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OBSERVATIONS ON *LACCOPHILUS ANTICATUS ANTICATUS* SHARP (COLEOPTERA : DYTISCIDAE) AS A PREDATOR OF MOSQUITO LARVAE IN WEST BENGAL, INDIA.

T. K. PAL
Zoological Survey of India
Arunachal Pradesh Field Station
Itanagar-791 111, India

and

K. K. GHOSH
M.U.C. Women's College
Burdwan, West Bengal, India

INTRODUCTION

Biological agents undoubtedly play an important part in controlling mosquitoes, and a study of these organisms forms only a phase of the complex subject spoken of generally as natural control or bio-environmental control. Increasing environmental concern over the widespread dependence on insecticides for vector control and also growing pesticide resistance create a need for newer mosquito control techniques. A more efficient use of known predators is one strategy.

Various predatory organisms occur in or near most habitats of mosquito immatures. Dytiscids or predaceous diving beetles are conspicuous among these. They are completely carnivorous (Balduf, 1935) and predation of mosquito larvae by dytiscids have been well accounted by various mosquito workers (James, 1961, 1964 b, 1967 ; Russell *et al.*, 1963 ; Jenkins, 1964 ; Notestine, 1971 ; Bay, 1974 etc.). Though the reports on predation by dytiscid beetles are not infrequent, a little is known about the quantitative relations between mosquito larvae and these beetle predators (James, 1964a, 1965 ; Roberts *et al.*, 1967 etc.).

Actual predation on mosquito larvae by the predaceous diving beetle, *Laccophilus anticatus anticatus* Sharp, common in many mosquito habitats in wetlands in West Bengal, is infrequently observed in nature. Destruction in the laboratory of a mosquito larval stock culture by a small population of beetles collected from field encouraged us to undertake this study. Further, reduction of larval mosquito on release of adult beetles in artificial breeding ground of similar nature in field led us to infer their influence on destruction of mosquito larvae.

Included are experiments to determine the killing behaviour, changing patterns of prey consumption in different seasons, influence of container size on predation, influence of alternative prey on larval mosquito predation and average longevity of *L. a. anticatus*. These and related information are necessary to properly interpret the relationship between this predator and its prey.

HABIT—HABITAT OF BEETLE

L. a. anticatus are small (3-4 mm.), dorsally subflattened bicoloured (yellow and blackish), glabrous beetles. They find their most favourable haunting place in West Bengal, in marshy areas, in relatively shallow bodies of water rich in vegetation and small animal life. Often they are found where there is dense growth of filamentous algae like *Spirogyra*. Such habitats in periurban and rural areas are highly mosquitogenic and breed species like *Anopheles subpictus*, *A. vagus*, *A. hyrcanus*, *Culex vishnui*. This beetle thrives well where the water is shared by larvae or nymphs of other aquatic arthropods and insects which they consume. Dense submerged vegetation affords an abundance of food for the alternative prey. The adults are active and spend most of their time under water. They obtain air either by breaking through the surface film or from bubbles attached to the aquatic plants. The frequency of beetle's visit to the surface is said to be proportional to the beetle's activity and to temperature (Blunck, 1916 ; Benick, 1927). These beetles are semigregarious and are found in societies. They can also fly when necessary. They occur abundantly during the monsoon and post-monosoon hot seasons in temporary pools and weed infested ponds. They show cannibalistic tendencies in aquaria, which was noticed earlier by Hodgson (1953) in other species.

MATERIAL AND METHODS

Beetles were collected from pools in swampy areas at the outskirt of eastern Calcutta using a cloth sweepnet of ca. 20 cm. diameter and were transported to the laboratory in plastic buckets. A few mosquito larvae were provided during transit to avoid cannibalism. 5 beetles were placed to a 1-1tr. glass jar with plain tap water of pH 7 and a piece of aquatic weed from the natural nabitat. Forty IV instar larvae of *Aedes aegypti* mosquito were provided daily to each jar for maintaining the beetle in the laboratory. The water was changed on every seven days and the dead beetles were removed when noticed.

To determine the killing behaviour of beetle for mosquito larvae, a beetle unfed for 24 hours, was isolated in a 500-ml. clean glass jar with twenty IV instar larvae of *A. aegypti* and was watched with a magnifying glass from a close range. Subsequently beetle predation was watched in a petri-dish under a binocular microscope. Four beetles were observed separately in containers to determine the frequency of predation.

In order to determine the destructive capacity of individual beetles for various stages of mosquito immatures, the beetles were isolated in jar (1-1tr.) with water. Ten each of I instar, III instar, IV instar and pupal stages of *A. aegypti* were added to all. After 24 hours, surviving larvae and pupae in all jars were counted and the difference in number of surviving larvae and pupae for each instar was attributed to beetle predation. After counting, new sets of immatures were replaced and the study was repeated for ten days.

To determine the rate of prey consumptions in different seasons of the year, the beetles were isolated in 1-ltr. jars. Twentyfive IV instar larvae of *A. aegypti* were added to all jars. Each day the number of prey consumed or killed during the previous 24 hours was recorded at 10·00 hrs. After counting, any remaining larvae or cadavers were replaced with twentyfive fresh larvae. Each container was observed for fifteen consecutive days. The procedure was repeated with new beetles for each season.

Another set of experiments involving containers of various sizes (250 ml., 500 ml., 1 ltr., 3 ltr.) and a single beetle per container with twentyfive IV instar prey larvae allowed estimating the effects of container size (in turn prey density) on predation. The variously sized containers used were cylindrical with a height to diameter ratio ca. 2·0.

The influence of alternative prey/food was studied by offering chironomid larvae (sp. indet.), in one group with fish flesh and in other group without fish flesh. Twenty IV instar *A. aegypti* larvae and an equal number of IV instar chironomid larvae were added to each 1-1tr. experimental jar. The number of larvae predated during a 24 hour period was recorded every day. This experiment was conducted in monsoon.

The longevity of the beetles was recorded from the laboratory maintained stocks.

RESULT

Prey capture and killing

L. a. anticatus was seen to locate its prospective prey when the latter was very close (8-10 mm.) to it. The senses of smell/taste seemed to determine the acceptibility or edibility of the animals seized. The beetles were normally not very fast-movers and became alert only when prey neared. After a stealthy approach beetles suddenly darted to capture their victims. They grasped the trunks of larvae with the first and second pairs of legs pressing them against their mouthparts. They chewed and tore the prey's body into solid bits which they ingested. They usually devoured all soft parts of the larval body leaving only the head and siphon. In at least twentyfive close observations the average consumption time was 4 minutes (range 2-10 minutes depending upon hunger). The elapsed time between attacking two successive prey ranged from 10 to 150 minutes for 10 hours observation in a monsoon day.

Differential destruction of various stages

Individual beetles receiving only mosquito (immatures as prey destroyed an average of 3·36 III instar and 2·90 IV instar larvae within 24 hours. The 24-hour mortality of I instar larvae averaged only 0·86. Only one pupa was destroyed in a single replicate. Table 1 shows a prey preference for third and fourth instar larvae. First instar larvae are less preferred and pupae are seldom attacked.

Table 1

Predatory behaviour of *L. anticatus anticatus* on various stages *Aedes aegypti* immatures in 1·0 ltr. container

No. of days observed	No of containers observed	Prey instar	Total larvae destroyed	Per Cent predation	Mean No. of larvae destroyed/bcetle/24hrs.
10	3	I	26	12·09	0·86
		III	101	46·97	3·36
		IV	87	40·46	2·90
		Pupa	1	0·46	0·03

Seasonal fluctuation of predation

The daily predation by *L. a. anticatus* was not uniform. Considerable variability occurred in prey consumption in different seasons of the year. The beetle was least active in winter and the daily consumption was recorded to be only 0·95 larva (range 0-3). With the rise of atmospheric temperature the activity and feeding capacity of beetles increased considerably. In summer an average of 4·46 (range 2-8) larvae were consumed by a beetle within 24 hours. The consumption reached maximum in monsoon days when atmospheric temperature and humidity were both very high and predation reached an average of 7·93 (range 4-15) larvae within 24 hours. Fig. 1 compares rate of destruction of mosquito larvae by this beetle in container habitat, in different climatic seasons of the year. The correlation of predation with the atmospheric temperature and especially with the humidity is evident (Fig. 1).

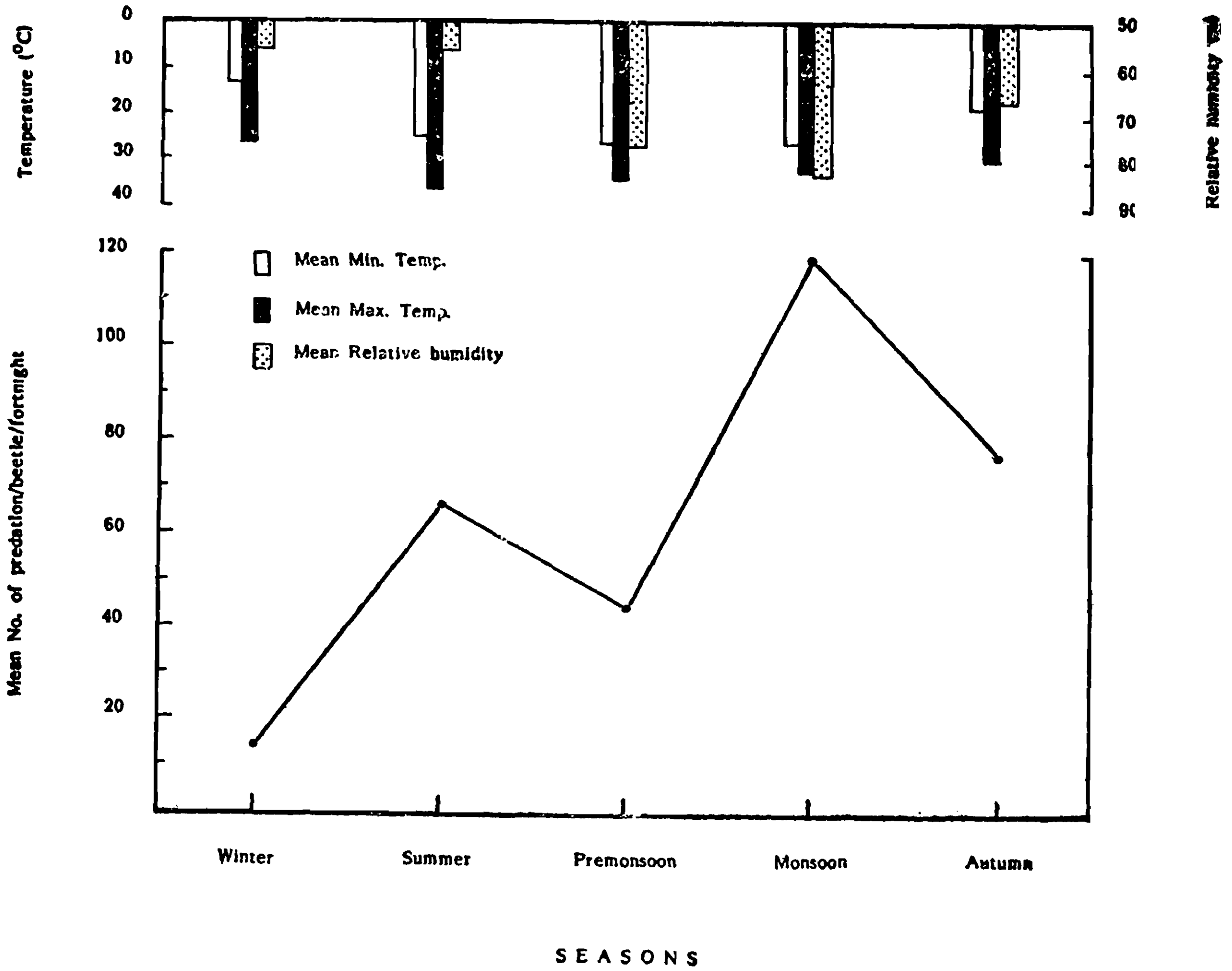

Fig. 1 : Mean fortnightly predation of *Aedes aegypti* larvae by one *Laccophilus anticatus anticatus* in different seasons of year.

Effect of container size on predation

In the experiment involving different size containers (0·25 ltr. to 3·0 ltr.), daily mean consumption varied directly (though not proportionately) with the size of containers. A 12-fold difference in volume resulted in only 1·45-fold difference in daily consumption. Fig. 2 suggests that predation was little dependent on prey density. This observation suggests that *L. a. anticatus* actively searches out its prey in larger arenas.

Effect of alternate prey on predation

In the alternative prey experiment neither mosquito nor chironomid larvae interfered with one another. The availability of chironomid larvae reduced mosquito larva consumption by approximately 37% (see Table 1). Surprisingly however, the presence of fish flesh seemed to reduce chironomid larval destruction by approximately 34%

(Table 2). From control replicates with only fish flesh, it was found that the beetles could thrive well on dead animal tissue alone if the water was not polluted. They did, however, shift to living prey when available.

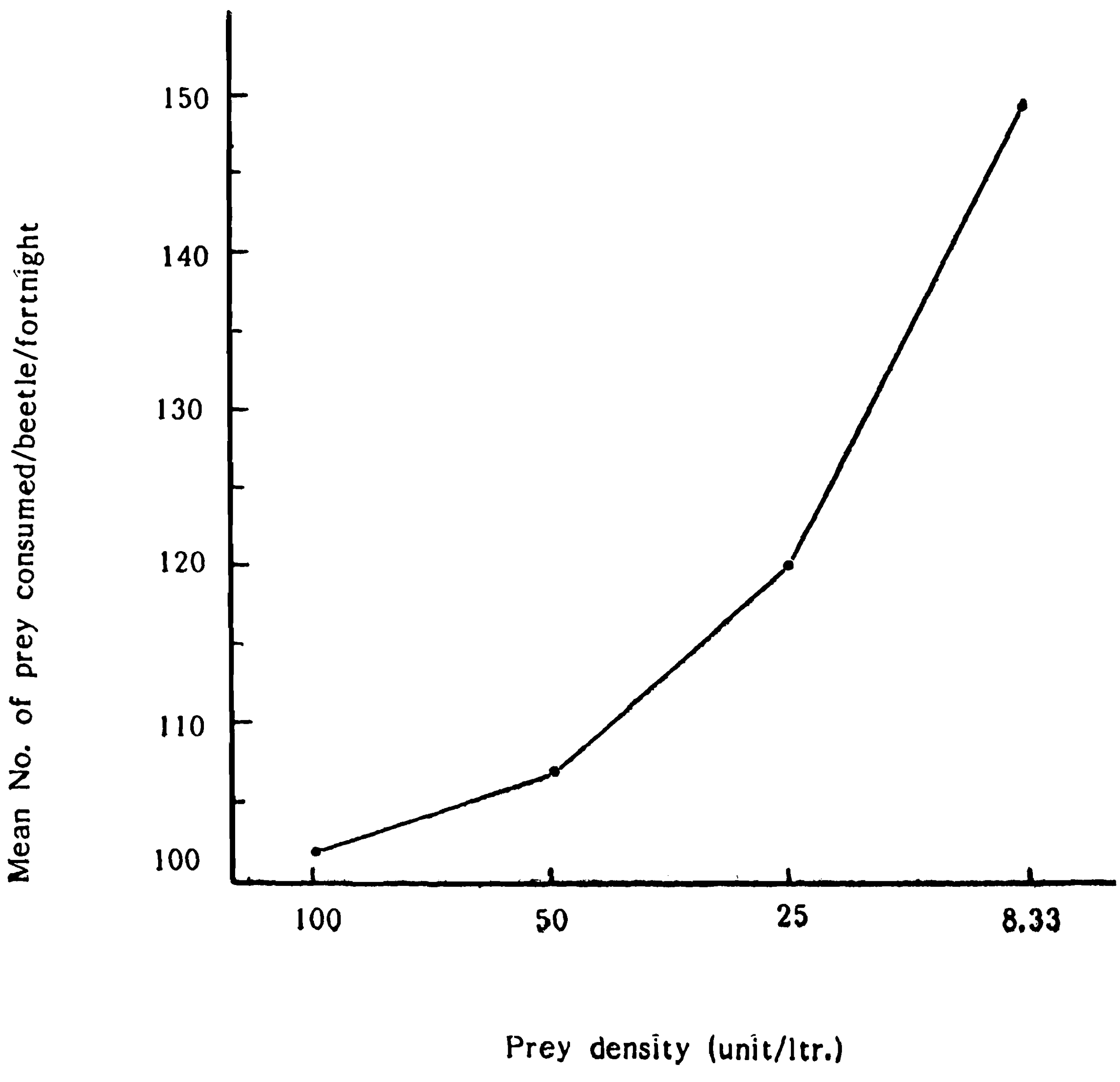

Fig. 2 : Mean fortnightly predation of *Aedes aegypti* larvae by one *Laccophilus anticatus anticatus* for various prey densities.

Table 2

Predatory behaviour of *Laccophilus anticatus anticatus of Aedes aegypti* and Chironomind larvae in presence and absence of fish flesh

Group	No. of days observed	No. of con-tainers observed	Total No. of mosquito larvae predated	Total No. of chironomid larvae predated	Per Cent mosquito larvae predated	Per Cent chirono-mid larvae predated	Mean No. of mosquito larvae destroyed/ beetle 24 hrs.	Mean No. of chirno-mid larvae destroy-ed/beetle/ 24 hrs.
I (plus fiish flesh)	15	3	211	127	62·43	37·57	4·68	2·82
II (minus fish flesh)	15	3	212	85	71·38	28·62	4·71	I·88

Longevity

The beetles receiving a regular supply of mosquito larvae in the laboratory stock lived for 28 days to 5 months 6 days, but majority survived between 50 to 60 days.

DISCUSSION

The pattern of prey capture by *L.* a. *anticatus* conforms typically to an insect with biting-chewing mouthparts. The adult beetles, unlike predaceous bugs, do not digest their food preorally. A midintestinal secretion flows forward into the crop where preliminary digestion takes place (Balduf, 1935). With the ingestion of enough food the beetles do not increase their body weight sufficiently to affect specific gravity or floating ability. Blunck (1923) noted that the food they take up is balanced by frequent elimination of rectal ampulla.

A monsoon peak in mosquito abundance in West Bengal coincides with the prevalence of shallow temporary breeding sites. Difference in climate affects the physiology and the duration of beetle's life cycle. Both the predator beetle and the prey insect are independently influenced by seasonal climatic rythms, especially temperature and rain fall. These factors influence the synchronization of predator's acvity (≡prey consumption) and prey prevalence.

In the experiment involving different size containers, while the overall trends in the effects of container, size on predation rate is apparent, analysis of daily data indicates that little can be said concerning the expected predation on any particular day. These variabilities indicate that more factors influencing beetle's activity are involved in predation than just prey density. In spite of the obvious relationship between size and density, size of container definitely affected predatory activity apart from prey density. It is felt that the inability to obtain good correlation between dependent variables (*i. e.*, daily predation) and the number of prey larvae per litre was perhaps due to variable ratios of container surface area to predator. Beetles have however, demonstrated their ability to search out prey in larger habitats independent of lesser prey density.

Laboratory studies showed that *L. a. anticatus* preyed about equally on third and fourth instars of *Aedes* mosquito larvae but less so on chironomid larvae. It is assumed that the *Aedes* larvae, those move between the bottom and surface for feeding and respiration, often come close to beetles between midwater and surface stratum. Chironomid larvae, as mostly bottom dwellers, are less exposed to active zone of beetles. James (1964a) found that the larvae of mosquitoes are consumed faster than those of chironomids by *Laccophilus*. It perhaps suggests the preference of mosquito larvae over chironomid larvae. It is evident that the beetle can switch over its feeding to some dead animal matter and Bay (1972) even found it to prey upon its own eggs when the preferred diet was scarce. Borland (1971) noticed that this sort of behaviour does not occur if the beetles are provided with adequate mosquito larvae.

The ability of the predaceous diving beetle. *L. a. anticatus* to cause mortality of mosquito larvae in the laboratory is encouraging and obviously there are situations where similar incidence happens in nature. Its significance in nature however, needs to be better understood. Predators under laboratory conditions, are not as a rule able to noticably reduce larval populations in natural situations. It is, moreover, a recognised fact that to bring about a desired level of adult mosquito suppression by territorial larval reduction is difficult to attain. Ignoring such complex population models, the influence of this beetles against larval mosquito population is apparently indicated. Their spatial and temporal distribution overlap well with those of their prey, they have good longevity and interact for a long period with prey population, and they disperse relatively well. The opinion of authorities, however, differ regarding the importance of dytiscids against mosquito larvae. Chidester (1917), Twinn (1931), James (1964b), Notestine (1971) recognised dytiscids to have very good potential as aquatic predators whereas, Kuhlhorn (1961) in Germany recognised them to be of minor importance. Although mosquito control factors in India are not the same elsewhere, there are many common attributes.

Species of *Anopheles viz.*, *subpictus*, *vagus*, *hyrcanus* appear quickly in newly filled depressions and temporary ponds, in marshy zones in West Bengal. These prey are followed almost simultaneously by considerable growth of aquatic vegetation and array of *Laccophilus* beetles. Although *Laccophilus* through regulation does not totally prevent mosquitoes from breeding in its habitat, it does generate mortalities to cause partial suppression of these mosquito populations.

SUMMARY

In the field predators of mosquito larvae can be very efficient against various species. Adult dytiscid beetles, *Laccophilus anticatus anticatus* sharp are semigregarious and occur in swampy humid zones of moderately large water bodies in West Bengal. Laboratory tests reveal that these beetles select mosquito larvae as prey over chironomid larvae. Prey consumption also varies with seasons of the year. In a fortnight, a single beetle on average is seen to predate 14 larvae of *Aedes aegypti* (L.) in winter, 67 in summer, 44 in pre-monsoon, 119 in monsoon and 77 in autumn days. The role of predation is to some extent affected by size of the containers. Individuals of *L. a. anticatus*, in laboratory, lived for 28 days to 5 months 6 days. These beetles were found to be responsible for low larval mosquito populations in their abode. The results of laboratory tests together with low larval population in temporary ponds and rain-fed depressions suggest that *L. a. anticatus* plays a significant biotic role in regulating the wetland mosquitoes in West Bengal.

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