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Response of the Larvae and Pupae of *Aedes aegypti*, *Anopheles stephensi* and *Culex pipiens* to Light Intensity Changes-II

by

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Response of the Larvae and Pupae of *Aedes aegypti*, *Anopheles stephensi* and *Culex pipiens* to Light Intensity Changes-II*

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ABSTRACT

This study covers the qualitative and quantitative estimates of the larvae and pupae of the three species *Aedes aegypti* (L.), *Anopheles stephensi* Liston and *Culex pipiens* L. to light intensity increase and decrease directed from above and from below. In these three species a similar diving down response was observed to light intensity decrease, however, the nature of the response to light intensity increase varied, i. e. it was slowly diving down in *Ae. aegypti*, a sideways run in *An.stephensi* and rapid diving down in *Cu. pipiens*. The response was found to be influenced by the direction of the light, being higher in light directed from above than in light directed from below.

INTRODUCTION

The role of the light in orientation responses of insects was investigated extensively and reviewed by FRAENKEL and GUNN (4). Their studies clearly showed that some insects tend to move towards the light (photo-positive) and some tend to move away from the light (photo-negative).

These photic tendencies were also described for larvae and pupae of some mosquitoes. The larvae of *Cu. territans*, *Cu. pipiens*, *Culiseta inornata*, *Ae. fuscus* and *Ae. currei* studied by HOLMES (9) and larvae of *Cu. pipiens* studied by MİLLER (13) were recorded to be photo-positive. The larvae and pupae of *Ae. aegypti* were recorded to be photo-negative by OMARDEEN (14), SHANNON (15) and CHRISTOPHERS (1). OMARDEEN (loc. cit.)

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also found that the photo-negativity became stronger with age. MELLANBY (12) found that when the larvae of *Ae. aegypti*, *An. maculipennis* and *Cu. pipiens* were steadily illuminated from one side they all aggregated at the darker end of a tank, as far from the source of the light as possible.

However, the studies of above authors have been concerned with determining chiefly the photo-positivity and photo-negativity of the larvae and pupae; this assumes response to be constant over time and all or nothing. FOLGER (3) was the only author who was interested in both photic tendency of the larvae and pupae in a *Culex* species and in responses dependent on variation in stimulus intensity in the *Culex* sp.. He observed that in the strong light intensities the animals were repelled by and in dim light they were attracted to the light source, so he concluded that the tendency to move towards or away from the light depended on the light intensity. Studying the response of the larvae and pupae to light intensity changes FOLGER also found that the animals were more responsive to light intensity decrease than to light intensity increase; they were more responsive to the decrease in light intensity when the light was above than below and they failed to respond at all to an increase in light from below. GORDON (in BATES, 6) arrived at a similar conclusion for *Anopheles darlingi* with above light-off but found no response to above light-on.

These authors, however, did not investigate the difference in the manner and the level of the response to light intensity increase and decrease within and among the species nor the effect of the light intencity changes from above and from below on the manner of the response. The following experiments were therefore undertaken to compare the manner and the number of the animals responding to light intensity decrease (light-off) and light intensity increase (light-on) within and among the species. These aspects were investigated throughout whole duration of the larval and pupal phase; (1) to determine the ontogeny of the response, (2) to assess effect of the direction of light either from above or from below in response to light intensity decrease (light-off) and light intensity increase (light-on), and (3) to compare the results of the responses to above light-off and to a moving shadow studi-

ed in the previous article (KASAP, 11) to determine whether the response of the animals were to on-off-on combination of the stimulus or only to on-off part of it.

EXPERIMENT-1: Response of the larvae and pupae of *Aedes aegypti*, *Anopheles stephensi* and *Culex pipiens* to decrease and increase in intensity of light directed from above.

MATERIALS AND METHODS

The larvae and pupae, used in these experiments were reared in an insectary with 25°C constant temperature and about 80 % humidity. The insectary was illuminated with 12 florescent lamps on a 12 hours on and 12 hours off cycle; no natural light was allowed into it. The experiments were also made in the same insectary so as not to effect the behaviour of the animals.

The apparatus used in these tests consisted of a 50 cm wooden frame and 6 cm diameter dish containing 2.5 cm depth of water. A 100 watt lamp 35 cm above the container was fitted in the centre of the ceiling of the frame and a switch was placed outside the frame so as to prevent any disturbance to the animals during the test.

In these experiments 5 or 6 group of 6 animals were tested by alternatively applying the light-on and off stimuli after at least 5 minutes interval and when at least half number (3) of the larvae of *Ae. aegypti* and the full number (6) of the pupae of *Ae. aegypti* and the larvae and pupae of *An. stephensi* and *Cu. pipiens* were at the surface. After the application of either the light-on or the light-off stimulus the number of the animals responding by breaking contact with the water surface in the first 5 seconds was counted. This gave a quantitative estimate level of response. The trials were repeated 6 times for each group every day between 9.00–12.00 hrs. and 14.00–17.00 hrs. during the whole period of 3 rd and 4 th instar larvae and pupae. The percentage response was calculated for each group after 6 trials. The mean values shown in figs. 1,2,3, were calculated from the percentages of all the groups tested.

The behaviour of the larvae and pupae within 5 seconds after the application of the stimulus was carefully observed: detailed notes were taken on the apperance of the response, this formed the qualitative record of the response.

In these experiments the light intensity decrease was made equal to that in the moving shadow experiment. Light intensity readings were taken with a Weston-Master V photographic light-meter; the light intensity reading was 13 when the light was turned on and it was 7 when it was turned off and in the moving shadow experiment the light intensity reading was 12 before shadow over the dish and it was 6 when the shadow was over the dish (KASAP, 11).

RESULTS

(1) *Aedes aegypti*

Behaviour observed.

The observations on the larval response of *Aedes aegypti* to light indicated that larvae responded to either above light-off or above light-on stimuli by swimming down from the surface of the water in the same manner but at different speeds.

They responded to above light-off stimulus by diving very rapidly downwards from the surface of the water to the floor without a perceptible delay. This response was much like the response given to a moving shadow (KASAP, 11) in appearance. On reaching the floor, the rate of movements of the larvae somewhat slowed down but they continued swimming around for about half a minute before returning to the surface, 4 th instar larvae always and 3 rd instar larvae usually returned to the surface by active swimming. There were always a few larvae on the floor at the time of application of stimulus; these larvae were also responsive to the decrease in light intensity and responded by making a few very rapid swimming movements by bending the abdomen from side to side on the floor, without moving in a particular direction.

The response of larvae of *Aedes aegypti* to above light-on was also swimming downwards but this response started after a per-

ceptible delay and the speed of swimming was not so rapid as it was when light was turned off. While the light was on, the larvae did not return to the surface in a straight line as they always did in pre-stimulus situation, but swam around before coming to the surface.

The pupae of this species responded to above light-off and light-on stimuli in the same way, i.e. by rapidly diving downwards, however the response to light-off was immediate whereas the response to light-on was preceded by a perceptible delay. They swam around in the dish for 1–2 minutes before returning to the surface. The time spent in swimming decreased with the age of pupa.

Quantitative findings (fig. 1)

The number of the larvae and pupae of *Aedes aegypti* responding to above light-on and -off decreased more or less gradually within each instar (fig. 1).

There was no significant difference between the light-off and light-on response of the 3 rd and 4 th instar larvae ($p > 0.1$, Mann-Whithney U-test). However, the difference in pupae was significant ($p < 0.01$, Mann-Whitney U-test). The response of the pupae to both above light-off and -on suddenly dropped in 2 nd day morning and the overall mean responsiveness of the pupae to both light-off and -on stimuli was lower than that of larvae ($p < 0.01$).

The level of the response of the larvae and pupae to light-off was not significantly different from the level of the response to a moving shadow ($p > 0.3$) (table. 1).

(2) *Anopheles stephensi*

Behaviour observed.

The response of larvae of this species to above light-off differed from the response to above light-on in the manner and direction of swimming. When the light was turned off, larvae responded by escaping from the surface by either rapidly swimming downwards or breaking contact with the water surface and sinking downwards; on reaching the floor, they lay there motionless for 1 minute and occasionally for up to 2 minutes before returning to the

surface with a rapid active swimming. This response was similar in apperance to the response given to a moving shadow stimulus.

Larvae responded to above light-on stimulus by swimming across the surface with only a few jerky movements, still keeping the contact with the surface. This response was called *sideways run* which was essentially the only response given to above light-on stimulus as almost no larvae responded by sinking or swimming down. The larvae lying on the floor responded to light-on stimulus by swimming upwards to the surface.

The pupae responded to above light-off and light-on stimuli in the same way by rapidly swimming downwards. They spent about 20 sec. in swimming around before returning to the surface. The return to the surface was either active swimming or passive without swimming.

Quantitative findings (fig. 2)

The percentage of the response to both light-off and light-on fluctuated from the beginning to the end of each instar (Fig. 2).

In each instar, the light-off response was always higher than the light-on response at $p > 0.01$ level for each instar (Mann-Whitney U-test).

Pupae gave almost no response to above light-on stimulus but showed an appreicable response to above light-off, i.e. 17 % on the lst day morning (fig. 2). The response given to above light-off stimulus decreased suddenly on the 1 st day afternoon. The overall mean responsiveness of the pupae both to light-off and light-on stimuli was significantly lower than that of the larvae ($p < 0.05$).

(3) *Culex pipiens*

Behaviour observed.

The larvae of *Culex pipiens* responded to both above lightoff and light-on in the same way, either by swimming rapidly downwards or swimming for a very short time breaking contact with the water surface before sinking. In both cases when the larvae reached the floor they lay there for 1–2 minutes and occasionally for

up to 5 minutes. While on the floor, they lay motionless except for a few feeding movements with the mouth brushes. They returned to the surface with a rapid active swimming.

The pupae of this species were less responsive to above light-off than light-on. Their response was also of brief duration, as they swam 1–1.5 cm. down in the water rapidly then returned to the surface passively without swimming.

Quantitative findings (Fig. 3).

The response of each instar to light-off and light-on was given with some fluctuations, usually increasing every afternoon dropping down every morning (fig. 3).

The light-off response was significantly higher than the light-on response in 3 rd instar ($p < 0.001$) but the light-on response was significantly higher than the light-off response in the 4 th instar larvae ($p < 0.01$) and pupae ($p < 0.001$).

The overall mean responsiveness of pupae to both light-off and light-on stimuli was significantly lower than that of the larvae ($p. < 0.05$).

The response of the larvae and pupae to light-off was significantly lower than the response given to a moving shadow ($p < 0.02$) (table 1).

Table 1: A comparison of the level of the response given to above light-off and a moving shadow of larvae and pupae of the three species using Mann Whitney U-test (SIEGEL, 16). The oversell mean responses are given in percentages but the comparison was made by using the actual number of the animals responding to the stimuli out of the total number.

Species	Instar	Overall mean response (%)		Z	P
		To above light off	To a moving shadow		
Aedes aegypti	3 rd larval	94	96	0.47	> 0.3
	4 th larval	93	95	0.37	> 0.3
	pupal	34	36	0.53	> 0.2
Anopheles stephensi	3 rd larval	41	55	3.93	< 0.001
	4 th larval	23	76	16.32	< 0.001
	pupal	6	3	1.92	< 0.05
Culex *pipiens*	3 rd larval	18	52	12.85	< 0.001
	4 th larval	14	17	1.92	< 0.05
	pupal	2	0.5	1.94	< 0.05

EXPERIMENT-2: Response of larvae and pupae of *Aedes aegypti*, *Anopheles stephensi* and *Culex pipiens* to a decrease and an increase in intensity of light directed from below.

MATERIALS AND METHODS

This experiment was conducted as experiment 1 (above light-on and -off), except that the light was positioned directly underneath the dish containing the larvae. The apparatus of expeririment 1 was turned upside down and then used for this experiment for two reasons, firstly when it was turned upside down the glass floor on which the dish containing the animals was placed let the light pass through, so that the stimulus was positioned underneath the dish without any difficulty, secondly, the distance between the light and the experimental dish was kept constant throughout these two above and below light-on and -off experiments. The counts of percentages and mean values of the animals responding to below light-off and -on stimuli were assessed as in the experiment-1.

RESULTS

(1) *Aedes aegypti*

Behaviour observed.

The larvae of *Aedes aegypti* responded to a below light-off stimulus by diving rapidly downwards from the surface of the the water, without perceptible delay. This is the same response as given to above light-off or to a moving shadow. When the larvae reached the floor this rapid swimming movement slowed down they swam around slowly for about half a minute before returning to the surface.

The larvae at the surface responded to below light-on stimulus by slowly swimming down. When the light was turned on some of the larvae broke contact with the water surface after a perceptible delay and swam half way down in the water then came back to the surface and stayed there; some repeated the above action several times before eventually swimming down to the floor. Af-

ter reaching the floor they continued swimming around at the same speed as in the descent. The response of the larvae lying on the floor to light-on was swimming upwards.

Pupae responded to both below light-off and-on stimuli exactly in the same way, by rapidly swimming downards. The time spent in swimming differed according to age of the pupae; it was about 1–2 minutes in the first day pupae but had declined to 20 seconds in the 2 nd day pupae.

Quantitative findings (fig. 1)

The number of the larvae and pupae responding to light stimuli coming from below was not significantly different from the response to the equivalent stimuli directed from above ($p > 0.1$) (tables 2, 3), only the response of 4 th instar larvae and pupae given to below light-on was significantly lower than their response to above light-on ($p < 0.05$) (table 3).

The number of animals responding to both light-off and -on stimuli decreased with the age of the larvae and pupae. Except for the light-on response of the 4 th instar the decline was more or less gradual (fig. 1).

The light-off responses, except for the 3 rd instar larvae were found to be significantly higher than the light-on response at $p < 0.05$ level for each instar.

The pupal response suddenly dropped from 53 % to 6 % in light-off and from 26 % to 7 % in light-on response in 2 nd day (fig 1). The overall mean response of the pupae to both the light-off and -on stimuli was significantly lower than the overall mean response of larvae at $p < 0.01$ level (fig. 1).

(2) *Anopheles stephensi*

Behaviour observed.

The response of the larvae of *Anopheles stephensi* to below light-off and light-on was not qualitatively different from their response to the corresponding above light stimulus. The larvae resting at the surface responded to below light-off stimulus by rapidly swimming down or swimming for very short time to break

contact with the water surface then sinking down. When they reached the floor they lay there motionless about 2 minutes before returning to the surface by active, rapid swimming. Larvae lying on the floor did not respond to below light-off stimulus.

The response of the larvae to below light-on stimulus was mostly sideways run as described in the experiment-1 without breaking contact with the water surface. However, a few larvae responded after breaking contact with the surface by sinking down to the floor, usually upside down, turning the dorsal side of their body towards the light. They stayed on the floor motionless before actively swimming back to the surface.

Pupae responded to below light-off in exactly the same way as they responded to above light-off, by rapidly diving downwards and returning to the surface rather quickly in about 20 seconds. A very low level of response to below light-on was observed for pupae.

Quantitative findings (fig. 2)

The response of the larvae and pupae to below light-off was significantly lower than their response to above light-off ($p < 0.01$) (table 2) (fig. 2) for each instar. But the response of the larvae to below light-on was not significantly different from the response given to above light-on ($p > 0.1$) (table 3). The below light-on response of pupae was significantly lower than above light-on response ($p = 0.01$) (table 3) (fig. 2).

The response given to below light-off and to light-on by the larvae and pupae fluctuated during the instars. It was found that there was no significant difference between the below light-off and light-on responses of 3 rd instar larvae ($p > 0.1$) but the below light-on response of 4 th instar larvae was significantly higher than the below light-off response ($p < 0.0001$) and the below light-on response of pupae was significantly lower than the below light-off response ($p < 0.01$).

The response of the pupae to below light stimuli ceased on the 2 nd day. The overall mean responsiveness of pupae to both below light-off and light-on was significantly lower than that of larvae ($p < 0.05$) (fig. 2).

(3) *Culex pipiens*

Behaviour observed.

The larvae of *Culex pipiens* responded similarly to the light-off and light-on stimuli from below by swimming fully down or swimming for a very short time to break the contact with the water surface then sinking down. On reaching the floor, they stayed there motionless for 1–2 minutes then came back to the surface with very rapid, active swimming.

The pupae of this species responded to both the light-on and -off stimuli in the same way by swimming halfway down in the water then floating back to the surface passively without swimming.

Quantitative findings (fig. 3).

The response of the larvae and pupae to below light-off was not significantly different from their response to above light-off ($p > 0.1$ for each instar) (table 2). It was found that in 3 rd instar there was no significant difference between above and below light--on response ($p > 0.1$) but in 4 th instar the response to below light-on was significantly higher than their response to above light-on ($p < 0.05$) and in pupae the below light-on response was significantly lower than the above light-on response ($p < 0.001$) (table 3).

The response of the larvae and pupae to below light-off and -on stimuli fluctuated from the beginning to the end of each instar (fig. 3).

In both larvae and pupae, the light-off and -on responses were either not significantly different or the light-off response was significantly higher (fig. 3).

The overall mean response of pupae to light-off and light-on was significantly lower than the larval response ($p < 0.05$) (fig. 3).

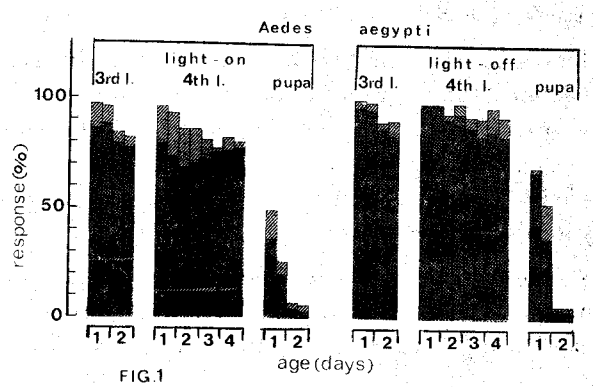

FIG.1

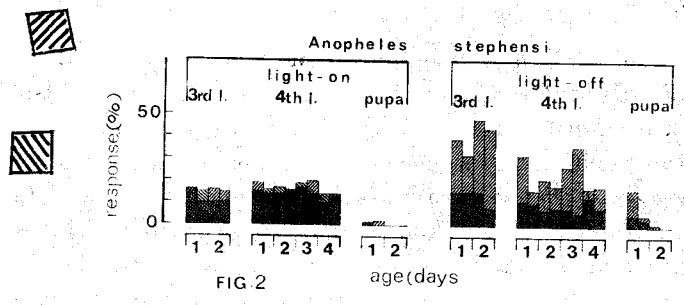

FIG.2

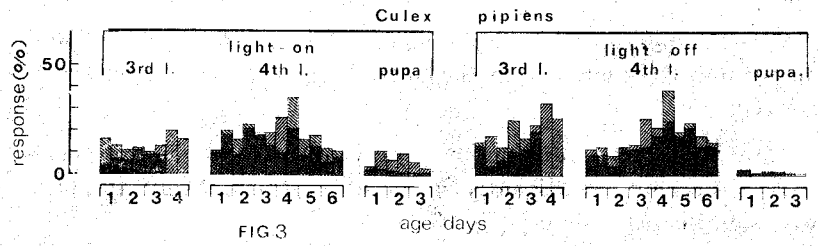

FIG.3

Figs. 1–3. The mean response of the 3 rd and 4 th instar larvae and pupae to above  **and below**  **light-on and light-off and changes of the response in relation to age of animals; the first column of each day indicates the morning and second column indicates the af ternoon response:**

(Fig. 1) ***Aedes aegypti;*** **(Fig. 2)** ***Anopheles stephensi;*** **(Fig. 3)** ***Culex pipiens.***

Table 2: A comparison of the level of the response given to above and below light-off of the larvae and pupae of the three species using Mann Whitney U-test (SIEGEL, 16). The overall mean responses are given in percentages but the comparison was made by using the actual number of the animals responding to the stimuli out of the total number.

Species	Instar	Overall mean response (%)		Z	P
		To above light-off	To below light-off		
Aedes aegypti	3 rd larval	94	90	0.93	> 0.1
	4 th larval	95	90	0.97	> 0.1
	pupal	34	28	1.18	> 0.1
Anopheles stephensi	3 rd larval	41	13	9.39	< 0.001
	4 th larval	23	9	7.55	< 0.001
	pupal	6	2	2.24	< 0.01
Culex pipiens	3 rd larval	18	16	0.78	> 0.2
	4 th larval	17	16	0.12	> 0.2
	pupal	2	1	0.21	> 0.1

Table 3: A comparison of the level of the response given to above and below light-on of the larvae and pupae of the three species using Mann Whitney U-test (SIEGEL, 16). The overall mean responses are given in percentages but the comparison was made by using the actual number of the animals responding to the stimuli out of the total number.

Species	Instar	Overall mean response (%)		Z	P
		To above light-on	To below light-on		
Aedes aegypti	3 rd larval	90	83	0.59	> 0.2
	4 th larval	85	74	1.99	< 0.05
	pupal	22	16	1.71	< 0.05
Anopheles stephensi	3 rd larval	14	13	0.19	> 0.2
	4 th larval	15	16	1.25	> 0.1
	pupal	1	0.25	1.13	> 0.1
Culex pipiens	3 rd larval	11	12	1.27	> 0.1
	4th larval	15	17	1.38	< 0.05
	pupal	7	0.5	6.20	< 0.001

CONCLUSIONS AND DISCUSSION

The behavioural observations on the larvae and pupae of *Aedes aegypti*, *Anopheles stephensi* and *Culex pipiens* showed that the light intensity decrease is more effective stimuli than the light intensity increase in eliciting a behavioural response. The response of the three species to light intensity decrease was essentially

the same, rapidly diving downwards similar to the response shown to a moving shadow (KASAP, 11)

In mosquito larvae, including the species studied here, the same type of escape responses to the same stimuli have been previously described by several authors; HOLMES (9), MİLLER (13). In nature a sudden decrease in light intensity may represent the presence of a predator above, so that the diving response to this kind of stimulus could be anti-predator behaviour since mosquito larvae and pupae apparently have no particular organs of active self-defence.

The difference in the strategy of response of larvae of the three species may offer different type of protection suited to their particular microhabitat. In general, if the prey animals can run faster than the predators, this enables them to get away from their predators. In some cases being inactive may, nevertheless, offer a greater protection than being active; because many predators have rather well developed eye sight so that movement of the prey animals may permit detection and subsequent capture by the predators. For example, Hansell (pers. comm.) observed that Siamese Fighting Fish (Betta splendens) feeding on *Culex* larvae attacked the larvae if they actively swam in water but failed to do so if they sank passively down. The above assumption may equally be true for the predators detecting vibration in the water. The escape reactions of the larvae and pupae of *Ae. aegypti, An. stephensi* and *Cu. pipiens* fit very well into the strategy of the flight behaviour reviewed by EDMUNDS (2). This seems to confitm that the responses shown to light-off are antipredator reactions.

Presumably the predators approaching from above will frequently provide light-off cues advertising their approach. Therefore, the response of larvae and pupae to above light-off is likely to be an anti-predator response to this naturally occuring stimulus. However, the response to below light-off stimulus is less easy to account for in terms of naturally occuring stimulus. Because below light-off could be produced by a predator in clear waters with a floor suitable to reflect the light, in such a habitat a predator passing between the light reflected from the water floor and the prey will provide a naturally occuring below light-off stimulus.

The habitats of mosquitoes are, however, mostly very unlike this as they usually contain cloudy water collections with dark substrates. Thus this may explain the greater response to above light-off than to below light-off. This, of course, has important implications for survial value as it suggests that for *An. stephensi* the main predatory threat may be from above the water. This point should be related to its habitat which at the moment is not very well known. However, HADDOW (7) found in Africa that another *Anopheles* species, *An. gambiae*, breeds in permanent exposed pools and semi-permanent water collections. Hansell (pers. comm.) observed *An. gambiae* larvae in very small temporary pools in Sudan. At least in These semi-permanent and temporary habitats the threat of aquatic predators will probably be less than of extraaquatic predator. If *An. stephensi* lives in semi-permanent and temporary water collections the above assumption might also be true for this species. Since *Anopheles* larvae are surface feeders, all their activity occurs at the surface and therefore they are very likely to be attacked by the predators from outside water or the predators living on the water surface. The predators living within the water may receive little or no visual attention at all; however, larvae may have other means of detecting such predators, e.g. mechanoreception.

The light-on responses are different from the light-off responses in *Ae. aegypti* and *An. stephensi*: in *Ae. aegypti* the response to light-on is a much slower speed of swimming than that in response to light-off. In *An. stephensi* the light-on response is a sideways run but diving down in response to light-off. This light-on stimulus may represent an aquatic predator because in nature the light reflected from predators approaching from below may well reach the eyes of larvae, evoking a sideways run response to evade the predator. The light-on responses being slower and at a lower level than the light-off responses suggest that either animals can easily get away from the aquatic predators or else the light-on responses are not antipredetory and that possibly larvae have other senses, e.g. mechanoreception for detecting aquatic predators. In this case, the light-on responses may be caused by the high light intensity causing the animal to select new environment with lower light,

i.e. habitat selection; however, these responses could be nonfunctional, being produced as an artifact of the experimental situation.

Overall responsiveness of the larvae and pupae of all the three species studied changed with age. In the larvae of *An. stephensi* and *Cu. pipiens* it fluctuated during the period of each instar, instar, in *Culex* usually increasing every afternoon in accordance with the increase in the room temparature and decreassed in the last day of each instar. This decrease in the last day might be due to the pre-ecdysial stage, but since this stage starts in different times in different individuals (HİNTON, 8), it is rather difficult to determine whether the decrease in the responsiveness is closely correlated with the onset of pre-ecdysial stage. However, there was a more or less gradual decrease in response during each larval instar of *Ae. aegypti*. Here again effect of the pre-ecdysial stage on the responsiveness is not certain.

The response of the larvae of *Ae. aegypti* is negatively correlated with the age of the animals. These results are hard to explain however, some conclusions may be drawn. Firstly, in mosquitoes, the larval stages are known as the only growth phase (GİLLETT, 5). During this period the animals may concentrate on the growth so that the external stimuli become less and less effective. HUMPHREY (10) also, while discussing the decrement caused by the habituation, pointed out that a response decrement result from maturation, which is different from the habituation in being irreversible.

Secondly, as has already been discussed, the light responses are most ikely to be anti-predatory, but animals may also protect themselves from predators by being less active.

Thirdly, the response decrement is consistent with the increase in the oxygen requirement of the animals. The older larvae of *Cu. pipiens fatigans* spend much longer time at the surface than the younger larvae (THOMAS, 17) suggesting that the oxygen needs of older larvae is higher than that of younger larvae. As the larvae of *Cu. pipiens* spend most of their time at the water surface and descend to the bottom only for feeding, their response should be rather less influenced than the response of the *Ae. aegypti*.

The larvae of *An. stephensi* are surface feeders and live attached to the water surface. Therefore during normal resting and feeding they should not suffer from any oxygen deficit so that their response may not be depressed by the oxygen requirement.

In the three species the overall responsiveness of the pupae was lower than that of larvae; after pupation the decline in responsiveness with age continued during the whole pupal stage. This stage is known as a transitional stage in which although no more growth occurs, there are drastic changes towards the development of adult characters at the expense of which afficiency of nervous and sensory mechanism of pupae may have to be sacrificed. However, it was observed that if pupae responded they could swim vigorously; therefore although pupae are capable of swimming vigorously they prefer not to move possibly to allow the development of adult in pupal skin; this preference may also favour their being less recognisable by the predators as disscused previously for larvae.

Also in pupae there is an air cavity in thorax. With the developing adult in pupal skin the amount of air in thoracic cavity increases and animals become more and more buoyant so that they can not swim for a long time in water; if they stop swimming they float back up to the water surface. The response threshold of pupae is raised because, although vigorous swimming is still possible, its effectiveness is reduced due to buoyancy.

Another factor that could account for or contribute to lowering of response in pupae is the anatomical evidence found by CHRISTOPHERS (1) that the cuticle of pupae is much thicker than that of larvae. The thicker cuticle may allow less light to reach the eyes.

One or any combination of these four factors discussed above could accound for pupae being less responsive than larvae.

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ÖZET

Bu çalışmada *Aedes aegypti*, *Anopheles stephensi* ve *Culex pipiens* larva ve puplarının üstten ve alttan gönderilen ve ışığın azaltılıp çoğaltılması ile oluşturulan etkiye gösterdikleri davranışlar incelenmiştir. Her üç tür ışık şiddetindeki azalmaya aynı biçimde hızlı bir dalışla cevap vermiştir. Buna karşılık ışık şiddetindeki çoğalmaya gösterilen davranış türlere göre farklıdır; örneğin, *Ae. aegypti* yavaş bir hareketle, *Cu. pipiens* hızlı bir biçimde tabana doğru dalar, *An. stephensi* ise yüzeyde yana doğru hareket eder. Işığın geliş yönü de davranışı etkiler; üstten gelen ışığa, alttan gelen ışıktan daha çok sayıda larva ve pup tepki gösterir.

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