

Fluorescent Pattern Expressions Found in Common Arthropods with Exposure to UV Light

Natalie Johnson and Nicole Pardue

Texas A&M University, Department of Entomology

Edited by: Seth Blackwell

Abstract: Fluorescence occurs in arthropods due to the absorption of electromagnetic radiation from UV light rays. Many species of arthropods exhibit this trait as a result of unique pigments within their cuticle layers. This trait is useful for certain arthropods because it can aid in sexual selection and help them recognize other organisms of the same species. In this experiment, twenty different common arthropods were photographed under normal lighting and under UV light in order to determine if they exhibit fluorescence. Each specimen was then compared to the normal image under standard lighting in order to determine the amount of fluorescence. Many of the arthropods photographed demonstrated slight amounts of fluorescence on certain body regions. The majority of fluorescence was concentrated on the softer cuticle inside the sutures on their body segments. The differing amounts of fluorescence exhibited by each arthropod may help to reveal the different evolutionary pressures their ancestors faced. The majority of the sample displayed only a slight fluorescence, which may indicate that high amounts of fluorescence are not evolutionarily favored.

Keywords: Fluorescence, Ultraviolet, Arthropods

Many organisms, including arthropods, are known to display fluorescent patterns when exposed to UV light. UV light, a type of electromagnetic radiation with wavelengths of 40 to 400 nanometers, can cause arthropods to reflect light waves back into the environment (Silberglied 1979). Fluorescent emissions are the result of a type of radioactive decay in certain molecules after they have been excited by the absorption of electromagnetic radiation, like UV light (Mouchet, et. al., 2016). In arthropods, these molecules are fluorescent pigments that are embedded inside the cuticle layers of their exoskeletons (Mcdermott 1911). Fluorescence is significant because it can reveal some of the patterns within arthropod behavior. Many arthropods, including

various species of Lepidoptera and Arachnida, utilize fluorescent patterns in order to locate sexual partners (Eguchi and Meyer-Rochow, 1983; Lim, et. al., 2007). Arthropods are able to see within the UV light spectrum because their ocelli and compound eyes are UV sensitive (Brunton, 1998; Silberglied 1979). This is useful for arthropods because certain plants, including flowers, display patterns in the UV light spectrum in order to attract arthropods for pollination (Silberglied 1979). Areas of plants that contain nectar or pollen are typically UV-absorbing, which creates a bulls-eye that insects will head towards to pollinate the plant (Joel, et. al., 1985). Fluorescence is important for entomologists because it can help track insects and can help

with species identification for mark and release studies (Sandidge and Brandt 2003). While fluorescence is an important characteristic of arthropods, not many studies have been carried out to determine which arthropods exhibit this trait. Due to the paucity of studies on this topic, we conducted this research project to determine which common arthropods fluoresce when exposed to UV light. We believed that arthropods with a harder exoskeleton would experience greater fluorescence due to thicker cuticle layers that possess more fluorescent molecules. We also hypothesized that the arthropods with lighter visible colorings may be able to exhibit more fluorescence due to a greater ability to absorb the UV light rays.

Materials and Methods

Twenty different arthropods were collected and photographed in order to determine the amount of fluorescence they exhibit under UV light. The following subsections highlight which organisms were selected and the exact procedure followed to acquire the desired photographs.

Organisms in Study. Twenty different specimens were selected. Seven of the nineteen specimens were chosen from the personal collection of Nicole Pardue. These specimens were the *Tenebrio molitor* (pupa), *Tenebrio molitor* (larva), *Zophobas morio* (larva), *Zophobas morio* (super worm beetle), *Blatta lateralis*, *Aphonopelma hentzi*, and *Grammostola pulchra*. The remaining thirteen specimens were chosen from around homes in Canyon Lake, Texas and San Antonio, Texas. Seven of these arthropods

were found and photographed on glue traps around Canyon Lake. These specimens were the Diplopod, *Vespula*, two different Arachnids (Specimens 13 and 15), *Armadillidiidae*, *Tipulidae*, and *Lepisma*. Three of the remaining six arthropods were found alive in the environment near Canyon Lake. These specimens were *Coccinellid*, Arachnid (Specimen 9), and Lepidopteran. The final three arthropods were all found deceased, with two found outside in Canyon Lake and one found outside in San Antonio. These three specimens were the *Phyllophaga* and the two different Coleopterans (Specimens 6 and 11).

Materials. The specimens were all photographed with iPhone 10 cameras (Apple, Cupertino, CA). The phones used have Dual 12-megapixel cameras. The same type of phone camera was used for all the specimens as a control under standard lighting (either outside or under typical indoor lighting). The UV light source for the experimental group was from a UV LED Flashlight (Taotronics, China) that uses wavelengths between 390-410 nanometers and contains 12 LED lights. This light source was chosen because it was small, portable, and easy to use. The twenty different specimens were all photographed on their dorsal sides. Each specimen was first photographed under normal lighting using an iPhone 10 camera. This control was created in order to show the qualitative fluorescence experienced by each arthropod under UV

light. After the control was established, each specimen was photographed again beneath the UV light source. The black light was held approximately four inches away from the specimens and the light was directed toward them. The specimens were then

photographed again with the iPhone 10 camera under the UV light. The relative fluorescence of each arthropod was determined based on the descriptions in the following table (*Table 1*) as seen by the naked eye.

Table 1: Fluorescence Score Rankings and Descriptions

Ranking	1	2	3	4	5
Description	No fluorescence	Slight fluorescence (part of a single body part)	Moderate fluorescence (full body segment fluorescent)	Significant fluorescence (almost all body parts fluorescent)	Complete Fluorescence

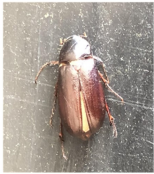









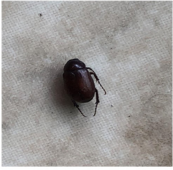



The arthropods were ranked on this scale to allow comparison of the relative fluorescence of each specimen under the UV light. The scores determined by this method were then counted in order to discover the frequency of each fluorescent value. These counts were then graphed in *Figure 3* to illustrate how often each fluorescent ranking was seen in the arthropods selected.








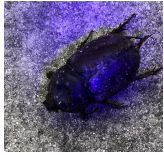





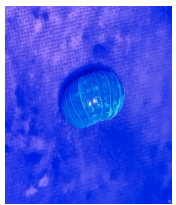
following images. The fluorescent ratings were determined based upon the in-person fluorescence rather than the images because the photographs slightly distorted the true value of fluorescence






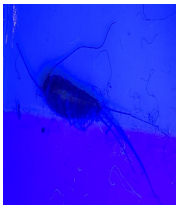

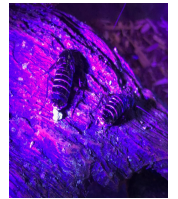
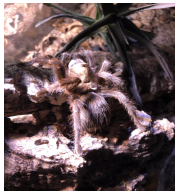

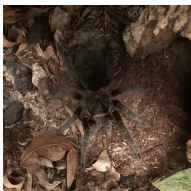

Results

Both UV images and control images of specimens are present in *Table 2*. Each arthropod was ranked on the previously described scale of 1 to 5, with 5 as complete fluorescence and 1 as no fluorescence. The relative fluorescence of each arthropod was different in person when compared to the

Table 2: Data Collected on Fluorescence in Common Arthropods

Specimen Number	Arthropod Name	Fluorescence Score (1-5, with 5 as the completely fluorescent)	Image under Normal Lighting	Image under UV Lighting
1	<i>Phyllophaga</i> spp.; June Bug Beetle	2, abdomen under wings fluoresce slightly		
2	<i>Tenebrio molitor</i> , larva; Mealworm	1, no fluorescence		
3	<i>Tenebrio molitor</i> , pupa; Mealworm	4, significant fluorescence on majority of body segments		
4	<i>Zophobas morio</i> ; larva, Superworm	1, no fluorescence		
5	<i>Zophobas morio</i> ; adult, Superworm Beetle	2, slight fluorescence at junction between body segments		
6	Coleoptera, beetle	1, no fluorescence		
7	Diplopoda, millipede	3, moderate fluorescence in spiracles and sutures		

8	<i>Coccinellidae</i> , Ladybug	1, no fluorescence		
9	Arachnida, spider	2, slight fluorescence		
10	Lepidoptera, moth	2, slight fluorescence on scaled wings		
11	Coleoptera, beetle	1, no fluorescence		
12	<i>Vespula</i> , Yellow Jacket	3, segments of the head and thorax are moderately fluorescent		
13	Arachnid, spider	2, slight fluorescence throughout		
14	<i>Armadillidiidae</i> , Roly-Poly	3, moderate fluorescence in sutures and slight patterns on segments		

15	Arachnid, Spider	2, slight fluorescence on edges of abdomen and thorax		
16	<i>Tipulidae</i> , Crane fly	2, slight fluorescence on abdomen and in sutures		
17	<i>Lepisma</i> , Silverfish	2, slight fluorescence in sutures		
18	<i>Blatta lateralis</i> , Cockroach	2, slight fluorescence in sutures		
19	<i>Aphonopelma hentzi</i> , Tarantula	3, moderate fluorescence on abdomen		
20	<i>Grammostola pulchra</i> , Tarantula	3, moderate fluorescence on body segments		

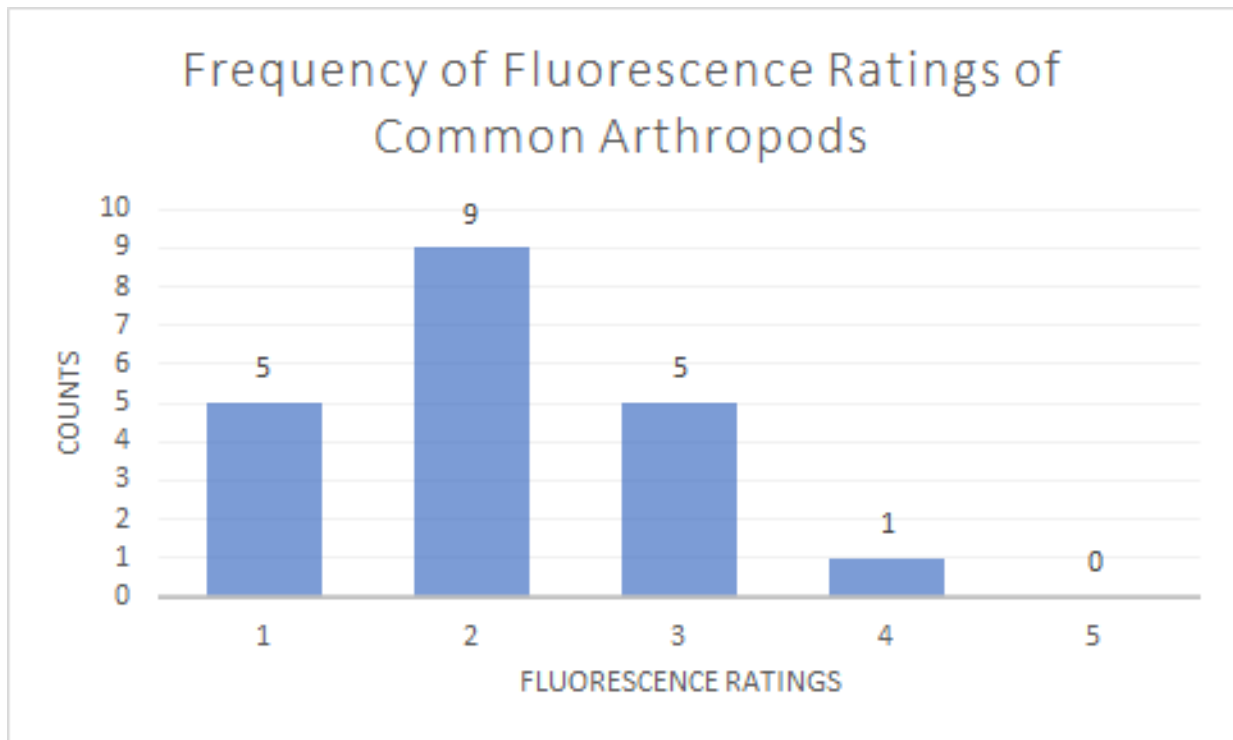
One observation was that different body parts exhibited more fluorescence than others. For example, Specimen 14, *Armadillidiidae*, demonstrates fluorescence primarily in the sutures between the body segments. The hard exoskeleton of the insect did not fluoresce

while the softer, more pliable cuticle layer that allowed for movement did fluoresce. This is interesting because we assumed that it was the harder layer of the exoskeleton that primarily caused the arthropod to fluoresce. The abdomen of Specimen 18, the *Blatta*

lateralis, experienced a greater fluorescence than the other body regions. This could potentially be due to molecules in the exocuticle present in that region. The sutures on the *Blatta lateralis* also appeared to fluoresce, which is like the *Armadillidiidae*. This could help to indicate that the proteins in the cuticles contribute to the fluorescent patterns on certain arthropods. Similarly, the spiracles on the Diplopoda (Specimen 7) demonstrated a moderate amount of fluorescence compared to the rest of the body. The remainder of the body of Specimen 7 did not fluoresce to the same extent as the spiracles. This may indicate that there are special molecules within the spiracles that are more receptive to UV light. Another interesting observation was with Specimens 2 and 3, the *Tenebrio molitor* larva and pupa. The pupal stage of the *Tenebrio molitor* experienced the greatest amount of fluorescence that we found (ranking of 4), while the larval stage did not experience any fluorescence (ranking of 1). Significantly different levels of fluorescence were observed at different life stages in this one species. Similarly, the larva and adult *Zophobas morio* (Specimens 4 and 5) also exhibited different amounts of fluorescence. The larva stage exhibited no fluorescence while the adult exhibited slight fluorescence at the junction between body regions. This is notable because it may reveal that the composition of the cuticle of a species may change throughout their life cycle. Some of the arthropods which were photographed while alive appeared to dislike the UV light that was shined on them because they attempted to move away from the light rays. This behavior was noted especially with the

Tenebrio molitor mealworms, who fled from the UV light while their photographs were taken. The figure below (*Figure 1*) illustrates the counts of each fluorescence rating determined in the experiment. This helps to reveal that most of the arthropods selected did not experience a large rate of fluorescence. This discovery could be due to our limited sampling as we were restricted to arthropods found around our homes, but it could also indicate that large fluorescent patterns are not common among arthropods.

Figure 1: Frequency of Fluorescence Ratings of Common Arthropods



Discussion

The results of this experiment may demonstrate which common species of arthropods fluoresce when exposed to UV light. Some of the arthropods in this experiment, like the arachnids, were already suspected of fluorescence due to previous investigations (Andrews, Reed, & Masta, 2007). Arachnids are known for fluorescence because, in many species, their cuticles contain UV-absorbing molecules that fluoresce under the small wavelengths associated with UV light (Silberglied, 1979). Our findings with Specimens 9, 13, 15, 19, and 20 (the various arachnids and the tarantulas) confirm this belief that arachnids fluoresce because they all exhibited a slight fluorescence under the UV light. According

to the article by Lim, the UV absorbance exhibited by arachnids is used in courtship signaling to find a conspecific host for mating (2007). The tarantulas in our study, *Aphonopelma hentzi* and *Grammostola pulchra*, experienced moderate fluorescence on their abdomens. This is notable since tarantulas have limited visual acuity due to only a single photopigment in each eye (Hsuing, et. al., 2015). Tarantulas are not able to see the same range of colors and light rays as other arthropods due to their poor visual ability, but they still display the same fluorescent behavior as other arthropods in our study (Hsuing, et. al., 2015). This suggests that fluorescence may have evolved independently in tarantulas since they cannot

see all of the same wavelengths of light as other arthropods. Many of the arthropods that exhibit fluorescence can see in the UV light range because of special photoreceptors in their eyes that can detect the shorter wavelengths. This provides an evolutionary advantage to many arthropods because they can detect a wider variety of visual stimuli, such as different patterns on flowers and on other arthropods. Since tarantulas have a more limited range of vision and they experienced fluorescence in our study, this could indicate that the ability to fluoresce has evolved independently due to natural selection. Another finding was that certain species fled from the UV light. This behavior was noted especially with the *Tenebrio molitor* mealworms because they actively ran away from the light source while their photographs were taken. This is notable since many other species of arthropods, such as *Lasioderma serricornis* or the cigarette beetle, are attracted to UV light (Hironaka, et al., 2017). Different species of Lepidoptera are also attracted to UV light because it can help signal areas of flowers that are rich in nectar (Silberglied, 1979). This finding about mealworms is notable because it indicates that there may have been some evolutionary stimulus that caused them to avoid UV light. Since the mealworms primarily live in dark environments, such as under rocks, they may have an aversion to UV light because it could signal their location to their predators. Our findings support previous studies as to which species of arthropods fluoresce under UV light. Since our study was able to look at common arthropods that normally are ignored, we were able to discover fluorescent behavior in species that were not known to

fluoresce, such as the *Armadillidiidae* and the *Tenebrio molitor* pupa. We hypothesized that arthropods with a harder exoskeleton would display a higher rate of fluorescence due to their thicker cuticle layers prior to beginning this experiment. However, we were able to discover that the softer, more pliable cuticle layers were the ones that fluoresce on some of the arthropods, not the harder exoskeleton. This pattern is especially evident in the *Armadillidiidae*, which only experienced fluorescence in the soft sutures between the hard, sclerotized plates. We also thought that the lighter colored arthropods would fluoresce more due to a higher absorbance of the UV light rays. This proved true with the *Tenebrio molitor* pupa when compared to the *Tenebrio molitor* larva. The pupa, under natural light, is a more light, cream color while the larva is darker and more sclerotized. When both were exposed to UV light, the pupa experienced a significantly higher fluorescence than the larva (a ranking of 4 compared to a ranking of 1). This could be due to the lighter colored exterior of the arthropod and to the different exterior layers that are exposed to the UV light. In *Figure 1*, we were able to track how many arthropods experienced each fluorescent rating. In this analysis, we discovered that the majority of the sample experienced very slight fluorescence (14 specimens with scores of 1 or 2), while only one experienced significant fluorescence (1 specimen with scores of 4 or 5). This can indicate that, among common arthropods, a high amount of fluorescence may not be evolutionarily favorable. A slighter amount of fluorescence in arthropods may allow them to be able to take advantage of the benefits of fluorescence, such as

finding a mate, but will not make them as visible to predators. This may be used to reveal how the amount of fluorescence an arthropod exhibits may be influenced by natural selection. Our experiment allowed us to identify which arthropods could fluoresce under UV light. However, our sample size was limited due to arthropods found in our direct vicinity due to the inability to visit a large insect collection. Further study could

verify which of these common arthropods fluoresce and what body parts precisely display this trait. Fluorescence in common arthropods can be utilized in order to identify different species and to help track the evolutionary pressures certain arthropods may experience. Determining which arthropods experience fluorescent traits can further reveal the significance of UV light in the lives of these species.

References

- Andrews, K., Reed, S. M., & Masta, S. E. (2007).** Spiders fluoresce variably across many taxa. *Biology Letters*, 3, 265-267. doi:doi:10.1098/rsbl.2007.0016.
- Brunton, C. F. A. (1998).** The evolution of ultraviolet patterns in European Colias butterflies (Lepidoptera, Pieridae): a phylogeny using mitochondrial DNA. *Heredity*, 80(5), 611–616. doi: 10.1046/j.1365-2540.1998.00336.x.
- E, Eguchi & Meyer-Rochow, Victor. (1983).** Ultraviolet photography of forty-three species of Lepidoptera representing ten families. *Annotationes zoologicae Japonenses*. 56. 10-18.
- Hironaka, M., Kamura, T., Osada, M., Sasaki, R., Shinoda, K., Hariyama, T., & Miyatake, T. (2017).** Adults of *Lasioderma serricorne* and *Stegobium paniceum* (Anobiidae: Coleoptera) Are Attracted to Ultraviolet (UV) Over Blue Light LEDs. *Journal of Economic Entomology*, 110(4), 1911–1915. doi: 10.1093/jee/tox127.
- Hsiung, B.-K., Deheyn, D. D., Shawkey, M. D., & Blackledge, T. A. (2015).** Blue reflectance in tarantulas is evolutionarily conserved despite nanostructural diversity. *Science Advances*, 1(10). doi: 10.1126/sciadv.1500709.
- Joel, D. M., Juniper, B. E., & Dafni, A. (1985).** Ultraviolet Patterns in The Traps Of Carnivorous Plants. *New Phytologist*, 101(4), 585–593. doi: 10.1111/j.1469-8137.1985.tb02864.x.
- Lim, M. L. M., Land, M. F., & Li, D. (2007).** Sex-Specific UV and Fluorescence Signals in

Jumping Spiders. *Science*, 315(5811), 481–481. doi: 10.1126/science.1134254

Mcdermott, F. A. (1911). Luciferesceine, The Fluorescent Material Present in Certain Luminous Insects. *Journal of the American Chemical Society*, 33(3), 410–416. doi: 10.1021/ja02216a022.

Mouchet, S. R., Lobet, M., Kolaric, B., Kaczmarek, A. M., Deun, R. V., Vukusic, P., ... Hooijdonk, E. V. (2016). Controlled fluorescence in a beetle's photonic structure and its sensitivity to environmentally induced changes. *Proceedings of the Royal Society B: Biological Sciences*, 283(1845), 20162334. doi: 10.1098/rspb.2016.2334.

Sandidge, J., & Brandt, L. (2003). Individual Identification and Nocturnal Observation of Small Arthropods Using Fluorescent Powders. *Journal of the Kansas Entomological Society*, 76(3), 417-425. Retrieved April 6, 2020, from www.jstor.org/stable/25086129.

Silberglied, R. E. (1979). Communication In the Ultraviolet. *Annual Reviews*, 373–399.