Adv. Odonatol. 4 : 5-11 December 1989

SATIATION TIME AND PREDATORY BEHAVIOUR IN THE LARVA OF *LESTES ELATA* HAGEN (ZYGOPTERA : LESTIDAE)

S. BEENA, A. PALAVESAM & J. MUTHUKRISHNAN

School of Biological Sciences, Madurai Kamaraj University,
Madurai – 625 021, India.

Different weight classes (W) of larval *L. elata* (15 ± 1.5, 25 ± 1.5 and 40 ± 2.0 mg) were allowed to predate on healthy larvae of the mosquito, *Culex pipiens quinquefasciatus* or the chironomid, *Kiefferulus barbitarsis*. Odonate larvae starved for 24 h were exposed to a constant density of 15 mosquitoes per dragonfly. Satiation time (ST) ranged from 8.5 ± 0.62 min for 15 mg W classes exposed to *K. barbitarsis* larvae. The ST was significantly prolonged when the mosquito larvae were offered as prey. Longer deprivation of prey for about 25-48 hr extended the ST to 10, 17 and 22.5 min in the 15, 25 and 40 mg W classes feeding on *K. barbitarsis* larvae. Increase in the prey density significantly shortened the ST. On the other hand, ST significantly increased with increase in the volume of water. Briefly, increase in body weight, extension of food deprivation duration and decrease in prey density extended the ST of the dragonfly.

INTRODUCTION

Several workers have demonstrated the significant role played by aquatic insect larvae in the control of mosquitoes (HINMAN, 1934 ; BATES, 1965 ; SERVICE, 1965 ; ELLIS & BORDON, 1970 ; MATHAVAN, 1976). Adult damselflies play an important role in the control of scale insects (BASALINGAPPA *et al.*, 1984). *L. elata* nymphs inhabit the littoral area of temporary or permanent freshwater systems which are subjected to fluctuations in water volume and depth during the different seasons of year. The dragonflies feed on larvae of mosquito and *Chironomus* almost throughout the year. The predatory behaviour of larvivorous odonate larvae is significantly influenced by different intrinsic (e.g. body weight : PANDIAN *et al.*, 1979 ; hunger level : MATHAVAN, 1976) and extrinsic factors (e.g. temperature : PANDIAN *et al.*, 1976 ; volume and depth of water : MATHAVAN & JAYAGOBAL, 1979 ; prey density : MATHAVAN, 1976). REDDY (1973) and REDDY & PANDIAN (1974) have demonstrated that depth and volume of water drastically influence the predatory behaviour of larvivorous fish *Gampusia affinis.* In a series of publications FISCHER (1966, 1967, 1971) highlighted the food preference and energy budget of *Lestes sponsa* and its role in energy transfer in aquatic systems. The present paper reports the effect of body weight, food deprivation time, prey density and volume of water on predatory behaviour of *Lestes elata* exposed to larvae of the mosquito *Culex pipiens quinquefasciatus* and the chironomid *Kiefferulus barbitarsis.*

MATERIALS AND METHODS

Lestes elata larvae were collected from ponds and separated into different W classes (15 ± 1.5 ; 25 ± 1.5 ; 40 ± 2.0 mg). They were individually acclimatised to the ambient laboratory temperature (20° ± 2°C) in glass beakers (100 ml) for about 3 days. They were fed *ad libitum* on the larvae of *C. pipiens* or *K. barbitarsis.* The prey larvae were obtained from our laboratory culture. Only acclimated dragonflies were used for the experiments.

Satiation time (ST) is described as the time from the start of feeding to voluntary cessation of the feeding process (BRETT, 1971). ST was determined by exposing individually the chosen W classes (15 ± 1.5 ; 25 ± 1.5 and 40 ± 2.0 mg) of *L. elata* larvae previously starved for 24 h to a constant number of 15 *K. barbitarsis* or *C. pipiens* larvae. As and when a mosquito was predated by the dragonfly, one larva of the former was added and the prey density was maintained constant at 15 mosquitoes per dragonfly. The time from the commencement of feeding to the voluntary cessation of feeding was noted. A number of workers (BEUKEMA, 1968 ; WARE, 1972) have considered the amount of food consumed in relation to food deprivation time as a criterion for the assessment of hunger level of fish.

For the experiment on the effect of hunger level on predatory behaviour, *L. elata* larvae starved for 6, 12, 24, 36 and 48 h were used. The effect of prey density was studied by varying the number of prey larvae from 15 to 75 per dragonfly. The effect of the volume of water on predatory behaviour was studied by varying the volume of aquarium water from 150 to 1000 ml.

In all the experiments other than that on the effect of prey density, a constant density of 15 prey larvae per dragonfly was maintained. Except for the experiment on food deprivation time, the dragonflies were always starved for 24 hours before the commencement of the experiment. Except for the experiment on volume of water, the dragonfly larvae were allowed to predate in a volume of 100 ml of water. The weight of one *C. pipiens* and *K. barbitarsis* larva averaged 0.8 mg ± 0.015 mg (N = 50). Considering the number of larvae predated and the mean body weight of the larvae, food consumption by the dragonfly in terms of percent body weight was calculated.

RESULTS

With inreasing body weight the number of prey larvae required for satiation increased irrespective of the prey quality : the number of prey larvae required for satiation ranged between 5 and 14. Consequently the time required for satiation increased from 8.5 to 19.3 min while feeding on *K. barbitarsis* larvae and 11.3 and 20.3 minutes while feeding on *C. pipiens* larvae (Tab. I).

Food deprivation time is a function of hunger level of the predator. In general, dragonfly larvae deprived of food for a longer duration consumed more food.

Consumption of *K. barbitarsis* larvae by the dragonfly increased from 1.2 mg in the 15 mg W class to 2.4 and 3.2 mg in the 25 and 40 mg W classes. Prolongation of the deprivation time to 48 h increased the food consumption to 4.8, 8.0 and 11.2 mg in the 15, 25 and 40 mg W classes, respectively. Similar trends were observed for the individuals predating *C. pipiens* larvae (Tab. II).

Table I

Effect of body weight and food quality on satiation time
and prey consumption by *Lestes elata* nymphs
Each value (X ± SD) represents the mean of five observations

Body weight (mg)	*K. barbitarsis*		*C. pipiens*	
	Satiation time (min)	Prey consumed (N°)	Satiation time (min)	Prey consumed (N°)
15.0 ± 1.5	8.5 ± 0.6	6.0 ± 0.0	11.3 ± 0.6	5.3 ± 0.6
25.0 ± 1.5	15.3 ± 0.4	10.5 ± 0.5	19.0 ± 0.5	9.8 ± 0.4
40.0 ± 2.0	19.3 ± 0.5	13.5 ± 0.5	25.3 ± 0.9	12.0 ± 0.1

Table II

Effect of food deprivation time on prey consumption
by *Lestes elata* nymphs
Each value is the mean of five observations

Deprivation time (hr)	Body weight (mg) ± S.D.					
	15 ± 1,5		25 ± 1,5		40 ± 2,0	
	Prey consumed (mg)	% body weight	Prey consumed (mg)	% body weight	Prey consumed (mg)	% body weight
			Prey : *K. barbitarsis*			
6	1,2	8,0	2,4	9,6	3,2	8,0
12	2,4	16,0	5,4	21,6	5,6	14,0
24	4,8	32,0	8,0	32,0	10,8	27,0
36	4,8	32,0	8,0	32,0	11,2	28,0
48	4,8	32,0	8,0	32,0	11,2	28,0
			Prey : *C. pipiens*			
6	0,8	5,3	2,0	8,0	3,2	8,0
12	2,2	14,7	3,8	15,2	6,0	15,0
24	4,4	29,3	6,8	27,2	9,6	24,0
36	4,8	32,0	7,2	28,8	10,0	25,0
48	4,8	32,0	7,2	28,8	10,0	25,0

Irrespective of the W class, with increasing prey density ST decreased. However, an increase in the density beyond 60 mosquitoes per dragonfly did affect neither ST nor prey consumption. At the maximum density of 60 prey larvae per dragonfly ST ranged from 5 min in the 15 mg W class to 7 or 11 in the 25 and 40 mg W classes feeding on *K. barbitarsis* larvae. The dragonflies feeding on *C. pipiens* required a longer satiation time. This was quite obvious in the 25 and 40 mg W classes. For instance, a 25 mg dragonfly was satiated in 7 min while feeding on *K. barbitarsis* as against 13 min while feeding on *C. pipiens* (Tab. III).

Table III

Effect of prey density on satiation time and prey consumption by *Lestes elata* nymphs
Each value (X ± S.D.) represents the average of five observations

Body weight (mg)	Prey density (N°)	*K. barbitarsis*		*C. pipiens*	
		Satiation time (min)	Prey consumed (N°)	Satiation time (min)	Prey consumed (N°)
15 ± 1.5	15	8.5 ± 0.6	5.5 ± 0.5	11.3 ± 0.6	5.0 ± 0.0
	30	6.0 ± 0.5	6.5 ± 0.5	8.5 ± 0.5	6.0 ± 0.5
	45	5.5 ± 0.2	6.5 ± 0.5	6.5 ± 0.4	6.0 ± 0.2
	60	5.0 ± 0.1	6.0 ± 0.4	5.5 ± 0.3	6.0 ± 0.3
	75	5.0 ± 0.2	6.0 ± 0.4	5.5 ± 0.3	6.0 ± 0.3
25 ± 1.5	15	15.3 ± 0.4	10.5 ± 0.5	19.0 ± 0.5	9.8 ± 0.4
	30	12.3 ± 0.2	11.5 ± 0.4	16.5 ± 0.6	11.0 ± 0.5
	45	8.3 ± 0.5	11.0 ± 0.5	13.7 ± 0.5	10.0 ± 0.5
	60	7.0 ± 0.4	11.5 ± 0.6	13.0 ± 0.5	9.0 ± 0.4
	75	7.0 ± 0.3	11.5 ± 0.5	13.0 ± 0.6	9.0 ± 0.4
40 ± 2.0	15	19.3 ± 0.8	13.0 ± 0.5	25.3 ± 0.9	12.0 ± 0.7
	30	15.5 ± 0.6	14.0 ± 0.6	19.0 ± 0.7	13.5 ± 0.8
	45	12.0 ± 0.5	14.0 ± 0.6	14.8 ± 0.6	12.0 ± 0.5
	60	11.0 ± 0.5	14.0 ± 0.5	14.0 ± 0.6	12.5 ± 0.4
	75	11.0 ± 0.5	14.0 ± 0.5	14.0 ± 0.6	12.5 ± 0.4

Placed in 1000 ml water, a 25 mg dragonfly feeding *K. barbitarsis* larvae was satiated in 25 min compared with the 30 min needed in those feeding on *C. pipiens* (Tab. IV). Irrespective of W class or prey quality, ST increased with the inrease in water volume. However, the increase was not significant beyond a volume of 500 ml. Therefore, 500 ml water appears the highest reactive volume for the dragonflies. More or less similar trends were observed for the larvae feeding *C. pipiens.*

DISCUSSION

A critical analysis of the results presented above clearly shows that body weight influences satiation time more significantly than prey quality, food deprivation time, volume of water and prey density. Compared to food deprivation time, water volume and prey density, prey quality appears to have greater impact on the predatory behaviour of *L. elata* larvae (Tab. V). MATHAVAN (1976) also reported that satiation time in *Mesogomphus lineatus* larvae increases with body weight. The increase in gut capacity with increase in weight of the larva obviously explains the positive linear relationship between body weight and satiation time. The gut capacity of the tested W classes of *L. elata* varies from 28 to 32% body weight. Since, in the tested W classes, a minimum deprivation time of 24 h is required to digest the maximum capacity of the gut, an interval of at least 24 h between two meals is required for the return of appetite. *M. lineatus* larvae were also reported to require 12 to 24 h for the return of the appetite (MATHAVAN, 1976).

Table IV

Effect of volume of water on satiation time
and prey consumption by *Lestes elata* nymphs
Each value (X ± S.D.) is the mean of five observations

Body weight (mg)	Vol. of water (ml)	*K. barbitarsis*		*C. pipiens*	
		Satiation time (min)	Prey consumed (N°)	Satiation time (min)	Prey consumed (N°)
15 ± 1.5	50	8.5 ± 0.3	5.0 ± 0.1	11.0 ± 0.3	4.5 ± 0.3
	100	8.5 ± 0.3	6.0 ± 0.3	11.3 ± 0.6	5.3 ± 0.4
	250	13.5 ± 0.5	8.5 ± 0.4	17.5 ± 0.4	7.5 ± 0.1
	500	17.2 ± 0.6	7.0 ± 0.4	20.3 ± 0.6	6.0 ± 0.1
	1000	17.5 ± 0.7	7.0 ± 0.4	21.5 ± 0.6	6.0 ± 0.1
25 ± 1.5	50	15.0 ± 0.5	9.0 ± 0.4	19.5 ± 0.8	8.0 ± 0.3
	100	15.5 ± 0.7	10.0 ± 0.6	19.0 ± 0.6	9.8 ± 0.4
	250	19.3 ± 0.3	12.5 ± 0.5	23.0 ± 1.4	11.5 ± 0.8
	500	22.5 ± 0.6	11.0 ± 0.6	28.5 ± 1.6	9.5 ± 0.6
	1000	23.0 ± 1.2	11.0 ± 0.5	30.0 ± 1.8	9.5 ± 0.6
40 ± 2.0	50	18.0 ± 0.3	12.0 ± 0.3	24.0 ± 1.4	11.0 ± 0.6
	100	19.5 ± 0.7	13.3 ± 0.4	25.3 ± 1.4	12.0 ± 0.8
	250	23.5 ± 1.9	15.5 ± 0.9	31.5 ± 1.9	14.5 ± 0.8
	500	27.5 ± 2.0	14.0 ± 1.0	35.0 ± 2.0	12.5 ± 0.9
	1000	28.0 ± 2.2	13.0 ± 0.9	36.0 ± 2.1	12.0 ± 0.9

Prey density and volume of water influence the satiation time by varying the number of encounters made by the predators with the prey (PANDIAN *et al.*, 1979 ; MATHAVAN & JAYAGOBAL, 1979). Therefore it may be concluded that an increase in the prey density with a concomitant decrease in the water volume could maximise the predatory efficiency of the dragonfly by increasing the number of encounters with the preys. Of the tested prey larvae, *K. barbitarsis* is preferred by *L. elata.* A comparison of chemical composition and energy content of *K. barbitarsis* and *C. pipiens* larvae provided by BEENA (unpublished) reveals that *K. barbitarsis* larvae contain more total proteins, fat, water and energy than *C. pipiens* larvae. Besides the high nutritional quality, the red colour of *K. barbitarsis* larva is also responsible for its preference by *L. elata.* While *K. barbitarsis* larvae remain at the bottom of the aquarium, those of *C. pipiens* maintain themselves at the surface. *L. elata* larvae mostly stay at the bottom, hence increasing the chance of encountering *K. barbitarsis* larvae.

PANDIAN *et al.* (1979) reported on the number of *Culex* larvae (4th instar) consumed by *M. lineatus* ranging from 25 to 160 mg at a wide range of temperature 10-35°C. At 30°C *M. lineatus* weighing 60 mg were reported to consume 7 IV instar *Culex* larvae. On the other hand, the present study shows that larval *L. elata* weighing 40 mg consume twice as many IV instar *C. pipiens* as do the 50 mg *M. lineatus* larvae. MATHAVAN (1976) compared the predatory capacity of selected insect and fish predators of mosquito larvae and concluded that odonates are by far the most efficient in regulating mosquito populations. Within the order, the Zygoptera appear to be more effective than Anisoptera).

Table V

Summary of two way analysis of variance for the data on predatory behaviour of *Lestes elata* nymphs fed on *Chironomus* or mosquito larva
Conclusions were drawn based on F-ratio

Parameter compared	Source of variance	Df	F-ratio	P-value	Remarks
Body weight vs Prey quality	Body weight	2	56.30	< 0.05	Body weight is more significant
	Prey quality	1	18.73	< 0.05	
Body weight vs Deprivation time	Body weight	2	74.66	< 0.001	Body weight is more significant
	Deprivation time	4	27.13	< 0.001	
Body weight vs Water volume	Body weight	2	531.64	± q 0.001	Body weight is more significant
	Water volume	4	215.48	< 0.001	
Body weight vs Prey density	Body weight	2	12.88	< 0.001	Body weight is more significant
	Prey density	4	4.05	< 0.05	
Prey quality vs Deprivation time	Prey quality	1	42.35	< 0.001	Prey quality is more significant
	Deprivation time	4	10.95	< 0.05	
Prey quality vs Water volume	Prey quality	1	7.05	< 0.05	Prey quality is more significant
	Water volume	4	4.75	< 0.05	
Prey quality vs Prey density	Prey quality	1	152.04	< 0.001	Prey quality is more significant
	Prey density	4	47.00	< 0.001	

ACKNOWLEDGEMENT

The second author gratefully acknowledges the CSIR, New Delhi, for the award of a Senior Research Fellowship.

REFERENCES

BATES, J. J., 1965. *The natural history of mosquitoes.* Harper & Row, New York.

BASALINGAPPA, S., M. R. GANDHI, S. B. HAVALAPPANAVAR, K. S. MURALIDHAR, S. V. MODSE & P. THARABAI, 1984. Enumeration of damselfly *Lestes elata* (Odonata : Lestidae) and their possible role in the control of insects. Proc. first Indian Symp. Odonatol. 20-25.

BEUKEMA, J. J., 1968. Predation by three-spined stickleback (Gasterosteus aculearus). The influence of hunger and experience. *Behaviour* 31 : 1-126.

BRETT, J. R., 1971. Satiation time, appetite and maximum food intake of sockeye salmon (Oncorhynchus nerka). *J. Fish Res. Bd Can.* 28 : 409-415.

ELLIS, R. A. & J. H. BORDEN, 1970. Predation by Notonecta undulata (Heteroptera : Notonectidae) on larvae of yellow fever mosquito. *Ann. ent. Soc. Am.* 63 : 963-973.

FISCHER, Z., 1966. Food selection and energy transformation in larvae of Lestes sponsa (Odonata) in astatic waters. *Verh. int. Verein. theor. angew. Limnol.* 16 : 600-603.

FISCHER, Z., 1967. Food composition and food preference in larvae of Lestes sponsa (L.) in astatic waters environment. *Polskie Archwm Hydrobiol.* 14 : 59-71.

FISCHER, Z., 1972. The energy budget of Lestes sponsa (Hans.) during its larval development. *Polskie Archwm Hydrobiol.* 19 : 215-222.

HINMAN, E. H., 1934. Predators of the Culicidae (mosquitoes). 1. The predators of the larvae and pupae, exclusive of fish. *J. trop. Med. Hyg.* 37 : 145-150.

MATHAVAN, S., 1976. Satiation time and predatory behaviour of the dragonfly nymph Mesogomphus lineatus. *Hydrobiologia* 50 : 55-64.

MATHAVAN, S. & G. P. JAYAGOBAL, 1979. Effect of volume and depth of water on predatory behaviour of the tropical dragonfly nymph. *Comp. Physiol. Ecol.* 4 : 56-58.

PANDIAN, T. J., S. MATHAVAN & G. P. JAYAGOPAL, 1979. Influence of temperature and body weight on mosquito predation by the dragonfly Mesogomphus lineatus. *Hydrobiologia* 62 : 99-104.

REDDY, S. R., 1973. *Mosquito control through larvivorous predators.* Ph.D. thesis. Bangalore University. Bangalore.

REDDY, S. R. & T. J. PANDIAN, 1974. Effect of water current on the predatory efficiency of Gampusia affinis. *Oecologia* 16 : 253-256.

SERVICE, M. W., 1965. Tacharomia sp. as predators of adult anopheline mosquitoes. WHO/FBL/64 : 1-4.

WARE, D. M., 1972. Predation by rainbow trout (Salmo gairdneri). The influence of hunger, prey density and prey size. *J. Fish Res. Bd Can.* 29 : 1193-1202.