeared to be infested. This situation also had the potential to cause damage to the reputations of the manufacturer, the distributor, and the grocery store.

The manufacturer was able to obtain pictures of the specimen quickly, and eventually had the actual insect and packaging returned to the US for analysis. They sent this to our laboratory for identification and root cause analysis. We examined the package, and determined that there was no damage to the plastic, other than the package was opened, as would be expected. The ant was easily identified as a species of carpenter ant (*Camponotus sp.*). We took pictures of the specimen (Figure 1), and began researching to determine the exact species. We eventually determined that this ant was *C. obscuripes,* commonly known as "Muneaka-oo-ari" in Japanese (literally translated "giant red chest ant"). This particular species is found in southeastern Asia, including throughout most of Japan. It is not known to occur outside this area, and is not found within the continental United States.

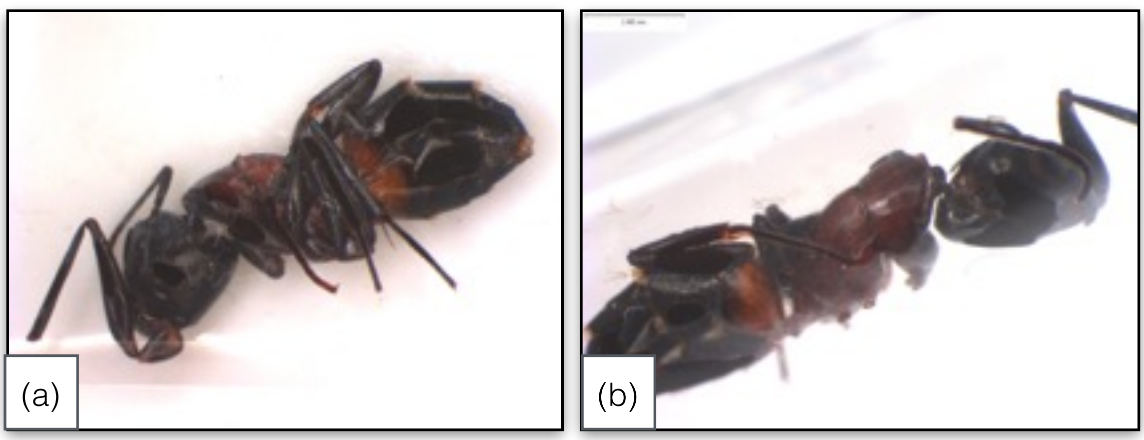


Figure 1: Ant submitted, showing characteristic coloration found in this species. Clear view of the red pronotum, which separates this species from closely related species, can be seen on the right in Figure 1a.

After the examination and based on this evidence, it was concluded that this ant could not have come from the manufacturer of the raisins. The ant must have entered the product sometime after it arrived in southeast Asia. Based on the intact packaging, it seems highly likely the ant crawled into the package after it was opened (as opposed to chewing through the packaging), and became trapped in the bag. This ant did not represent an infestation of any sort or negligence on

the part of the manufacturer. We provided a written report stating the findings that the ant was a species which only occurs in southeast Asia. The manufacturer was able to use this information to satisfy the distributor that this situation was not an indication of larger problems or a reason to cease purchasing their products.

<u>Maggots in My Potato!</u>

Humans have a way of slightly exaggerating stories. We often do this without even realizing it, although it may also be done intentionally. This story illustrates how something small was turned into a "mountain of maggots" with a little exaggerated storytelling. The case involved a sweet potato, which a woman reported she purchased, took home, and cooked in a microwave for 6-8 minutes. Upon cutting into the potato, she found what she claimed was a mass of live, wriggling maggots crawling in the potato.

The woman returned the potato and "maggots" to the store and issued a complaint. The store returned her money, and offered her replacement sweet potatoes as compensation, which she refused. The women insisted she and her husband became sick and were up all night, and that some sort of action must be taken. She claimed she had witnesses in the store who saw the live maggots, and that she had pictures.

The first indication of something unusual in this case was the claim that live maggots were found in the potato. Few insects are capable of surviving temperatures above 120°F. No known insect would be capable of surviving inside a fully cooked sweet potato, as a potato must reach temperatures of approximately 200°F to fully cook. This temperature would be lethal to even the most heat tolerant insects (Sherwood, 1996). The pictures taken by the consumer were sent to our lab for analysis. In the pictures, we observed was a single piece of whitish material in

the potato, but it did not appear consistent with the shape, size, or appearance of a maggot (Figure 2). We requested the sample be sent to our laboratory for closer analysis.

Upon receiving the sample, we confirmed that the potato was softened and appeared fully cooked. The small piece of foreign material which had been visible in the original pictures was located and removed, and a thorough examination for any additional pieces was conducted. Only a single piece of foreign material was found. This piece was placed in a petri dish and carefully examined. Rearranging the pieces revealed it was a very small plant, complete with leaves, roots, and a stem (Figure 3). In addition, no segmentation, mouthparts, spiracles, or other characteristics unique to insects were found.

Figure 2: Picture of contaminant submitted by consumer.

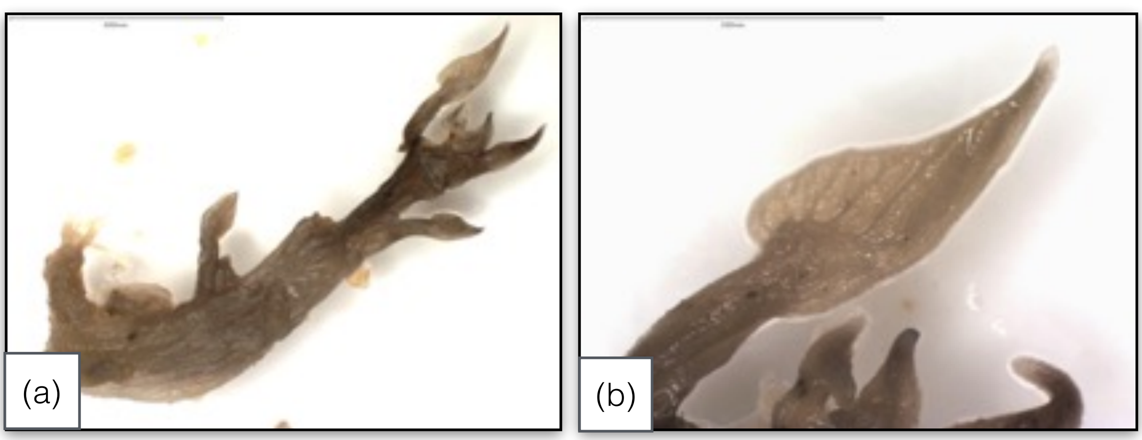


Figure 3: Contaminant after removing from potato and laying flat. Leaves, roots, and other plant characteristics can clearly be seen.

We did not pursue the identification of this sample beyond “plant,” as this information was enough to determine the story from the consumer was inaccurate and no maggots were present. However, it is likely this was a small piece of a potato shoot, or possibly other plant matter which was introduced from the meal the consumer was eating (e.g. from a salad). However, what was certain was that this was certainly not an insect, there was not a “mass of maggots” in the potato, the sample provided could not have been wriggling and alive as the consumer insisted, and is unlikely to represent any health concerns or to have caused any illness.

<u>Extra Protein for Fido</u>

This case consisted of a pair of rawhide dog chews returned to a pet store with evidence of insect activity and damage to the chews. The question was what species of insect was in the package, and where this infestation could have originated. The insects could have been introduced to the product during manufacturing, while sitting on the shelves at the store, or at the consumer’s home after purchase.

The dog chew package was sent to our laboratory for analysis. The bag was sealed upon arrival with no visible holes, and the package appeared to be airtight. Examination of the package revealed hide beetles (*Dermestes maculatus*) inside the package. There were living larvae inside (Figure 4), varying in age from early instars to almost mature larvae, and some dead adults. A large amount of frass and cast larval skins could also be seen inside the bag, and the rawhides had visible feeding damage.

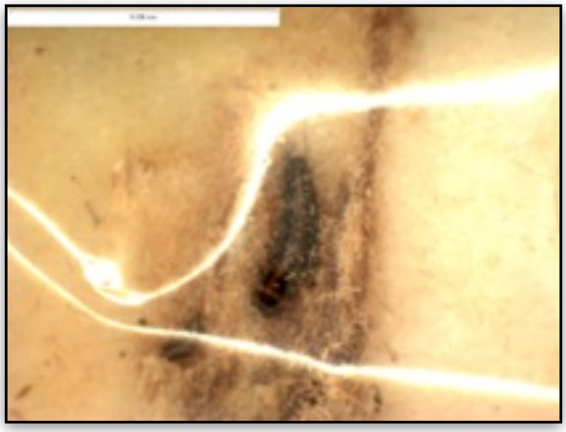


Figure 4: Live larva inside the bag. Image was taken through the packaging to ensure evidence of intact packaging was not destroyed.

The sealed package indicated that these insects did not penetrate the packaging after manufacturing, and were present before the package was sealed. Based on the amount of damage seen on the rawhides, the presence of large amounts of frass and many cast skins, and the presence of adult beetles along with living young and mature larvae, we concluded this population of insects had likely been in the package for some time.

While it is possible for multiple life stages to be introduced to a package during manufacture, it is much more common to see a few small larvae or eggs go undetected. This is likely what happened in this case, and we recommended the manufacturer inspect their processes and facility to put preventive measures in place.

Health Food Invasion

The hospitality industry is very sensitive to complaints about insects in guest rooms, especially with the current focus on bed bugs. Any guest sighting of insects can be cause for concern, particularly if these sightings end up on social media or review websites. In addition, many people cannot tell the difference between a bit of pocket lint and a bed bug nymph, and may often overreact before receiving a formal identification. So when a hotel location began

finding clumps of “insect eggs” stuck to the doors and walls in bathrooms, they were quite concerned and desperate to determine what type of pest this could be an how to eliminate it quickly. Hundreds of these “eggs” were found, laid individually and in clusters in multiple rooms over a period of a few months. We recommended the sample be mailed to the lab for identification.

When the sample was received, it did in fact look like it could be insect eggs. However, upon closer inspection, there were several characteristics distinctive to insect eggs which were missing. In particular, there was no evidence of any sort of micropyle, and the eggs did not appear to have any of the micro-sculptures common on insect eggs. In addition, they were very hard, could not be crushed, and there were a variety of colors, which is unlikely to be seen with insect eggs. The “eggs” looked more like extremely tiny beans than eggs (Figure 5).

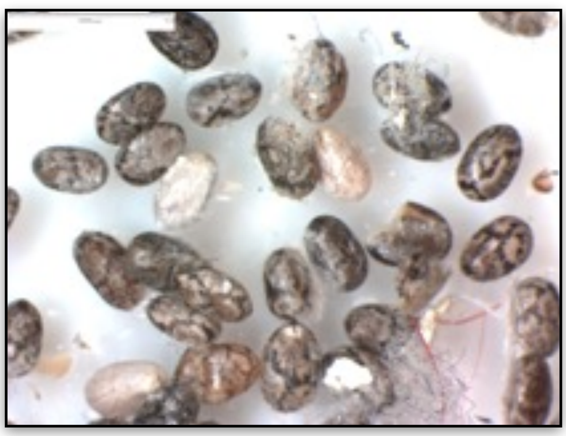


Figure 5: Sample as received after being scraped off a door jamb at the hotel.

After studying the sample for a while longer, they started to look familiar. In fact, they looked an awful lot like the small seeds that come with a Chia Pet! Most people are familiar with Chia Pets and the small seeds which are included with the package. Wetting the seeds turns them into a gel like substance, which can be adhered to a clay sculpture. However, what many people don’t know is that chia seeds are edible, and can be mixed in with foods or drinks. Thanks to a

recent health food trend, mixing chia seed into drinks such as orange juice has become rather popular among certain people.

Some known chia seeds were obtained for comparison, and they were an exact match for the “insect eggs” submitted. In this case, it is easy to imagine a hotel guest had made a chia seed beverage and spilled some in the bathroom. Chia seeds are quite sticky when wet, and would have easily adhered to a door or wall. Once dried, they were found and mistaken for the eggs of an insect.

<u>Swimming Spiders</u>

Imagine your son was drinking a bottle of chocolate milk, suddenly cried out in pain, and you then found a found a spider in the milk bottle. It would probably not seem like a leap of faith to assume the spider had been in the bottle and bitten your son, and of course you would be worried about his safety. After seeing to your son and seeking appropriate medical attention, you may conclude that the milk was infested with this spider, and that you deserve compensation for your trouble and your son’s pain. Such was the case in a situation we encountered.

The spider in question was fortunately saved as evidence and sent to our lab (Figure 6). We determined it to be a yellow sac spider (*Cheiracanthium sp.*). Based on information received from the milk bottling company, their milk products were bottled with approximately ½” of air above the milk, and the milk is held under refrigeration at all times. The time between when the milk in question was bottled and when the spider was found was at least 13 days. Being ectothermic, spiders are not capable of moving quickly or responding to danger at refrigeration temperatures. Under refrigeration, a spider in a bottle of milk with only ½” of air space would certainly be knocked into the milk by splashing liquid, and would be unable to climb out. Yellow

sac spiders are not capable of surviving submerged for any substantial period of time, and 13 days in a refrigerated bottle of milk would certainly be lethal to any spider.

Figure 6: Spider as received, still within the plastic packaging it was shipped in.

Yellow sac spiders are commonly found in homes, and they are capable of biting humans. With this in mind, it appeared the spider in question managed to entered the bottle after it was opened. It is quite possible it had been crawling on the bottle and was knocked into the milk either before or after it bit the son. However, it is almost certain a live spider could not have been present in the bottle at the time it was purchased or before it was opened.

Extras in the Steak

Not all samples received while working in entomology will actually come from insects. Because there is often overlap between entomology and pest management, we will occasionally receive samples related to rodents, birds, or other pests. In most cases, the principles of investigation are the same, and these cases can often be handled even by an urban entomologist, although care must be taken not to overstep available expertise.

In this case, a women purchased a steak at a local grocery store. After taking the steak home, she returned it to the store, claiming that there were rodent droppings on the steak and

demanded her money back. A few hours later, she went back to the store store and purchased another steak, again claiming it had rodent droppings on it. This time, she wanted further compensation and began contacting lawyers, the health department, and the local newspaper. We were contacted and asked for assistance determining if this contamination was in fact rodent droppings, and if we could determine what the material was.

The company sent one of the steaks with the "droppings" to our laboratory for analysis. By the time it arrived, the woman's story had changed and she now claimed was that the contaminants were metal shavings. Upon inspection, we found many small (~1mm), uniformly sized pieces of black material on the surface of the steak (see Figure 7). We determined through visual analysis that the material was not metal shavings, as the material was black, non-metallic, had a soft texture, and was transparent in some areas. We also examined the material for any evidence of insects, insect parts, or droppings of any sort. No evidence of insects or dropping was found.

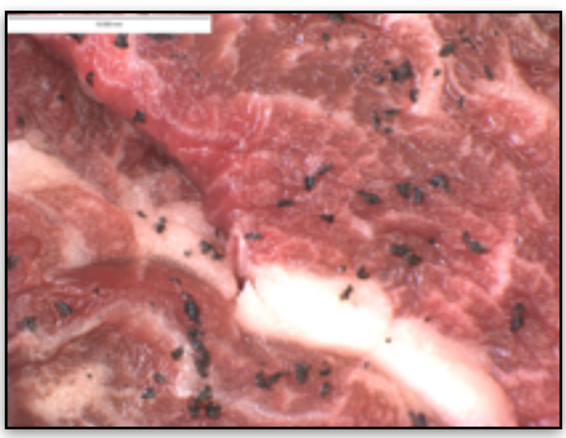


Figure 7: Steak with small pieces of foreign material on the surface.

Based on the initial visual analysis, we tentatively identified the material as black foam, such as Styrofoam or foam padding of some sort. A black Styrofoam tray, which the steak would have been originally sold on, was sent to our lab as well. We did a visual comparison of the

foreign material on the steak to pieces of the foam tray, and it was determined that the materials were a very close visual match (Figures 8a and 8b).

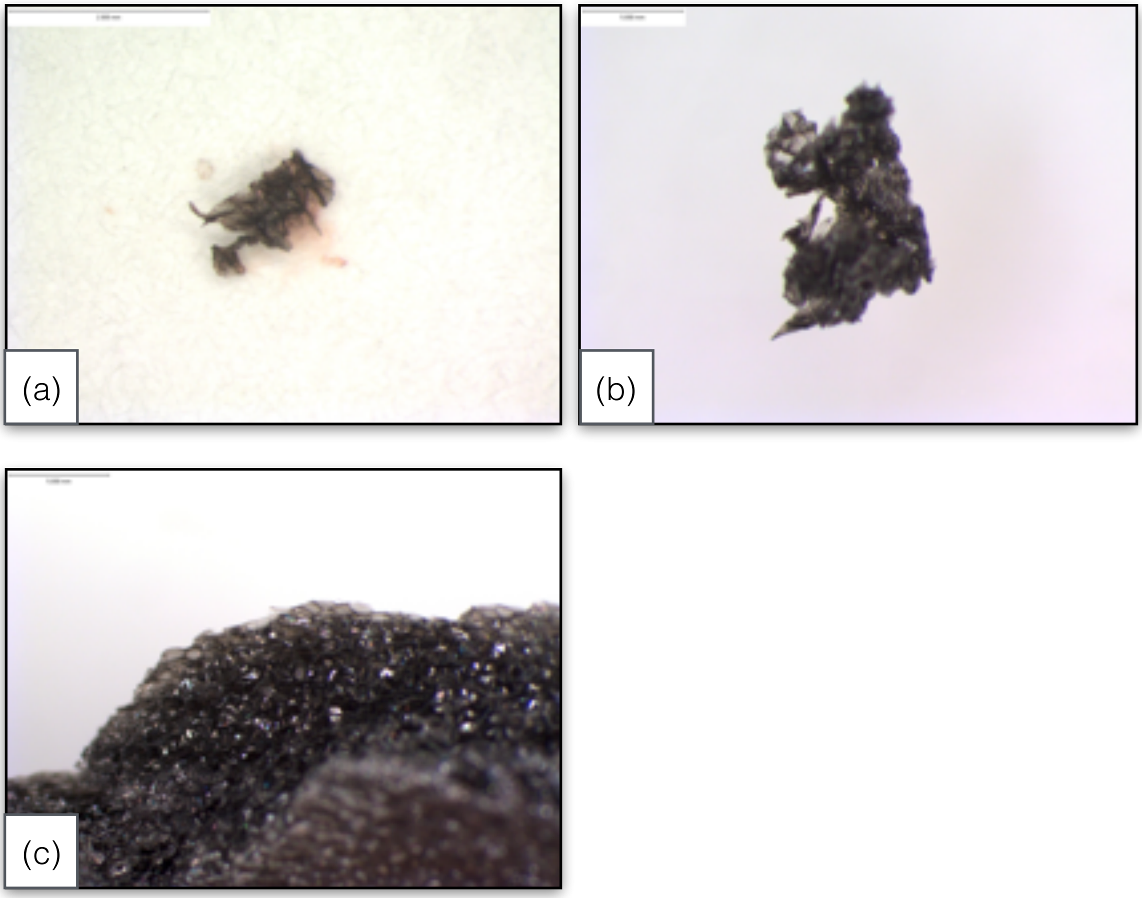


Figure 8: A - Closer view of the foreign material removed from steak, showing foam-like structure, B - Piece of tray which was torn into a similar size as specimen, and C - Edge of sample foam tray after being broken.

Next, pieces of the material from the steak and the foam tray were submitted to a Analytical Chemistry Laboratory (internal to the same company as our laboratory) for chemical analysis using Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) and Energy-Dispersive X-ray Spectroscopy (EDS) to identify the chemical components. The analytical tests provided very strong evidence that the material on the steak and the foam tray had the same chemical composition, consisting of polystyrene, indicating the foreign material on the steak was the same as the foam tray.

Finally, we conducted tests to see if we could replicate the appearance of the polystyrene pieces found on the steak using methods which would be expected in a home kitchen or butcher shop. Methods included tearing the tray, scraping the tray with a spoon, cutting with a butter knife, cutting with a razor blade, crushing with fingers, picking the tray apart with fingers, bending/snapping the tray, freezing steak to the trays and quickly removing, and other tests. None of the methods produced small, uniform pieces of foam similar to the pieces on the steak. We were able to form some small pieces using these methods, but they were non-uniform in size and we could not get large quantities. The store director informed us that small pieces of foam occasionally occur on the sides of the foam trays in the original packaging. We considered this as a source, but found these pieces would also not be found in high enough concentrations to produce the material seen on the steak.

In this case, our conclusions were that no droppings or metal shavings had contaminated the steak. The foreign material found was very likely small pieces of the foam trays the steak was packaged on. We also concluded that no likely explanation could be found for how pieces of these trays could have been introduced to the steak accidentally. Of course, we did not comment in our report on where the pieces could have come from, as it could have originated from a disgruntled employee, for example. However, the evidence pointed to the woman herself having placed the foam pieces on the steak in an attempt to receive compensation. Regardless of who may have placed the foam pieces on the steak, it did appear to have been done intentionally. After we submitted a report stating our findings, the women ceased her attempts at contacting lawyers, the health department, and newspapers and dropped the case.

In or Out?

When insects are found in food, the first question is typically "when, where, and how did the insects get into the food?" Oftentimes, this question is difficult to answer, especially when the only information or evidence available to the investigator is the specimen without much context. However, there may be clues if you are willing to look close enough.

We received a sample consisting of food pouches that had an inner foil lining and an outer paper layer. These had been filled with food product and shipped from the US to Mexico. Upon arrival in Mexico, the samples were found to be infested with warehouse beetles (*Trogoderma variabile*). The pouches had been in storage for some time between the date of manufacture and their arrival in Mexico. In addition to the beetle infestations, the pouches contained many holes, and the manufacturer wanted to determine if the holes were from warehouse beetles. If so, they wanted to know if they had been chewed in or out of the pouch. The logic was that if the holes had been chewed out of the bag, the beetles had likely been in the pouches during manufacturing, and the infestation was the fault of the manufacturer. If the holes had been chewed into the pouch, the infestation likely occurred during the storage period. Of course, if the holes had been chewed both in and out, the results would be inconclusive.

The damaged packages were sent to our laboratory and viewed under magnification. The majority of the damage was consistent with insect damage. The holes were consistent in size with what would be expected if caused by *Trogoderma* beetles. The damage typically appeared along a seam or bend in the package, or along a small tear or imperfection in the paper. In particular, the chew marks were seen on the outside of the bottom seam of the package (Figure 9). This is typical of insect damage, as insects can more easily grab and bite through the packaging in areas with bends or tears.

Additionally, in many of the damaged areas, the paper package on the outer portion was more damaged than the foil lining, or damaged in areas the foil underneath was not damaged. No damage to the foil was visible in areas where the paper was not damaged. We concluded the insects likely chewed from the outside into the package based on the location and other characteristics of the damage. This indicated the infestation most likely occurred while the product was being stored.

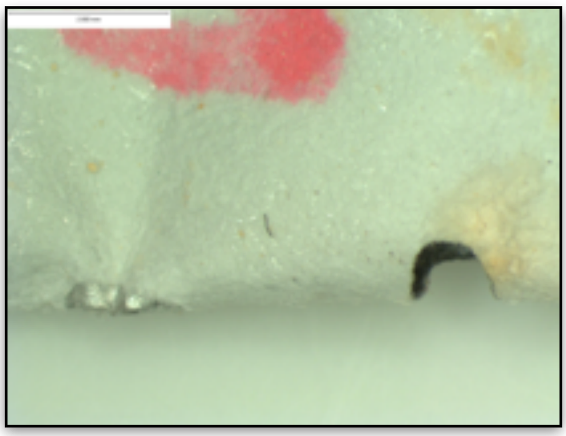


Figure 9: Example of chew marks in the bottom seam of a pouch. Left mark has damage to paper packaging but not foil liner.

Buttery Parasites

Complaints from consumers will often contain inaccurate facts and misidentification of specimens. Of course this is sometimes done intentionally, but often it is simply misunderstandings of the subject at hand. As an example, we received a sample that consisted of what the consumer reported to be a “parasite” on a stick of butter. It seemed that the consumer assumed the critter they found in the butter must have come from the cow’s milk that was used to make the butter. We were unaware of any parasites which are found in cow’s milk, and could find no reference to parasites in cow’s

milk in the literature, so this seemed to be an unlikely explanation for what the specimen was. We requested it be sent to the lab for analysis.

Upon receiving the sample and examining it under a microscope, it became clear the sample was not a parasite of any sort, but instead a soil centipede (Order Geophilomorpha). The centipede was under the wrapper of the butter, but was on the surface of the butter and did not appear to be embedded in the butter. (Figure 10) It was fully intact and undamaged. The condition and location of the centipede indicated it likely entered the package after the butter had cooled, and was not mixed into the butter during production.

Figure 10: Soil centipede on the surface of the butter.

As their name suggests, soil centipedes live in soil, burrowing up to 70cm below the surface. They are predacious, typically feeding on small arthropods or worms in the soil, and have no interest in feeding on or living in butter. They would be unlikely to enter a cold environment such as a refrigerator or cold package of butter. Soil centipedes require high levels of moisture and will not reproduce indoors under normal circumstances, so they are unlikely to be found in a food manufacturing facility. In this case, the most likely explanation is that the centipede accidentally entered the butter

packaging, probably while it was sitting out on a counter or other warm surface. This is most likely to have occurred after purchase, as the butter was tightly wrapped and kept cold until purchase.

Laminated Flies

As discussed previously, the question of where an insect was introduced to a product is often asked. Identification to species can provide information about the distribution of that species, allowing the origin of the insect to be determined in some cases. However, identification to species is often impossible due to damage or other considerations. In cases where the species cannot be determined, there are some other methods which are often useful for determining, or at least ruling out, some areas as the geographic origin. In these cases, the identification should still be carried out to the most specific taxonomic level possible, and then other factors should be examined.

In one case, a manufacturer of pouches made from laminated plastic sheets received a complaint of insects sandwiched between the sheets of plastic. The plastic pouches in question were of uncertain origin, as the manufacturer produced some of the pouches in December at their facility, but also purchased some from an outside vendor in a different location. The manufacturer wanted to determine if these insects were from the pouches they produced in December, or if they came from the alternate supplier.

When the samples were received, we determined they contained a mosquito (Culicidae) and a crane fly (Tipulidae) (Figure 11). The insects were, in fact, sandwiched between the layers of plastic, so they were almost certainly introduced during manufacturing. We were unable to determine the species of these specimens with any

certainty, as they were quite badly damaged. However, in this case, the exact species did not matter because both of these insects would be inactive in cold weather. The manufacturer of the product was located in a temperate climate which was quite cold during December. The alternate supplier had produced their pouches in a time and location where mosquitos and crane flies would have been active. Based on this information, we concluded the contaminated pouches must have come from the alternate supplier, and that they had been contaminated with the insects during manufacturing.

Figure 11: A - Mosquito and B - crane fly laminated between layers of plastic.

Chicken Fried Maggots

It is unfortunate to think that some people will attempt to plant insects on products in order to sue or gain some other form of compensation. It is difficult to prove that insects were intentionally planted, and it is not the responsibility of a forensic scientist to prove intent. However, we have seen many cases where it certainly appears to be intentional fraud. In one such case, we received videos taken by a consumer showing live maggots on fried chicken. In this case, a consumer had purchased fried chicken from the deli counter of a grocery store. The purchase was completed at 3:09 pm, after which the consumer took the chicken home. At 4:21 pm the same day, the consumer returned to the

store with the videos claiming the maggots were on the chicken when purchased. One video showed several maggots on the chicken, and the other showed a number of maggots which had reportedly been pulled from the chicken and placed on paper by the consumer (Figure 12).

Figure 12: Screen shot from video showing maggots which consumer claims to have found on fried chicken.

We were not able to identify the fly species from what was visible on the video, but based on the large size of the larvae, we determined they had to be at least several days old, regardless of the species and growing conditions. There was simply no way for these larvae to have grown on the chicken to the size they were in the time since being removed from the store. In addition, fly maggots are certainly not capable of surviving in a deep fat fryer. The chicken at this store would have been fried within 24 hours of being sold (likely less). Finally, the chicken was immediately transferred into a hot storage area after frying, and held at 140°F, which would also be lethal to any fly maggots.

In this case, it is difficult to imagine any scenario where these maggots were not placed on the chicken intentionally after removal from the store. Of course, we are not able to determine who may have put the maggots on the chicken. Security cameras could be used to rule out if this was done by an employee, which would greatly strengthen the

argument that these maggots did not come from the store. But we can not rule out the possibility this was a prank done by a friend of the customer, for example. This is why, as a objective investigator, it is important to only state the available facts in the report, and not place blame on anyone or imply we know the underlying intentions of the parties involved.

Process of Elimination

When dealing with entomological identifications, there are often mistakes made by the general public. It is incredibly common for people to identify items such as plant parts, bits of food, specks of cardboard, and seeds as some sort of insect. Humans have a tendency to see “bunnies in the cloud,” and shapes that vaguely resemble a known item are often labeled as such. See Altschuler et al. (2004) for a great example of this phenomenon, which can even occur in the scientific community (this paper was later retracted for poor methodology and image manipulation). Identifying “harmless” insects as a pest of major concern, such as mistaking a carpet beetle larva for a bed bug, is also quite common.

Misidentifications relating to bed bugs, cockroaches, and “bugs” in general are the most commonly encountered misidentification in many commercial settings. Bed bugs, cockroaches, and “bugs” can quickly lead to upset customers, negative social media attention, and legal action if the claim is not addressed. In these cases, the general population often does not care about the identification beyond confirming or denying if the sample was what they thought it was. Therefore, many of these cases can be rapidly

resolved by demonstrating that the specimen is not what was claimed. The following cases illustrate this principle.

Bed Bugs Everywhere!

Over the past decade or so, bed bugs have become an extremely hot topic, both for entomologists and the average person. Everyone likely knows someone who has encountered a bed bug infestation, either in a hotel room, their private residence, or elsewhere. Many people are terrified of encountering this pest. It has become common for hotel guests to inspect their rooms for bed bugs before settling in. Due to the heightened awareness and fear surrounding bed bugs, reports of bed bugs in a hotel room or other location typically causes quite a stir. However, when the majority of people are looking for bed bugs, but are not well versed in how to identify these insects, it is common for insects and items which are not bed bugs to be misidentified as bed bugs. Following are some of the samples we have received which were misidentified as bed bugs, with their actual identification listed in the caption (Figure 13).

In some of these cases, such as the lint and plant seeds, items which hotel guests misidentify as bed bugs are harmless, and could simply be cleaned up and discarded. However, sometimes the samples found did include other pest species, such as german cockroach nymphs or carpet beetles. In these cases, the identification does not remove all concern, but does allow proper treatment to be conducted targeting the correct pest.

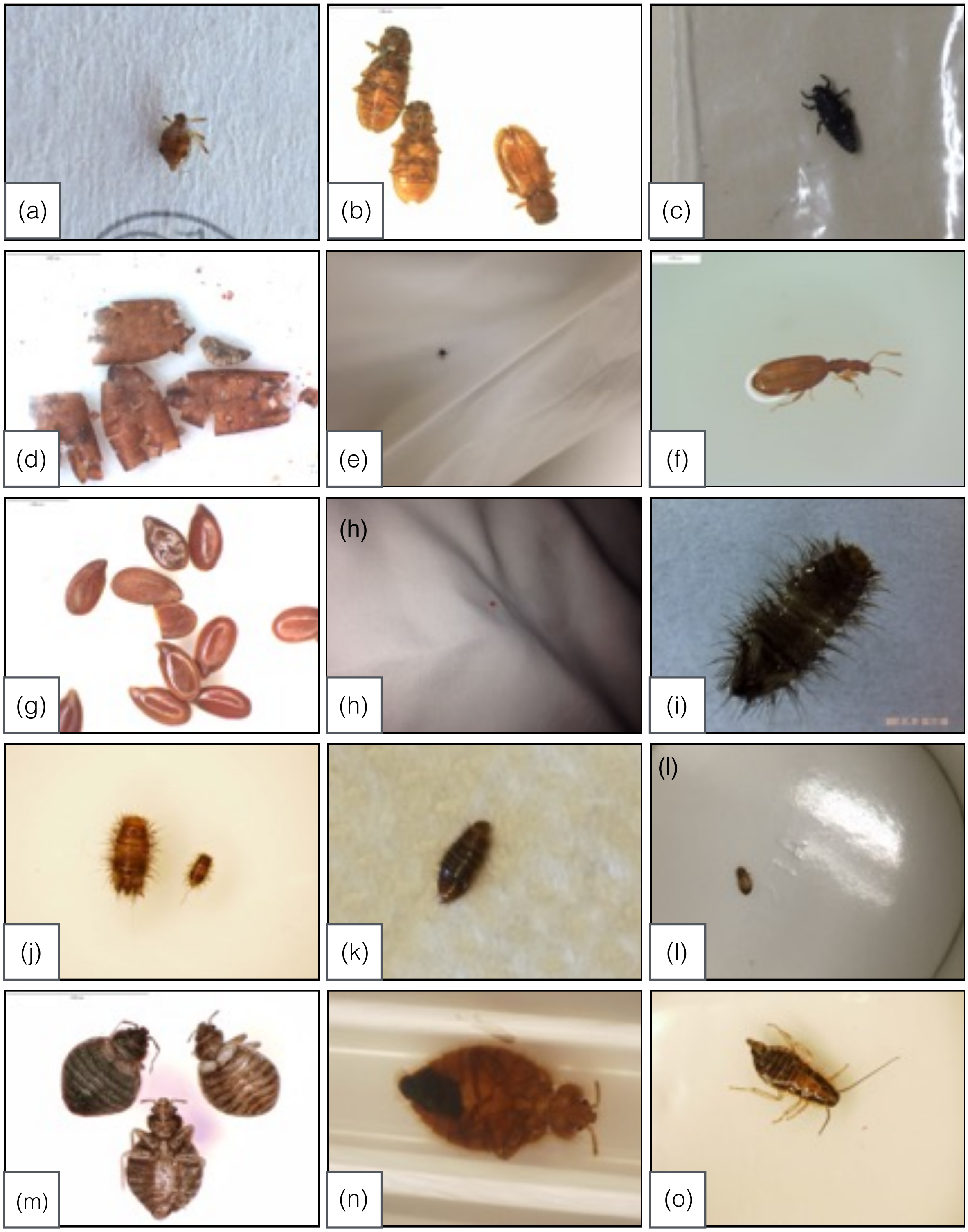


Figure 13: Actual identification of specimens thought to be bed bugs (*Cimex lectularius*): A - Aphid (Aphididae); B - Plaster beetles (*Migneauxia sp.*); C - Lady beetle larva (Coccinellidae); D - Flesh fly pupae (Sarcophagidae); E - Spider beetle (*Mezium americanum* or *Gibbium aequinoctiale*); F - Plaster beetle (Latridiidae); G - Plant seeds (likely flax seeds); H - Bit of red lint; I,J,K,L - Carpet beetle larvae. M - Swallow bugs (*Oeciacus vicarius*); N - Eastern bat bug (*C. adjunctus*); O - German cockroach nymph (*Blattella germanica*).

As stated above, confirmation that a specimen is not a bed bug, even though it may still be a pest species, is often enough to calm guests and settle the situation. In some cases, such as finding bat or swallow bugs, the client could still be held liable, as the guests can still be bitten and there is a pest present. In this case, the guest's perspective may be that the species name is irrelevant. However, proper identification is still necessary, as the treatment strategy will be very different depending on the species. In the case of bat or swallow bugs, the ultimate solution is to target the bats or birds, which ultimately caused the infestation of bugs in the first place, and elimination of the bug infestation in the nests or harborage areas is necessary.

Not A "Bug"

Many plant pieces, bits of food, cardboard shavings, and other items have been submitted after a complaint about someone finding a "bug." These samples are often in poor shape. Thankfully, there are a number of characteristics entomologists can look for to determine if a sample is an insect, insect part, or even an arthropod. These characteristics are typically visible even on damaged specimens, and include segmentation, setae, and spiracles, which in some form or another are found on all insects, including immature insects such as maggots. Other useful characteristics include mouthparts, eyes, antennae, legs, wings, wing venation, tarsal claws, and other structures which are commonly found in insects. While there is no single characteristic that can always be used to identify any particular sample as an insect or insect part, the

combination of characteristics found can often be used to identify the sample. A few examples of samples which were reported to be insects are covered below.

The specimen seen in Figure 14a and 14b was thought be an insect found on a piece of clothing. Without magnification (Figure 14a), the sample appeared to have legs, antennae, and a body. Once magnified (Figure 14b), it is clear this was not an insect, and is a made up of a mass of brown fibers. It was most likely a small bit of cardboard. Figure 14c shows some material which was found on a hotel bed by a guest. The guest thought these were insects, however, none of the characteristics of insects described above could be seen, and they do not have distinct body parts or the correct shape. This sample appeared to be of plant origin, such as seeds.

The specimens in Figure 14d and Figure 14e were both found in food by customers and reported to be insects. Most notably on the sample in Figure 14d, no segmentation or eyes are present. This was not submitted to the lab for a more detailed analysis, but even based on the picture, it was possible to determine this material was not an insect. This sample in Figure 14e was thought to be a maggot. We could determine this was not a maggot because it does not have segmentation, and the distinctive mouthparts and spiracles which are found on fly maggots are absent. Finally, the sample in Figure 14f was reported to be found in a cup of hot tea after adding some milk. The consumer who reported this thought they were insects which came in with the milk. They were actually seeds of some sort, possibly coriander.

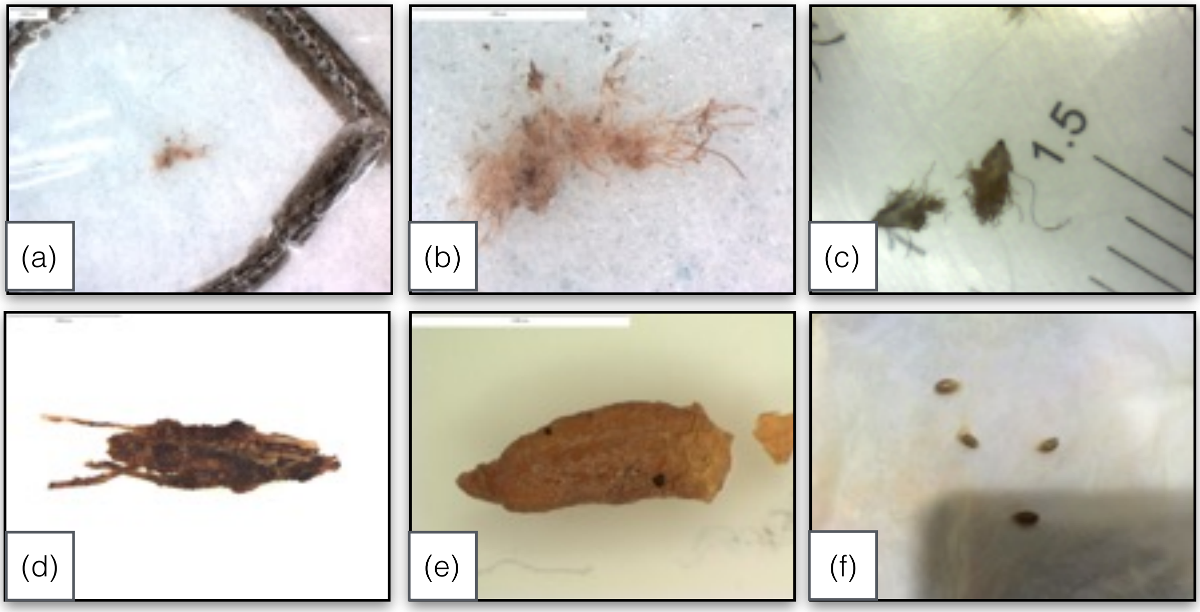


Figure 14: Specimens thought to be insects. All of these specimens were identified as something other than an insect or insect part.

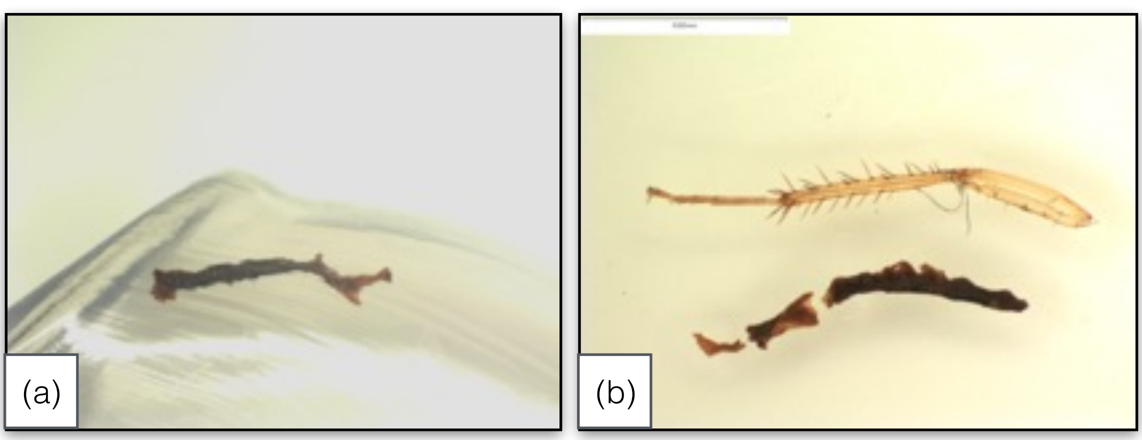
Not a Cockroach

Even though some other insects, such as house flies, are known to carry more diseases and be a greater health threat, cockroaches produce a visceral and negative reaction in many people. Despite logical arguments to the contrary, most people would rather see a house fly on their food than a cockroach. Unfortunately, cockroaches are common in many commercial establishments, so it is certainly not impossible for one to end up in a product. For these reasons, all reports of cockroaches in food need to be investigated fully.

Figure 15a shows a specimen found in a customer's dinner at a restaurant that was reported to be a cockroach leg. The image was taken through the container it was shipped in, as it was stuck to the side and would likely be damaged by removal. Figure 15b shows the specimen (bottom) after it was removed from the shipping container. The specimen was placed next to a known German cockroach leg (top) for comparison. Cockroach legs

have very distinct structures unique to this order. In particular, all cockroach legs are covered in very distinct spines on the tibia and have a slightly flattened femur. In addition, insect legs have segments, tarsal claws, and other distinct structures. The specimen submitted did not contain any of these characteristics, and it was determined this was not a cockroach or insect leg. It appeared to be a bit of burnt food, but the identification was not pursued beyond this point.

Figures 15c and 15d show two separate specimens which were found in food by customers. Both appeared to have been introduced to the food before cooking, and were reported to be cockroaches. Although identification to species was not possible, these specimens were both clearly moths, likely Noctuidae. These samples did both represent insect contamination in food, which is of course problematic and would still need to be addressed. However, in this case these “cockroaches” do not represented an infestation in the food production areas, so the situation should be handled differently. Most likely, this is a case where a night flying insect gained entry to the structure and accidentally flew into the food.



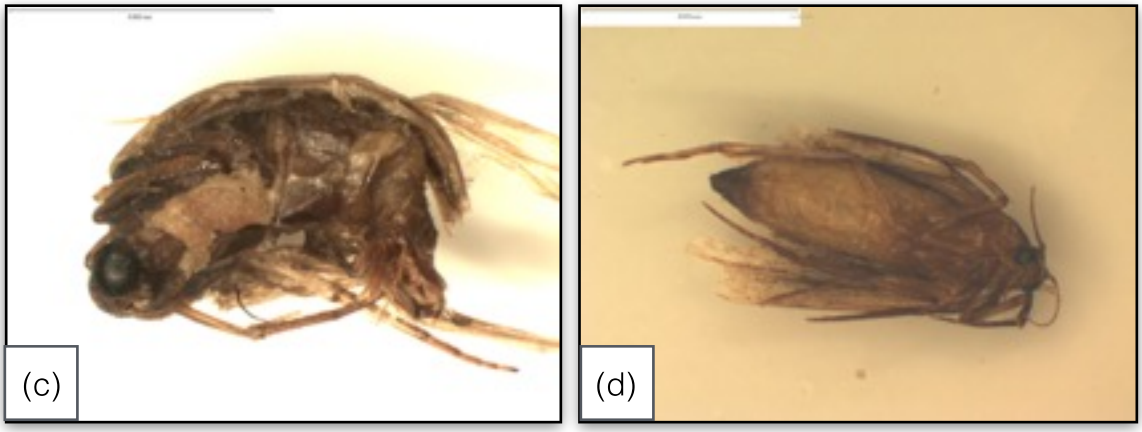


Figure 15: Specimens reported to be cockroaches.

Ethical Considerations

In theory, forensic scientists who are asked to conduct an analysis should be asked to determine what is true, they will be informed on how to determine that truth, they will be considered competent on how to analyze the information and come to sound conclusions, and they will have the integrity to report their findings honestly and completely. Of course, this does not always occur in the real world (Erzinçlioglu, 1998), and there are a number of ways in which those involved in a forensic investigation can conduct themselves in an unethical manner.

First, clients requesting analyses may try to engage in unethical practices. They may present information or evidence to a scientist that they hope will sway the scientist one way or another regarding the results or interpretation. They may falsify or omit important information or evidence when presenting information to the scientist. They may also outright request reports that support a certain claim or case, regardless of if there is evidence to back it up.

Second, forensic scientists can be guilty of looking for specific evidence to support a case they would like to see win. This can be especially problematic in the field

of civil forensics, where it is very common for the client seeking the analysis (often the plaintiff or defendant in a civil case) to have a vested interest in the results. The client is also often making a payment for the analysis to the scientist or laboratory. Scientists may feel pressure to present evidence as desired by their client so they will continue to receive work in the future. In fact, it is known that certain forensic labs can operate as "dry labs." These "dry labs" will, for the right fee, produce a report stating what their client wants to hear without having done honest or complete analysis, or sometimes with no scientific analysis at all (Erzinçlioglu, 1998).

We have received a number of samples that illustrate this principle. As an example, we received a specimen from a restaurant owner asking for support after a guest complained about finding a cockroach baked into their pizza while dining. The restaurant owner requested we examine a photo taken of the supposed cockroach to confirm it was not a cockroach. Unfortunately for the owner, the photo very clearly showed an adult German cockroach (*Blattella germanica*), and it was very clearly baked into the cheese. In this case, we thought it was unlikely the restaurant owner had any real doubt this was a cockroach, but he was still not happy we would not support his case against the guest.

The unfortunate fact of the matter is it would be incredibly easy to falsify, exaggerate, or omit information in a forensic entomology investigation. The majority of people involved in cases where forensic entomology is used do not understand entomology enough to disagree with or critically analyze the findings, and will typically accept a report at face value. In addition, the public perception of what is possible through forensic science has been distorted through the years. There is a plethora of modern crime shows in which scientists are almost instantly able to produce high quality

evidence and solve any crime in the span of an hour long TV show. These shows are thought to have shaped the public perception of how forensic science works. This is referred to as the CSI Effect (Kruse, 2010). Due to the perception that scientists can quickly answer any question, if scientists report that something is true, they are very likely to be believed. The lack of real public understanding of entomology paired with the CSI Effect and the public perception of what is realistically possible through forensic science can make it incredibly easy to falsify information and get away with it.

While no published recommendations on ethical practices in civil forensics entomology could be found, there are a number of resources available providing best practices and ethical standards for criminal forensics. Of course, the recommendations for criminal forensics will largely apply to civil forensics. However, the recommendations will vary slightly due to the differences between these fields. For example, civil forensic entomologists will often not collect evidence, and instead may have it submitted to them by a client, therefore recommendations for evidence collection at a crime scene may not apply.

Edmond et al. (2016) provide an excellent essay discussing the standards forensic practitioners should hold themselves to. They break their recommendations into four parts: 1) disclosure, 2) transparency, 3) epistemic modesty, 4) impartiality. Disclosure and transparency requires a forensic practitioner to make their practices, procedures, standards, and research available for review by the defense and clients. This allows the methods and practices used to be evaluated and any potential errors to be observed, creates more accountability, and increases the chances the work is done in a robust

manner. In addition, limitations, uncertainties, and controversies surrounding the methods used in the investigation should be disclosed.

Epistemic modesty requires a forensic practitioner to avoid being overly proud or confident about their abilities or knowledge. As stated by Edmond et al. (2016):

> "Epistemic modesty is inconsistent with hubris, ignorance and arrogance. Practitioners should avoid over-claiming and exaggerating performance, by acting in ways that are consistent with demonstrated ability. Opinions should be grounded in what is known about the capabilities and limits of procedures and the proficiency of individuals. Where there is limited knowledge, practitioners should concede uncertainties and limitations, and the strength of conclusions should be moderated accordingly. Opinions should be steeped in 'knowledge' rather than speculation, assumptions, subjective beliefs, traditions and past practices." (Edmond et al., 2016)

Finally, impartiality requires a forensic practitioner to act without bias or attempting to support one side of the other. Conclusions should be arrived at without considering the desires of the parties involved. Edmond et al. (2016) presented a question that forensic practitioners should ask themselves to determine if their conclusions are impartial: "Would I have written the same (or a substantially similar) report if I were engaged by the defense?" If the answer is "no," the conclusions are likely partial to one side, and the results should be reevaluated to ensure no unethical practices or conclusions are present.

It is unfortunate that there are laboratories and forensic scientists who engage in unethical practices. Neither criminal nor civil forensic entomology has established certification requirements or agencies which regulate the field. Any entomologist could claim to be a forensic entomologist, and it would not be considered illegal (even if it could be highly unethical). This lack of official oversight creates an environment where unethical practices, such as the use of “dry labs,” can all too easily go unchecked.

There have been several instances within the past few years where we had interactions with outside forensic laboratories that appeared to engage in unethical practices. In one case, we needed additional analysis on a sample which we were not able to provide. We contacted an outside laboratory, and they claimed they could answer the questions our client was asking. We told the client they could submit their sample to this outside lab, but that we had never worked with them before and could not necessarily vouch for them.

Our client decided to submit the sample, and after a few days (and a rather large sum of money), the lab provided a report stating their findings. To put it mildly, the findings were extremely favorable to the client. However, the report contained little to no information on how the lab arrived at their conclusions. When pressed for information, they would not explain their test methods, citing “trade secrets.” Of course, we had no way to prove our suspicions, but the impression we received was that they had made up results that supported the customer’s claims. However, as this case illustrates, the ultimate problem is that it is too easy too difficult for outside groups to prove if a lab is being dishonest even if there is suspicion.

While the situation described above is unfortunate, we learned some valuable lessons from this experience. In particular, this story highlights why it is important to present the information to a forensic lab in way which does not reveal your own bias or which side you are supporting. For example, we told the outside laboratory, “our client has a pending lawsuit against them claiming X.” We should have phrased it, “there are two parties, one which is alleging X, and one which is alleging Y.” This would have forced the lab to be honest and removed any doubt that they provided the desired results under coercion.

Keeping information vague when possible can protect forensic scientists from unconscious bias as well, and better allow them to conduct their analysis without partiality. In some cases, not requesting detailed information on the situation might be justified, but this can make the analysis difficult or impossible, as background information is often critical for conducting an analysis. If possible, technicians or others who are conducting individual portions of an analysis should only be told information on a need to know basis.

It is very easy to see why ethical standards are critical in the context of criminal cases. Falsified information could easily send an innocent person to prison, or cause the release of a guilty criminal. It may seem less obvious why these standards are critical in civil cases as well, as the consequences within civil law can seem small in comparison. However, within a civil forensic laboratory, there are certainly still significant consequences to not acting in an ethical manner. Falsifying information or failing to conduct impartial analyses can still harm innocent individuals or corporations when they are found liable and required to pay large, undeserved monetary fines. Even if the

consequences are “smaller,” lives can still easily be greatly harmed by falsified information in civil cases.

In addition to harming the clients or others involved in legal cases, falsifying information can harm the laboratory or individual conducting the analysis as well. For example, a laboratory or individual who falsified information could have civil lawsuits filed against them. it is not unheard of for a client to send a “test” sample to confirm the capabilities and honesty of a laboratory. Falsified information can also put the lab or individual in a very awkward position when they are called to testify and are unable to defend their positions.

Falsified information can also lead to some complicated situations for the laboratory as well. We once had a case where a client came to us and asked us to support their claim that insects could not have been present in their food product due to a screening processes they claimed to use. We were unable to confirm that they had the processes they described, as we could not travel to the facility. We were also not experts in the field of food manufacturing, and would have been overstepping our expertise to comment on this. In addition, we were able to envision scenarios where the insects could have entered the product despite the processes they described. We declined to write the report the way the client requested, and instead only provided an identification of the insects and information on the biology and habits of this particular species.

We discovered later that this client was fighting against a second company in court regarding this situation. We learned that this second company was also a client of the pest company when they submitted the same sample to our laboratory at a later date. They did not know the first company had submitted the sample, and also requested

support stating the insects could not have come from them. Luckily, we were able to provide them a similar report with an identification and biology information, and there was no conflict of interest on our end. Needless to say, it could have been an incredibly awkward and tricky situation if we had falsified information for the first customer. Remaining impartial in investigations will prevent issues like this, and many others, from becoming major problems at a later date.

Best Practice Recommendations

The following best practices are written specifically to apply to work conducted in the field of civil forensic entomology. Specifically, these were written for the research center in which the preceding case studies were conducted. They will also apply to others working in a civil context as forensic entomologists, especially in a laboratory where the service are being paid for by a client, but may need to be modified slightly. These recommendations should be considered an elaboration on the recommendations covered above for disclosure, transparency, epistemic modesty, and impartiality (Edmond et al., 2016), and will provide some practical tips for how to avoid the unethical practices too often seen in the forensic sciences. If followed, these recommendations can help forensic laboratories consistently produce high quality research and reports, and remove doubt as to the soundness of the methods used.

Perhaps the most important recommendation for a civil forensic entomologist is to document everything done in great detail. Incorrect or falsified information and missing or omitted information are both errors which need to be avoided. Information on the type of sample received (photograph or physical specimen), condition of the sample when received, number of samples received, the methods or characteristics used to analyze the sample, and conclusions are

among the information which should be carefully recorded. In addition, pictures of specimens should be taken to document the processing of the sample. The following steps should be followed when receiving a physical sample. Some of these steps will not apply to samples only consisting of electronic photographs. For non-physical samples, electronic records including emails and copies of the pictures submitted should be saved.

1) Upon receiving a sample, record the date the sample was received. Carefully open the shipping container. Document and photograph the initial condition of the sample and any damage to the shipping container.
2) Record any information provided with the sample, such as the client name, reported collection location, details about the situation, questions they want answered, etc. Specify who this information came from so it is clear the information was provided by a third party.
3) Carefully open any secondary containers and remove the sample for examination, taking pictures during each step while opening and processing the sample. Pictures should have scale bars or other items (e.g. ruler, coin) for size references.
4) Record details about the sample, such as the approximate number of each species or sample type included (e.g. 5 house flies, 10 suspected rodent droppings, etc.) or other relevant notes on the condition of the samples (e.g. arrived on a glue board, in alcohol, in tape, crushed, etc.).
5) Assign a unique sample numbers to each specimen. In the event multiple species or types of samples arrived in a single shipment, or the client specified that individual specimen should be treated as unique samples (for example, if they were collected in different locations), each species or type of specimen should be given a unique

sample number. This sample number should be included with all pictures, reports, information logs, emails, or other documents relating to the sample.

6) Conduct the analysis requested, recording steps taken to answer any questions and information used to come to conclusions. For example, during an insect species identification, record and photograph the specific characteristics used to determine the species. Make notes of characteristics seen which are possible to capture in pictures. List specific resources or techniques used to conduct the analyses when relevant.
7) After the analysis is complete, a written report should be provided to the client. The written report can be in the form of an email in some cases, but for most civil forensic entomology cases a formal written report should be completed. The report should include:
    a. Information provided with the sample (with notes regarding who the information is from)
    b. Relevant information on how the sample was received, what the sample consisted of, etc.
    c. Pictures of the sample taken during the analysis.
    d. Summary of the findings or conclusions from the analysis.
    e. Reasoning or resources used to arrive at the conclusions.
    f. Page count (page x of y) should be included so pages cannot be removed or added.
    g. Report should be written on official letterhead, should include information about to whom the report is addressed and who is completing the report.

Reports should be completed or approved by the person who did the analysis.

8) A response should be provided to the client within three business days. In the event the analysis will take longer than three business days, this should be communicated to the customer.
9) Samples will be retained at the research center for three months after the date they were received. If requested, the samples will be returned to the customer, and this should be noted on the information log.

Because samples will not be retained indefinitely in most cases, it is critical that the documentation be thorough. The information recorded will become very important if at a later date questions are asked about the samples. This may occur if the situation results in legal action, which can often take years. It is also important to establish the chain of custody of the sample. Additional information and best practice recommendations for analytical entomology work can be found in the essay by Zimmerman and Bickley (1996).

When providing the final report to a customer, it is important to be honest about what was found, even if it will make a client unhappy. Conclusions stated in the report should only be as strong as the evidence supports, and they should be written in a way which will avoid misinterpretation by the client or other parties involved. Even in situations where the small details do not appear to matter, these details should be reported honestly and accurately.

A good rule of thumb when writing the report should be to only include information you would be comfortable defending in court. As discussed above, the report should also be similar to what you would have written if the sample had come from a different party involved in the case. In the end, even if the client may be unhappy with the report if it doesn't say what they

wanted, one can only hope they will appreciate the opportunity to discover the truth so they can correct any underlying issues that may have led to the situation. This is not always the case, but still does not mean that the report should be modified just to make the client happy.

Future Research Directions

The field of civil forensic entomology has largely been neglected in the literature, and very few studies have been done which could relate to commonly encountered situations. There are several areas of research which could have significant impacts on this field and would be relevant to a large number of cases.

One of the most common questions we get asked is if a sample has been "cooked" or not. Currently, there is no reliable way we are aware of to answer this question when it relates to insects or other arthropods. The exoskeleton of insects is rather robust, and no visual differences are apparent between insects exposed to high heat and those exposed to other conditions (e.g. desiccation, damage from UV light, etc.). However, it is likely some consistent changes to insect exoskeletons or other structures occur after exposure to heat above a certain level. Studies to determine if consistent changes occur, and how to easily test for them, would be very beneficial.

Similarly, we are often asked if an insect was submerged in a liquid for a prolonged period of time (e.g. was it bottled in the juice?). In his book, Dr. Erzinçlioglu discusses a situation where he was able to determine a fly had not been bottled in wine as flies that have been submerged in a liquid for an extended time will shrivel after removal from the liquid. The fly in question did not shrivel when removed, and therefore could not have been in the wine for long (Erzinçlioglu, 2000). There are likely other consistent changes to soft and hard bodied insects in various types of liquids such as milk, soda, juice, wine, etc. It would be helpful to

know, even in a general sense, what occurs when insects are exposed to common liquids for extended periods of time, both in sealed and open containers.

Information on the identification of specimens commonly encountered in civil forensics would also be very useful. In particular, ant swarmers (alates) are frequently encountered, but very little information on identifying this caste to species exists. Identification keys for ant swarmers would be helpful for civil forensic entomology and other areas of study, such as ecology, insect identification, etc.

Identification keys for pest species encountered on a global basis would also be helpful, even though developing such a key would be a monumental task. There are many species which are known and common pests in certain geographic ranges, and examination of local literature would provide information. However, in civil forensic entomology, the location of origin is often the question being asked. In cases where the specimen is a pest in localized areas, a global pest identification key would be very useful. Of course, information in a key of this sort would need to be used with caution, and secondary confirmation of any identification should be conducted. This type of information would also allow an investigator to rule out pest species on a wider basis, which can be useful even when a species ID cannot be obtained.

Finally, better methods for identifying and differentiating quarantine pests would be helpful. In cases where shipments have crossed international borders, any insects found alive have the potential to cause introduction of a quarantine or new invasive species. The methods currently available to rule out species of major concern are very limited, and typically involve working with government agencies such as the USDA-APHIS, which can take a substantial amount of time. An example of when this would be helpful is in the case of the quarantine pest the Khapra beetle (*T. granarium*), which looks extremely similar to the cosmopolitan and very

common warehouse beetle (*T. variable*). More information on how to differentiate these two beetles, or at least rule out the Khapra beetle even in cases where the specimen is damaged would be very useful.

Many other avenues of research could be pursued in civil forensic entomology. Despite the lack of attention this branch of forensic entomology has received, it is a fascinating field with many interesting opportunities. There is a need for more research in this area to increase the quality of work and provide additional answers to parties involved in these investigations. Hopefully, this paper will provide information which can be built upon to increase awareness of and participation in civil forensic entomology.

References

Altschuler, D.Z., Crutcher, M., Duceanu, N., Cervantes, B.A., Terinte, C., Sorkin, L.N. (2004). Collembola (springtails) (Arthropoda: Hexapoda: Entognatha) found in scrapings from individuals diagnosed with delusory parasitosis. Journal of the New York Entomological Society. 112(1): 87-95.

Benecke, M. (2001). A brief history of forensic entomology. Forensic Science International. 120: 2-14.

Bevans, Neal R. (2008) Civil Law & Litigation for Paralegals. Boston: McGraw-Hill.

Catts, E.P., Goff, M.L. (1992). Forensic Entomology In Criminal Investigations. Annual Reviews in Entomology. 37: 253-257.

Crosby, T.K., Watt, J.C. (1986). Entomological identification of the origin of imported cannabis. Forensic Science Society. 26: 35-44.

Edmond, G., Found, B., Martire, K., Ballantyne, K., Hamer, D., Searston, R., Thompson, M., Cunliffe, E., Kemp, R., San Roque, M., Tangen, J., Dioso-Villa, R., Ligertwood, A., Hibbert, D., White, D., Ribeiro, G., Porter, G., Towler, A., Roberts, A. (2016). Model forensic science. Australian Journal of Forensic Sciences. 48(5): 496-537.

Erzinçlioglu, Z. (1998). British forensic science in the dock. Commentary. Nature. 392: 859-860.

Erzinçlioglu, Z. (2000). Maggots, Murder, and Men: Memories and Reflections of a Forensic Entomologist. New York, NY: Thomas Dunne Books.

Gennard, D. (2012). Forensic Entomology: An Introduction. 2nd ed., West Sussex, UK: John Wiley & Sons, Ltd.

Habermehl, G.G. (1994). Historical Review: Francesco Redi - Life and work. Toxicon. 32(4): 411-417.

Haskell, N.H., Williams, R.W. (2008). Entomology and Death: A Procedural Guide. 2nd ed., Clemson, SC: East Park Printing.

Kruse, C. (2010). Producing Absolute Truth: *CSI* Science as Wishful Thinking. American Anthropologist. 112(1): 79-91.

Mégnin P (1894) La faune des cadavres. Application de l' entomologie a la médicine légal, Encyclopdie scientifique des Aides-Mémoire, Masson, Paris.

Rivers, D.B., Dahlem, G.A. (2014) The Science of Forensic Entomology. West Sussex, UK: John Wiley & Sons, Ltd.

Sherwood, V. (1996). Most Heat Tolerant. In University of Florida Book of Insect Records. Gainsville, FL: University of Florida.

Zimmerman, M.L., Bickley, P.M. (1996). Forensic Evidence Development. In Fundamentals of Microanalytical Entomology: A Practical Guide to Detecting and Identifying Filth in Foods. Edited by Olson, A.R., Sidebottom, T.H., Knight, S.A. Boca Raton, FL: CRC Press, Inc.