

Growth Rate and Thigmotactic Behavior of Turkestan Cockroach (*Blatta lateralis*) Under Different Illumination Conditions

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DOI: <https://doi.org/10.51584/IJRIAS.2023.8714>

Received: 10 June 2023; Accepted: 29 June 2023; Published: 03 August 2023

Abstract: Insects, including cricket, fly, locust, and cockroach species, exhibit growth and escape (thigmotactic) responses to aversive stimuli. This study aimed to investigate the growth rate and thigmotactic behavior of Turkestan cockroaches (*Blatta lateralis*) under different illumination conditions: natural (direct) sunlight, artificial white light, and dark control in Davao City, Philippines. In this study, gentle agitation of the container (i.e., wind puffs and food drops during feeding) stimuli stimulated *B. lateralis*, and the more they are exposed to natural (direct) sunlight and other bright displays, the lesser they survive, and their growths are. Thigmotaxis and body length were measured weekly starting on the 5th week of observation, utilizing the six experimentally nymphal organisms as subjects starting with 1.1 cm in size each organism to a 7" x 55" container with the 20 cm x 28 cm paper shelters folded within a 10° angle in a room with direct sunlight, a dark edge, and floor lit by a 60-W light bulb with 1 inch above the center of the container, and plain darkness. The results demonstrated that the organism's selection from a finite set of preferred escape trajectories (ETs) could cause variation in ETs where overall thigmotactic stimuli response was higher and had the largest growth with a body length of 2.05 cm for nymphs placed under artificial white light. In conclusion, Turkestan cockroaches exhibited flight responses even to impending and particularly gentle agitation stimuli and had a more dark or natural light condition survival rate.

Keywords: Turkestan cockroach, *Blatta lateralis*, nymphs, Davao City, thigmotaxis, growth rate, illumination

I. Introduction

Turkestan Cockroach (*Blatta lateralis*) is a significant invasive species that inhabit inground containers in urban areas [1] and is considered a household pest along clay floors [2]. They are native to Central Asia [3] and India [4], occasionally inhabiting the indoors but primarily thriving on piles of dung in garden soils [5]. Their dispersal has been widely associated with human commerce and movement [6] and also served as significant models in numerous disciplines, including neurology and chemical ecology [7]. Despite their invasiveness and habitation across peridomestic areas, there is limited information on strategies for managing these pests [8]. Moreover, despite their known popularity among reptile breeders and availability for marketing (both online and traditional markets), there is scarce information regarding their biology [1] and comparative data on cockroach mating and behavioral patterns are the most extensive [7].

In California, cockroaches are the most chronic and problematic species, living and breeding in indoor sites linked with food preparation, causing health risks owing to food contamination and indoor allergen generation. Cockroaches feed on garbage, rotting food, and feces, allowing them to become vectors of diseases through infecting surfaces and leaving droppings that contain pathogenic microorganisms; partnered with the nocturnal habits that make them ideal carriers of microbes [9]. That aside, they can become a nuisance in schools, homes, hospitals, restaurants, warehouses, apartments, and nearly any other building with food processing or storage capabilities. They spoil food and dining utensils, damage the fabric and compostable bags, and leave surfaces with stains and foul odors [10].

The mentioned impression elucidates that the cockroach's demand for food, water, and refuge from potential predators and unfavorable microclimate significantly impacts its behavior and longevity [11]. The adult *B. lateralis* is three cm tall, with females shorter than males. Female *B. lateralis* generate between two and twenty-five ootheca, or egg capsules, in their lifecycle. Each ootheca has approximately 18 eggs. The species matures after five molts, and the nymphal development period at 26.7°C is around 224 days. It takes roughly three years for five generations of Turkestan cockroaches to mature [1].

Since these organisms cause water and food contamination, transfer viruses that cause human disease, and provoke allergic reactions and disorders [12], it is gaining a growing interest, especially with the scarcity of studies on the biology, behavior, and development of *B. lateralis*. A recent study by [13] revealed that *B. lateralis*' orientation is impacted by illumination, also known as phototaxis. The roaches were subjected to different light wavelengths (red, green, yellow, blue, white, and dark control), where data obtained showed that sensitivity to illumination is directly proportional to light intensity. Cockroach orientation was highest

in dark control and lowest in the blue light of 2500 lux intensity. Additionally, roaches' orientation to red light was higher than green, yellow, blue, and white light. The researchers then concluded that blue light has a repellent effect on *B. lateralis*, and red light is more attractive for them than other wavelengths; with such, illumination can help develop an alternative for chemical control against these pests. However, no study exists on the effect of illumination, or deprivation from phototactic behavior, on the hemimetabolous development of *B. lateralis*.

Furthermore, [14] studied the impact of depriving German cockroaches (*Blatella germanica*) of their natural thigmotaxis (i.e., the movement of an organism in response to a stimulus) by placing them in shelters with different geometric features. Results reveal that thigmotactic deprivation results in stress responses of *B. germanica* where survival and fecundity in shelters with angles 90-180 degrees are relatively low as cockroaches cannot hide away from any stimuli, including illumination (light/dark cycle). They suffered from prolonged duration of nymph stage, low fecundity and survival rate, and high energy cost. Nevertheless, the result is limited to *B. germanica*, leaving out other species, such as *B. lateralis*.

Moreover, even though *B. lateralis* is introduced in the Philippines and is known best by reptile breeders in the country, fewer studies were conducted in the Philippines, and no existing studies have been conducted in the locality of Davao City. Philippine cockroaches are understudied, resulting in limited information available in the country [15], possibly because they have been regarded as household pests [16]. Recent local studies involving cockroaches include cave cockroaches of Pollilo Island and Nocticolidae, conducted by [15][16], respectively. Another analysis is limited to selected areas in Metro Manila, focusing on the parasitic infestation of *Periplaneta americana* (American cockroach) [17]. Further, cockroaches were discovered in two caverns: Baga Cave and Manan-ao Cave, out of the thirty caves on Samal Island for bat variety in 2019. *Periplaneta banksi* was collected in Baga Cave, whereas *P. americana*, widely known as the common house cockroach, was collected in Manan-ao Cave; however, only *P. americana* has been noted and emphasized since it was reported to outcompete and cause the extinction of other species [18]. These revealed no indications of in-depth assessment among studies conducted locally.

As such, this paper aimed to qualitatively assess the growth rate and thigmotactic behavior of *B. lateralis* under different illumination conditions: natural (direct) sunlight, artificial white light, and dark control. Additionally, the proponents intend to provide additional qualitative data on the limited biological information on *B. lateralis*, especially on the effect of thigmotactic and phototactic deprivation on their growth and development in Davao City, Philippines. This study is significant for future research to develop integrated pest management against *B. lateralis*. This may suggest illumination as a factor of the fecundity, mortality, and behavior of *B. lateralis*. The information garnered from this venture is also fundamental for understanding the biology, development, and behavior of *B. lateralis*, filling the gaps in the scarcity of studies across the globe.

II. Methodology

This study was carried out on the basis of experimental, was used through comprehensive and in-depth experimentation that strictly adheres to the scientific research design in the set research locale at Catalunan Pequeno, Davao City, located explicitly at Malachite Street, Wellspring Village (Fig. 1) with the consistency of temperature and precipitation extremes ranges from 25°C-30°C above and below desired range for the cockroaches to survive. Cockroaches can reproduce the fastest in these range of temperature according to the study conducted by [19]. The experimentation started on February 2023 and ended in April 2023. The independent variable is the illumination, while the dependent variables are the growth rate and thigmotactic behavior of *B. lateralis*. Purposive Sampling Method was used in selecting samples that fit the purpose of scrutiny rather than the level or area of sampling [20]. The first instar nymphs of *B. lateralis* colony were purchased online for this experiment.



Fig. 1. (A) Davao City radar map and (B) Catalunan Pequeno, Philippines radar map

B. lateralis nymphs were placed in a 7" x 55" container with the 20 cm x 28 cm paper shelters folded into a zigzag step shape within a 10° angle (see Fig. 2). Pinholes were established around the container for ventilation. Three set-ups were prepared, containing two nymphs for each set-up.

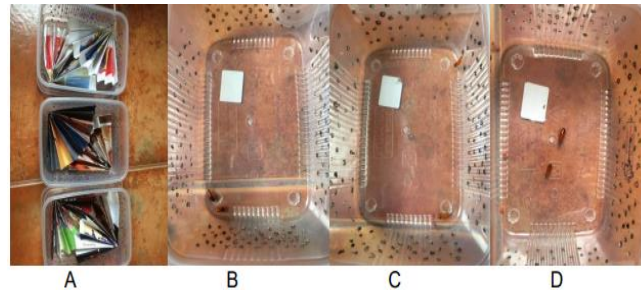


Fig. 2. Experimental design and set-up (Day 0). (A) *B. lateralis* nymphs were placed in a 7" x 55" container with the 20 cm x 28 cm paper shelters folded into a zigzag step shape within a 10° angle. Pinholes were established around the container for ventilation. (B) *B. lateralis* nymphs subjected to artificial white light (T1). (C) *B. lateralis* nymphs subjected to total darkness (T2). (D) *B. lateralis* nymphs subjected to natural (direct) light (T3).

The set-ups (Fig. 3) were subjected to different illumination conditions: artificial white light (T1), darkness (T2), and natural (direct) sunlight (T3). Moreover, the set-ups were placed in the same room to ensure equal room temperature and humidity. The specimens were subjected to the same feeding (frequency, amount, and type of food and water) every three days. Weekly observations and updates were recorded and reported to monitor the progress of the study.

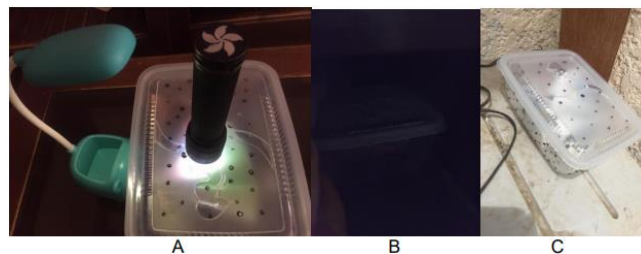


Fig. 3. Experimental design and set-up illumination conditions (Day 0). (A) *B. lateralis* nymphs subjected to artificial white light (T1). (B) *B. lateralis* nymphs subjected to total darkness (T2). (C) *B. lateralis* nymphs subjected to natural (direct) light (T3).

Weekly qualitative observations were recorded. Thigmotaxis was investigated in a parametric way, utilizing the six experimentally nymphal organisms as subjects starting with 1.1 cm in size each organism to a 7" x 55" container with the 20 cm x 28 cm paper shelters folded within a 10° angle in a room with direct sunlight, a dark edge, and floor lit by a 60-W light bulb with 1 in above the center of the container, and plain darkness. Insects, including species of cricket, fly, locust, and cockroach, have been seen to respond to aversive stimuli by escaping [21], as shown in Fig. 4. Hence, in this study, stimulus direction was used as the reference (i.e., zero) point, these ETs are uncovered by applying circular statistics concepts [22].

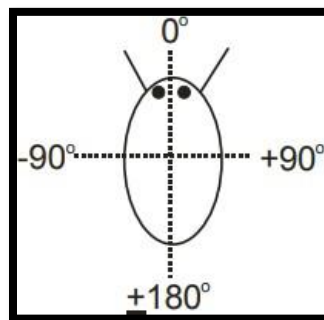


Fig. 4. Typical Angular Coordinate System [21]. The right turn was reported as a positive angle; the left turn was reported as a negative angle.

Taking everything into account, given the angle of paper shelters, assessing the thigmotactic behavior of *B. lateralis* takes advantage of the organisms' tendency to explore new environments. It is used to analyze their preferences interpreted as being determined by thigmotaxis [23]. Considering that there are no experiments assessing the role of thigmotaxis intrinsically, the goal was to present data to investigate the said behavior [24] and emphasize the significance of the organisms' personality for developmental processes in a more parametric way the organisms prefer [25].

In gaining more statistical power, two statistical methods were used in this study: Parametric test and non-Parametric test. Analysis of variance (ANOVA), using IBM® SPSS® Statistics 26.0 in windows x86-64, a parametric test of hypothesis analysis, was used to assess the main and interaction effects of categorical factors on a continuous dependent variable (growth rate and thigmotactic behavior) while accounting for the impact of a subset of other variables (illumination). In simpler terms, a one-way ANOVA is a method for collecting data about one independent variable and one quantitative dependent variable [26] where the independent variable should have at least three levels (i.e., darkness, artificial white light, and natural (direct) sunlight). ANOVA reveals whether the dependent variable's level varies with the independent variable's level [27]. Kruskal-Wallis rank-sum test (RStudio Version: 2023.0.6.0+421; Programming language for the functions: R-4.3.1), on the other hand, a non-parametric test, directed the stability (test-retest reliability) and thus the validity of the analysis, which yielded the same result and evidently showed approximation had been drawn correctly. In *B. lateralis*, this technique has been simplified. The growth rate of *B. lateralis* nymphs was observed through the span of their nymphal stage and molting rate under the different treatments. Body length was measured weekly in centimeters starting on the fifth week of evaluation (1.1 cm) until maturity. The level of activeness was measured through their fleeing behavior. In Fig. 5, ANOVA and Kruskal-Wallis rank-sum test compare the influence between the continuous response variable (growth rate and thigmotactic behavior) of *B. lateralis* and levels of a factor variable (illumination).

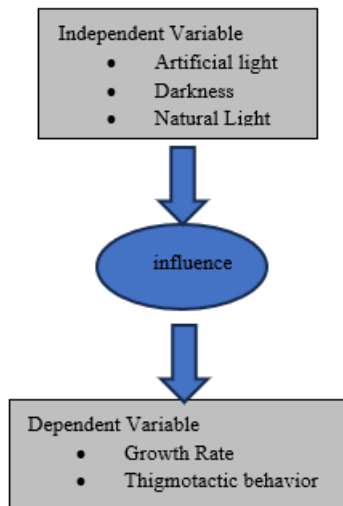


Fig. 5. The Conceptual Paradigm of the Study

In addition, the Kaplan-Meier curve, devised by Kaplan and Meier, is a statistical tool extensively employed in medical research to estimate and compare survival probabilities over time was used using IBM® SPSS® Statistics 20.0. It constructs a graphical representation of the proportion of individuals surviving at each time point, with a descending pattern indicating decreasing survival probability as events occur. This visual representation assists researchers in estimating key measures such as median survival time and allows for comparisons between different groups or treatments. Furthermore, repeated measures of ANOVA was also used to further investigate the growth and growth rate differences of the specimens over the experiment's duration. Multivariate tests scrutinized whether there are differences between or among the treatment groups with respect to their changes of growth means over time.

III. Results And Discussion

Thigmotactic Behavior of *B. lateralis* under different illumination conditions. Thigmotaxis in cockroaches and other insects is associated with foraging and hiding behaviors to escape threats, and the degree of thigmotactic behavior affects the fleeing behavior of cockroaches. It has also been demonstrated that cockroaches that develop in areas with shelters show faster development rates, higher adult body weights, and more fertile oothecae than those that develop without shelters. It has also been hypothesized that stimuli reflecting the geometric features of their environment, specifically the angles of the potential shelter, can affect their developmental homeostasis [14].

In this study, thigmotactic behavior was observed in *B. lateralis* by noting their shelter preference and fleeing behavior in response to a stimulus (i.e., gentle agitation of the container) under different illumination conditions inside the 20 cm x 28 cm paper shelters folded into a zigzag step shape within a 10° angle. The nymphal organisms as subjects preferred to hide inside after being allotted for shelter selection. Many *B. lateralis* chose to hide in such shelters in response to x', and even gentle agitation of the container, which may signal a predator attack by making a swift turn followed by a forward acceleration. In other studies, however, the wind did not elicit the escape reaction [28]. It has been recently shown that their escape trajectories exhibit directional preferences when assessed relative to the placement of the threatening stimuli [29]. Preliminary studies have frequently discriminated between the most common form of escape turn, which begins with a rotation away from the stimulus, and the comparatively uncommon type, which begins with a rotation towards the stimulus [22].

In light of this current laboratory on preferred escape paths assessing thigmotactic behavior of *B. lateralis*, away and towards responses (ETs) have been investigated. It has been found that the frequency distribution of the ETs of responses in the direction of the observer is identical to that of responses away from the observer. However, the range of body-turn angles toward reactions is substantially lower than that of away responses. This shows that nymphs reduce their turn while making a toward reaction, which may be an efficient anti-predator behavior that enables them to reach one of their chosen ETs in a relatively short amount of time.

Moreover, this paper has proven that the organism's selection from a finite set of preferred escape trajectories (ETs) can cause variation in ETs. Using stimulus direction as the reference (i.e., zero) point, these ETs are uncovered by applying circular statistics concepts [22]. Insects, including species of cricket, fly, locust, and cockroach, have been seen to respond to aversive stimuli by escaping [21]. The study of [29] revealed that electrical stimulation of both cerci and antennae could trigger an escape response.

In Fig. 6, the responses of *B. lateralis* to stimulation (vertical blue arrow) are either away (A), towards (B), or overshooting towards (C). In the away response (A), organisms rotate their bodies in the opposite direction of the stimulus. The final direction of motion (black arrow) corresponds to the sum of the stimulus angle (blue curve) and turn angle (red curve) (red curved arrow). In direction reactions (B), nymphs rotate their bodies toward the stimulus. The resulting ET is proportional to the stimulus angle minus the turn angle. In overshooting towards responses (C), nymphs continue to rotate away from the stimulus following an initial rotation in its direction. As with other towards reactions, the resulting ET is calculated as stimulus angle minus turn angle, i.e., $45^\circ - 135^\circ = 90^\circ$, which corresponds to an ET of 270° . This data is further supported based on the obtained results by [22].

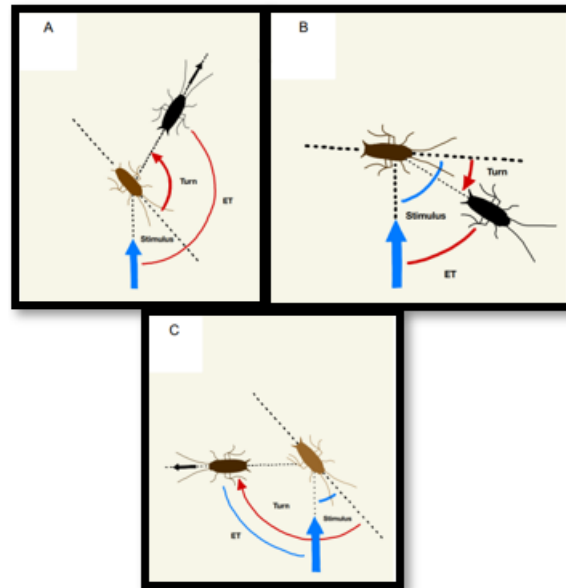


Fig. 6. Circular statistics concepts in *B. lateralis* using stimulus direction as the reference (i.e., zero) point (Escape Trajectories (ETs)). Responses of *B. lateralis* to stimulation (vertical blue arrow) are either away (A), towards (B), or overshooting towards (C).

Taking everything into account, although the nymphs' escape translation was oriented away from both food drop during feeding and gentle agitation of the container regardless of the illumination conditions they were treated under, the overall thigmotactic stimuli response was higher for T1 (see Fig. 8) - nymphs placed under artificial light - than for T2 (see Fig. 7) - nymphs placed under darkness condition.

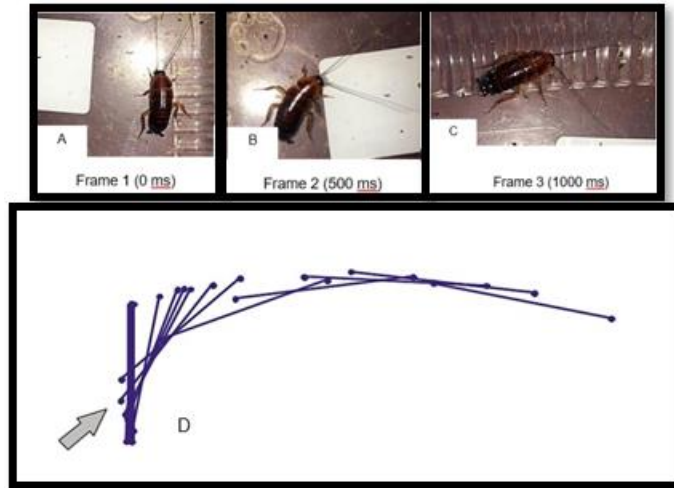


Fig. 7. A typical escape trajectory of *B. lateralis* nymph treated under dark conditions stimulated by food dropped during feeding and gentle agitation of the container. (A) 1st frame (0 ms) of escape trajectory; (B) 2nd frame (500 ms) of escape trajectory; (C) 3rd frame (1000 ms) of escape trajectory. (D) The stick diagram of the same escape trajectory as A. The filled circles correspond to the twotracked white marks on the nymph. The arrows correspond to the stimulus location (back-left tarsus).

The relationship between the turning angle and stimulus location or direction differed for T1 and T2. For T1 in Fig. 6, the turning angle was always close to 0° and was independent of the stimulus angle. The direction of T2 in Fig. 5 varied between 50° and depended heavily on stimulus location.



Fig. 8. A typical escape trajectory of *B. lateralis* nymph treated under artificial whitelight illumination stimulated by food dropped during feeding and gentle agitation of the container. (A) 1st frame (0 ms) of escape trajectory; (B) 2nd frame (25 ms) of escape trajectory; (C) 3rd frame (50 ms) of escape trajectory. (D) The stick diagram of the same escape trajectory as A. The blue dots correspond to the two tracked white marks of the nymph. The arrows correspond to the agitation direction.

These findings indicated that *B. lateralis* nymphs, like other insects and contrary to previous research, perform an escape behavior in response to unpleasant stimuli. Remarkably, the variables affecting their growth and behavior elicit significantly stronger responses than stimuli that resemble predators. These results raise questions regarding the normal level of danger posed by predators and potential risk agitation to *B. lateralis* cockroaches. Apart from that, the result further elucidates that cockroaches developing in areas with shelters show faster development rates, higher adult body weights, and more fertile ootheca than those that develop without shelters, which is further supported in the study of [14] that stimuli reflecting the geometric features of their environment, specifically the angles of the potential shelter, can affect their developmental homeostasis.

Growth rate of *B. lateralis* under different illumination conditions. The growth rate of *B. lateralis* under different illumination conditions, Body length from head to abdomen (M1), abdomen width (M2), head length (M3), and pronotum length (M4) and pronotum width (M5) were measured weekly starting on the 5th week of observation, utilizing the six experimentally nymphal organisms as subjects starting with 1.1 cm in size each organism to a 7" x 55" container with the 20 cm x 28 cm paper shelters folded within a 10° angle in

a room with direct sunlight (T3), a dark edge and floor lit by a 60-W light bulb 1 inch above the center of the container (T1), and plain darkness (T2 - control).

Table 1. Weekly average body measurements of *B. lateralis* under different illumination conditions (in cm): A Profile Analysis

Week	Treatment 1 (Artificial light)					Treatment 2 (Darkness)					Treatment 3 (Natural direct sunlight)				
	M ₁	M ₂	M ₃	M ₄	M ₅	M ₁	M ₂	M ₃	M ₄	M ₅	M ₁	M ₂	M ₃	M ₄	M ₅
5	1.1	0.5	0.09	0.1	0.03	1.1	0.5	0.09	0.1	0.03	1.1	0.5	0.09	0.1	0.03
6	1.2	0.5	0.09	0.1	0.06	1.2	0.6	0.09	0.1	0.03	1.1	0.5	0.09	0.2	0.05
7	1.4	0.6	0.1	0.2	0.07	1.3	0.6	0.1	0.2	0.04	1.2	0.5	0.1	0.2	0.05
8	1.8	0.7	0.2	0.3	0.09	1.6	0.6	0.1	0.2	0.04	0	0	0	0	0
9	1.85	0.8	0.2	0.3	0.1	1.7	0.7	0.1	0.2	0.05	0	0	0	0	0
10	2.05	1	0.2	0.5	0.2	1.8	0.8	0.1	0.3	0.07	0	0	0	0	0
Mean	1.567	0.683	0.147	0.2	0.092	1.4	0.6	0.1	0.1	0.05	0.5	0.2	0.0	0.0	0.0
Overall Mean	0.548					0.485					0.194				

Note: Mean was rounded up while overall mean was based on the actual summation of (mean) data.]

Results revealed in Table 1 that *B. lateralis* under artificial white light (T1) has the largest growth with a body length of 2.05 cm at the end of the 10th week of the experimentation, followed by organisms under complete darkness (T2) with 1.85 cm body length, and lastly, the organisms under direct natural sunlight (T3) that were found to be deceased on the 8th week of observation. Unsurprisingly, none of the organisms have undergone molting throughout the experimentation since the average developmental period for *B. lateralis* for male and female organisms is 222 ± 25.1 days, with a range of 126–279 days and 224 ± 30.6 and 126–279 days, respectively [1].

Ultimately, this suggests that *B. lateralis* nymphs under artificial white light are found to have the most favorable illumination condition in this experimentation. One of the underlying reasons for this could be the light adaptation that the organisms developed in the experimentation, given that cockroaches are known as negatively phototactic organisms. When exposed to light, nocturnal insects become light-adapted, influencing their circadian rhythms such as flight, mating, locomotion, feeding, and courtship [30].

In a study conducted by [31], rapid light adaptation in blowfly *Protophormia terraenovae*, the hoverfly *Volucella pellucens*, and the cockroach *Periplaneta americana* were scrutinized by examining how properties of quantum bumps change after light stimulation and multiquantal impulse responses during repetitive stimulation. Their results discovered three distinct light adaptation mechanisms where *P. periplanata* exhibited quantum bump amplitude decrease without changes in kinetics, showing decreased availability of transduction channels.

Researchers [32] defined light adaptation as a “deterministic and reversible process” where the increase or decrease in ambient light can stimulate the increase or decrease of the gain of transduction for the detection of stimuli, and this adaptation involves molecular pathways and transduction channels. As specified by [33], insects, including cockroaches, have undergone evolution to develop rhabdomeric photoreceptors that detect light sources. These receptors are found in insect compound eyes and respond to photons of light with quantum bumps due to microvillus activation. In night-active species such as *P. americana*, relatively slow phototransduction has been observed, along with increased photoreceptor size, allowing them to see in the dark.

In line with this, *B. lateralis* possibly exhibited the exact mechanisms for light adaptation where the organisms could have optimized their photoreceptor functioning in their compound eyes in response to artificial white light by modifying single-photon response since insects under taxonomic groups generally have similar phototaxis [34]. The researchers hypothesized that *B. lateralis* also exhibited a quantum bump amplitude decrease. In other words, the quantum bumps or the voltage fluctuation in the photoreceptor of the species have hypothetically been decreased to adjust to the presence of the artificial white light, thus, altering the availability of transduction channels for negative phototactic mechanisms. This can be correlated to the activeness and thigmotactic responses of the experimental species.

On the other extreme, it is important to note that the low survival rate of organisms under natural (direct) sunlight can be rooted in three factors: (a) cuticular water loss and permeability, (b) thigmotactic deprivation, and (c) disrupted circadian rhythm. Direct sunlight increases the temperature of the container and thus leads to cuticular water loss and permeability. This is supported by the findings of [35] that suggest that cuticular water loss and cuticular permeability are directly proportional to temperature with respective exponential increases. Consequently, this directly affects body water and inversely impacts body lipid content, disrupting cellular responses and homeostasis. High cuticular permeability at high relative humidity stimulates water loss, and ambient humidity affects water loss rates through the cuticle at constant environmental temperature.

On the other hand, thigmotactic deprivation [14] is also another factor for this. Under normal conditions, cockroaches are nocturnal, and they explore, feed, and mate overnight, avoiding illuminated areas [13]. However, due to the direct effect of sunlight on their experimental environment, they cannot eventually hide away from light and heat, causing stress and inescapable impermanence.

Addendum, their circadian rhythm has been disrupted, given that they cannot rest during the day due to negative phototaxis and nocturnal nature; hence this disruption also disorients their homeostatic and circadian regulation [36].

Table 2. Means and median for Survival Time in Kaplan-Meier Curve

Treatment Types	Means and Medians for Survival Time							
	Mean ^a				Median			
	Estimate	Std. Error	95% Confidence Interval		Estimate	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	
Treatment 1 (Artificial light)	7.500	.764	6.003	8.997	7.000	1.225	4.600	9.400
Treatment 2 (Darkness)	7.500	.764	6.003	8.997	7.000	1.225	4.600	9.400
Treatment 3 (Natural light)	8.000	.850	6.334	9.666	7.000	.	.	.
Overall	7.648	.449	6.768	8.529	7.000	.849	5.337	8.666

Nonetheless, according to the information presented in Table 2, the means and standard errors (SE) for survival rates are as follows: Treatment 1 (T1) has a mean of 7.5 with an SE of 0.76, Treatment 2 (T2) has a mean of 7.5 with an SE of 0.76, and Treatment 3 (T3) has a mean of 8.0 with an SE of 0.85. These means indicate that there is no significant difference in survival rates among the treatments. Additionally, the average survival time for the nymphs in the study is a maximum of 7 weeks. For the overall comparison, the log-rank (Mantel-Cox) survival analysis test was performed. The chi-square test statistic yielded a value of 1.497 (with 2 degrees of freedom) and a *p-value* of 0.743. This result suggests that, at a significance level of 0.05, there is no statistical difference in the distribution of survival times among the treatments.

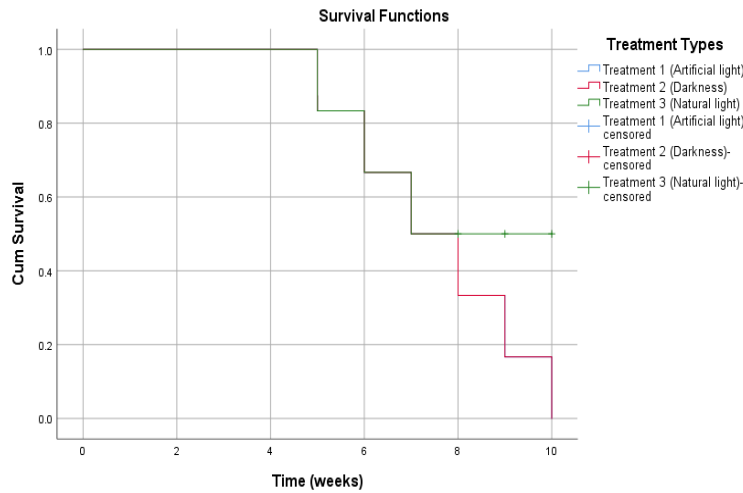


Fig. 9. Kaplan-Meier Survival Analysis Curve

Furthermore, Fig. 9 displays a Kaplan-Meier survival analysis curve. The graph indicates that Treatments 1 to 3 likely produced similar survival rate distributions. Only in Treatment 3, during weeks 8 to 10, were there instances of cockroaches dying. Nevertheless, statistical evidence indicates that there is no significant difference in their survival time distributions.

Moreover, the Kruskal-Wallis rank-sum test and ANOVA revealed that the average body measurement of *B. lateralis* under the first illumination condition of artificial white light is 0.5477 cm (SD = 0.1662). At one extreme, the average body measurement of the *B. lateralis* under the second illumination condition of darkness is 0.4847 cm (SD = 0.0980); On the third illumination condition, which is natural (direct) sunlight, the average body measurement of the *B. lateralis* is 0.3873 cm (SD = 0.0230). The analysis of the variance shows that the difference between the three illumination conditions is not statistically significant, $F(2, 12) = 1.658$, with a *p* value equal to 0.231, which is greater than the 0.05 significance. Hence, it can be concluded that the groups are different, indicating strong evidence of no relationship between the treatments. Considering the short range of time enough for the nymphs to develop into an adult, it is impossible to determine whether two or more population means differ based on the results of a single sample or experiment with a short interval of days given [37].

Table 3. Multivariate test table: interaction of growth means and illumination conditions

Effect		Value	F	Multivariate Tests ^a			Partial Eta Squared	Noncent. Parameter	Observed Power ^d
				Hypothesis df	Error df	Sig.			
growth	Pillai's Trace	.637	2.810 ^b	5.000	8.000	.094	.637	14.052	.535
	Wilks' Lambda	.363	2.810 ^b	5.000	8.000	.094	.637	14.052	.535
	Hotelling's Trace	1.756	2.810 ^b	5.000	8.000	.094	.637	14.052	.535
	Roy's Largest Root	1.756	2.810 ^b	5.000	8.000	.094	.637	14.052	.535
growth * bgroup	Pillai's Trace	.979	1.724	10.000	18.000	.151	.489	17.242	.598
	Wilks' Lambda	.183	2.137 ^b	10.000	16.000	.085	.572	21.369	.686
	Hotelling's Trace	3.572	2.500	10.000	14.000	.057	.641	25.005	.736
	Roy's Largest Root	3.305	5.949 ^c	5.000	9.000	.011	.768	29.745	.899

a. Design: Intercept + bgroup
 b. Within Subjects Design: growth
 c. Exact statistic
 d. The statistic is an upper bound on F that yields a lower bound on the significance level.
 e. Computed using alpha = .05

Additionally, the multivariate test, as shown in table 3, showed that the interaction of growth means and illumination conditions resulted to Wilks' Lambda value with an *F-value* equal to 2.137 with a *p-value* = 0.085, which means that 0.05 level of significance, the interaction effect is not statistically significant. This means that the growth means of cockroaches are just statistically the same across treatment groups in terms of their respective changes.

Table 4. Tests of Within-Subjects Effects

Tests of Within-Subjects Effects									
Measure: time									
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^d
growth	Sphericity Assumed	.647	5	.129	10.641	.100	.470	53.206	1.000
	Greenhouse-Geisser	.647	1.126	.574	10.641	.105	.470	11.979	.881
	Huynh-Feldt	.647	1.369	.472	10.641	.103	.470	14.567	.925
	Lower-bound	.647	1.000	.647	10.641	.107	.470	10.641	.849
growth * bgroup	Sphericity Assumed	.294	10	.029	2.417	.067	.287	24.166	.906
	Greenhouse-Geisser	.294	2.251	.130	2.417	.123	.287	5.441	.424
	Huynh-Feldt	.294	2.738	.107	2.417	.107	.287	6.616	.479
	Lower-bound	.294	2.000	.147	2.417	.131	.287	4.833	.393
Error(growth)	Sphericity Assumed	.729	60	.012					
	Greenhouse-Geisser	.729	13.509	.054					
	Huynh-Feldt	.729	16.427	.044					
	Lower-bound	.729	12.000	.061					

a. Computed using alpha = .05

In table 4, the sphericity assumed indicates the test of the main effect for growth means of cockroaches. In this study, the sphericity assumed generated an *F-value* of 10.641 with a *p-value* of 0.100 which means that there is no statistically significant result.

Table 5. Tests of Within-Subjects Contrasts

Tests of Within-Subjects Contrasts									
Measure: time									
Source	growth	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power ^d
growth	Linear	.638	1	.638	11.529	.005	.490	11.529	.876
	Quadratic	.002	1	.002	1.628	.226	.119	1.628	.217
	Cubic	.000	1	.000	.199	.664	.416	.199	.670
	Order 4	.004	1	.004	3.819	.074	.241	3.819	.436
	Order 5	.002	1	.002	2.224	.162	.156	2.224	.279
growth * bgroup	Linear	.273	2	.136	2.463	.127	.291	4.927	.400
	Quadratic	.010	2	.005	4.335	.038	.419	8.669	.636
	Cubic	.002	2	.001	.370	.699	.508	.739	.696
	Order 4	.005	2	.002	2.633	.113	.305	5.266	.424
	Order 5	.004	2	.002	2.147	.160	.264	4.294	.354
Error(growth)	Linear	.664	12	.055					
	Quadratic	.014	12	.001					
	Cubic	.028	12	.002					
	Order 4	.011	12	.001					
	Order 5	.012	12	.001					

a. Computed using alpha = .05

However, in table 5, the tests within-subjects contrasts showed that the main effect of time to growth means, without considering any type of interaction, showed a statistical significance of having linear curve ($F = 11.529, p = 0.005$) This suggested that there is differential change between groups following a straight-line manner with respect to the estimated marginal means of time as shown in Fig. 10 below.

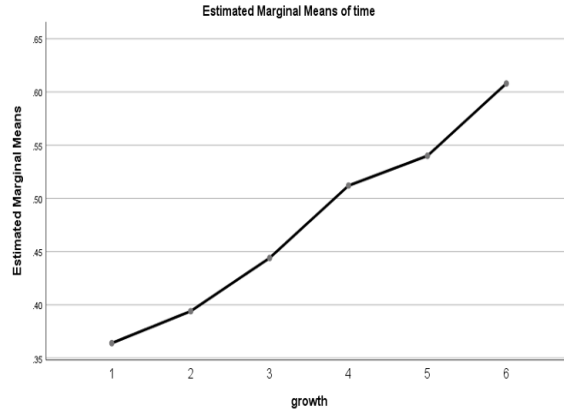


Fig. 10. Tests Within-Subjects Contrasts: Effect of time to growth without interaction

Meanwhile, the interaction effect between time and growth means of cockroaches depict a quadratic trajectory ($F = 4.335$, $p = 0.038$) as shown in Fig. 11 below.

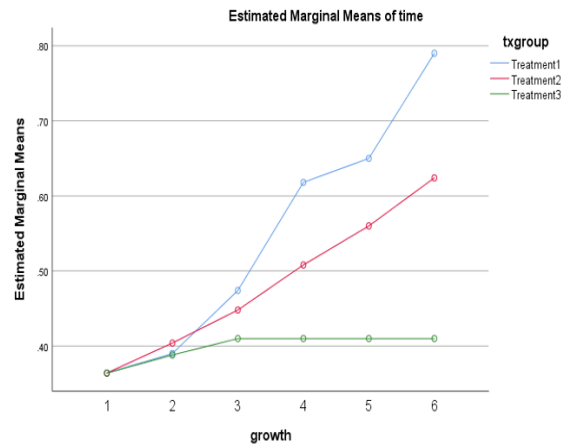


Fig. 11. Interaction Effect between Time and Growth means of Cockroaches

According to [38], the lifespan of cockroaches differs based on species, humidity, and temperature in each phase, ranging from 6 to 15 months of observation to maintain significant differences to more than a year. Even German cockroaches mature in about two months, and American cockroaches take about 600 days to reach adulthood. Nevertheless, the results have been considered considering that there are still differences unveiled throughout the laboratory report, and thus valuable insights into the behavior and growth of *B. lateralis* nymphs are considered: i.e., illumination conditions influence the overall response to thigmotactic stimuli, with nymphs exposed to artificial light exhibiting a stronger response than those exposed to darkness.

IV. Conclusion

The study was conducted in Malachite Street, Wellspring Village, Catalunan Pequeño, Davao City. Independent and dependent variable were identified before the conduct of the study. The illumination is the independent variable, while the dependent variables are the growth rate and thigmotactic behavior of *B. lateralis*. This study was carried out based on an experimental set-up using the Purposive Sampling Method. First instar nymphs from the colony were selected for the purpose of this study.

In this study, gentle agitation of the container (i.e., wind puffs and food drops during feeding) stimuli stimulated *B. lateralis*, and the more they are exposed to natural (direct) sunlight and other bright displays, the lesser they survive, and their growths are. The results demonstrated that the organism's selection from a finite set of preferred escape trajectories (ETs) could cause variation in ETs where overall thigmotactic stimuli response was higher and had the largest growth with a body length of 2.05 cm for nymphs placed under artificial white light. The growth rate of *B. lateralis* under different illumination conditions, body length from head to abdomen (M1), abdomen width (M2), head length (M3), and pronotum length (M4) and pronotum width (M5) were measured weekly starting on the 5th week of observation, utilizing the six experimentally nymphal organisms as subjects. In

conclusion, contrary to the literature, Turkestan cockroaches exhibited flight responses even to impending and particularly gentle agitation stimuli and have a more dark or natural light condition survival rate.

V. Recommendations

It is essential to note that the experimental species obtained in this paper are first-instar nymphs, which suggests the exclusion of their early embryonic development under different illumination conditions, and the observations were only done for ten weeks. It is recommended that research ventures related to this scrutiny should include early and postembryonic and adulthood. In addendum, this study is a qualitative descriptive study focused on morphological development; hence, it is suggested that future scrutiny must involve molecular and biochemical data, including circadian gene expression and quantum bumps, under different illumination conditions. The sex of the species was not also determined, which is fundamental in the rate of development of the species. Additionally, the discussions provided are based on previous research and, fundamentally, the mentioned correlation and possible mechanisms relating to thigmotactic responses, and light adaptation should be proven molecularly and biochemically given that transduction channels and quantum bumps are complex pathways that are foundational to the developmental biology of species and should not be underappreciated and require in-depth scientific analysis founded upon actual results.

Acknowledgment

The researchers express their gratitude to their families for providing daily encouragement, emotional support, financial assistance, and practical help. The researchers would like also to extend their appreciation to the statisticians, namely Cymber Orvie Quevedo, Dan Floyd Arnaiz, and James Charles Uy, whose contributions were vital to the success of the study. And most especially to the Almighty God for the strength, knowledge, wisdom, and courage to finish the study.

References

1. Kim, T. & Rust, M.K. (2013). Life History and Biology of the Invasive Turkestan Cockroach (Dictyoptera: Blattidae). *Journal of Economic Entomology* 106 (6), 2428–2432. Retrieved from <https://doi.org/10.1603/ec13052>
2. Roth, L.M. & Willis, E.R. (1960). The biotic associations of cockroaches. *Smithsonian Miscellaneous Collections* 141(1), 1–440. Retrieved from <https://repository.si.edu/handle/10088/22968>
3. Alesho, N.A. (1997). Synanthropic cockroaches of Russia. *Proc. Inter. Coll. Social Insects* 34: 45Ð50.
4. Sandhu, G.S. & Sohi, A.S. (1981). Occurrence of different species of cockroaches at Ludhiana Punjab India. *Journal of Bombay National Historical Society* 78, 179 Ð181.
5. Artyukhina, I. (1972). Ecology of Turkestan cockroaches (*Shelfordella tartara*) in some villages of the Uzber-SSR. *Medicinskaya Parazitologiya Parazitarnye Bolezina* 41: 49Ð53.
6. Rehn, J.A.G. (1945). Man's uninvited fellow traveler: the cockroach. *Sci. Mon.* 61: 265Ð276
7. Nalepa, C. A. (2019). Cockroaches. *Encyclopedia of Animal Behavior (Second Edition)* (pp. 281-286). Retrieved from <https://rb.gy/nol0lh>
8. Gaire, S. & Romero, A. (2020). Comparative Efficacy of Residual Insecticides against the Turkestan Cockroach, *Blatta lateralis*, (Blattodea: Blattidae) on Different Substrates. *Insects* 11(8), 477. Retrieved from <https://doi.org/10.3390/insects11080477>
9. Moges, F., Eshetie, S., Endris, M., Huruy, K., Muluye, D., Feleke, T.G, Silassie, F., Ayalew, G., & Nagappan, R. (2016). Cockroaches as a Source of High Bacterial Pathogens with Multidrug Resistant Strains in Gondar Town, Ethiopia. *BioMed Research International* 1–6. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/27340653/>
10. Sutherland, A., Chloe, D., & Rust, M. (2019). UC IPM Pest Notes: Cockroaches. UC ANR
11. Manyullei, N.S., Silalahi, N.F.D., Paluseri, N.A.M.A., Wahdaniyah, N., Waly, N.H., Jabalnur, N.W.R., & Putranto, N.A.R. (2022). Environmental factors affecting cockroach density: A systematic review. *International Journal of Life Science Research Archive* 3(1), 001–012. Retrieved from <https://doi.org/10.53771/ijlsra.2022.3.1.0048>
12. Shahraki, G., Parhizkar, S., Raygan, A., & Nejad, S. (2013). Cockroach Infestation and Factors Affecting the Estimation of Cockroach Population in Urban Communities. *International Journal of Zoology* 1–6. Retrieved from <https://doi.org/10.1155/2013/649089>
13. Burhan, A., & Gençer, N.S. (2020). The effect of illumination with different light wavelengths on the orientation of Turkestan cockroach, *Blatta lateralis* (Walker, 1868) (Blattodea: Blattidae). *Turkish Journal of Entomology* 44(4), 477–486. Retrieved from <https://doi.org/10.16970/-entoted.774867>
14. Chen, N. W., Li, D., Wang, H., Lin, S., & Yang, E. (2022). The impact of thigmotaxis deprivation on the development of the German cockroach (*Blattella germanica*). *IScience* 25(8), 104802. Retrieved from <https://doi.org/10.1016/j.isci.2022.104802>
15. Lucañas, C. C., & Lit, I. L., Jr (2016). Cockroaches (Insecta, Blattodea) from caves of Polillo Island (Philippines), with description of a new species. *Subterranean Biology* 19, 51–64. Retrieved from <https://doi.org/10.3897/-subtbiol.19.9804>

16. Lucañas, C. C., & Lit, I. L. (2015). Coaching for roach: status and trends in the taxonomy of Philippine cockroaches (Dictyoptera: Blattodea). *The Philippine Entomologist* 29(2). Retrieved from <https://www.ukdr.uplb.-edu.ph/jurnal-articles/4705/>
17. Su, G. L. S., Carillo, N., Pera, D., Sison, S., Tanalgo, B., Su, M. L. L. S., & Mistika, M. (2016). Parasitic Infestation in Cockroaches (*Periplaneta americana*) Obtained in Selected Areas of Metro Manila. *International Journal of Tropical Disease & Health* 13(4), 1–4. Retrieved from <https://doi.org/10.9734/ijtdh/2016/23820>
18. Afbale, J. (2022). Cave biologists report new records of cockroaches from caves in Samal Island, Davao del Norte. 2022 UPLB Museum of Natural History. Retrieved from <https://tinyurl.com/39ynfywe>
19. Perrine, M. (2022). What Temperature Kills Cockroach. Retrieved from <https://tinyurl.com/yc6jjpcd>
20. Arikunto, S. (2010). *Procedure Penelitian: Satuan Pendidikan Praktek*, Jakarta: PT. RenikaCipta. Retrieved from <https://scirp.org/journal/paperif-ormation.aspx?paperid=93068>
21. Ou, J. (2016). Escape strategy of the cockroach (*Gromphadorhina portentosa*) to heat and looming stimuli. Senior Honors Projects, 2010-current 163. Retrieved from [https://commons.lib.jmu.edu/cgi-viewcontent.-](https://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=1215&context=honors201019)
22. Domenici, P., Booth, D., Blagburn, J. & Bacon, J. (2009). Escaping away from and towards a threat. *Communicative & Integrative Biology* 2(6), 497-500. doi: 10.4161/cib.2.6.9408
23. Valle, F. P. (1970). Effects of strain, sex, and illumination on openfield behavior of rats. *American Journal of Psychology* 83, 103-111. PMID: 5465190
24. Lamprea, M. R., Cardenas, F.P., Setem, J., & Morato, S. (2008). Thigmotactic Responses in an Open Field. *Brazilian Journal of Medical and Biological Research* 41, 135-140. DOI: <https://core.ac.uk/download/pdf/37450487.pdf>
25. Salazar, M. L., Planas-Sitjà, I., Sempo, G., & Deneubourg, J. (2018). Individual Thigmotactic Preference Affects the Fleeing Behavior of the American Cockroach (Blattodea: Blattidae). *Journal of Insect Science* 18(1). Retrieved from <https://doi.org/10.1093/jisesa/ie x108>
26. Sarkar, S. (2008). Profile Analysis for Animal Growth Data. *The Indian Journal of Animal Sciences* 78(4), 401-405. DOI: <https://tinyurl.com/-wfkku9wx>
27. Bevans, R. (2022). One-way anova | When and how to use it. Retrieved from <https://www.scribbr.com/statistics/one-way-anova/>
28. Olsen, A. & Triplehorn, J. (2014). Neural responses from the filiform receptor neuron afferents of the wind-sensitive cercal system in three cockroach species. *National Library of Medicine* 68, 76-86. Doi: <https://pubmed.ncbi.nlm.nih.gov/25046275/>
29. Erickson, J. C., Herrera, M., Bustamaante, Shingiro, A. & Bowen, T. (2015). Effective stimulus parameters for directed locomotion in Madagascar Hissing Cockroaches Biobot. *PLoS ONE* 10(8), e0134348. Retrieved from <https://doi.org/10.1371/journal.pone.0134348>
30. Yadav, S., & Patel, S. (2020). Use of light source in Pest Management. *ResearchGate*. Retrieved from <https://tinyurl.com/2p94v2mt>
31. Ignatova, I. I., & Frolov, R. V. (2022). Distinct mechanisms of light adaptation of elementary responses in photoreceptors of dipteran flies and American cockroach. *Journal of Neurophysiology* 128(1), 263–277. Retrieved from <https://doi.org/10.1152/jn.00519.2021>
32. Abbas, F. & Vinberg, F. (2021). Transduction and Adaptation Mechanisms in the Cilium or Microvilli of Photoreceptors and Olfactory Receptors From Insects to Humans. *Frontiers in Cellular Neuroscience* 15. Retrieved from <https://doi.org/10.3389/fncel.2021.662453>
33. Frolov, R.V., & Ignatova, I.I. (2020). Electrophysiological adaptations of insect photoreceptors and their elementary responses to diurnal and nocturnal lifestyles. *Journal of Comparative Physiology A-neuroethology Sensory Neural and Behavioral Physiology* 206(1), 55–69. Retrieved from <https://doi.org/10.1007/s00359-019-01392-8>
34. Pan, H., Liang, G., & Lu, Y. (2021). Response of Different Insect Groups to Various Wavelengths of Light under Field Conditions. *Insects* 12(5), 427. Retrieved from <https://doi.org/10.3390/insects12050427>
35. Appel, A. G., Reiersen, D. A., & Rust, M. K. (1986). Cuticular water loss in the smokybrown cockroach, *Periplaneta fuliginosa*. *Journal of Insect Physiology* 32(7), 623–628. Retrieved from [https://doi.org/10.1016/002-1910\(86\)90091-0](https://doi.org/10.1016/002-1910(86)90091-0)
36. Michel, M., & Lyons, L. C. (2014). Unraveling the complexities of circadian and sleep interactions with memory formation through invertebrate research. *Frontiers in Systems Neuroscience*. Retrieved from <https://doi.org/10.3389/fnsys.2014.00133>
37. Mohr, D.L., Wilson, W.J., & Freund, R.J. (2022). *Statistical methods*. Retrieved from <https://www.sciencedirect.com/book/9780128230435/statistical-methods#book-info>
38. West Pest Services (2023). *Cockroach Life Cycle: Cockroach Eggs, Nymphs & Adult Stages*. Retrieved from <https://www.westernpest.com/-blog/cockroach-life-cycle/>