OBSERVATIONS ON *TOXORHYNCHITES SPLENDENS* (WIEDEMANN) (DIPTERA:CULICIDAE) IN SINGAPORE

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Since its first appearance in Manila in 1954, dengue haemorrhagic fever has become a serious public health problem in S.E. Asia where *Aedes aegypti* (L.) is the confirmed and probably primary vector (Lim *et al.*, 1961; Rudnick, 1966) and *Aedes albopictus* (Skuse) a suspected and probably subsidiary vector (Chan *et al.*, 1968).

As *Toxorhynchites* species had been widely used before World War II with some success to control *Aedes* vectors in the Pacific islands (Paine, 1934; Peterson, 1956; Nakagawa, 1963), it is particularly pertinent in Singapore at present to explore further into the potentiality and possibility of utilizing *Toxorhynchites splendens* as a control agent for the two *Aedes* mosquitoes.

MATERIAL AND METHODS. Material for study was obtained from shanghai jars in a rural area at Jalan Kayu, Singapore.

Collection of *Toxorhynchites splendens* in shanghai jars was done by using a torchlight and a small long-handled sieve as well as a Japanese-made hand-operated siphon pump to extract water and its contents (algae, silt and mud) from the jars. The pumped-out water was then passed through a sieve and the mosquito larvae and pupae collected with a pipette. In this way, a single three-quarters full jar could be emptied in about three minutes and a reasonable number of jars sampled per day.

Eggs laid singly on the water surface, easily seen by their white color and large size, were collected by using a thin wooden spatula.

All stages were reared and maintained at normal room temperature and relative humidity (circa 84° F. and 70 percent R.H.). Eggs were allowed to hatch in petri-dishes and larvae reared on *Aedes aegypti* and *A. albopictus* larvae. Adults emerging from pupae were fed on honey supplied in a cotton swab hung in the middle of a one cubic foot mosquito cage.

RESULTS AND DISCUSSION

1. *Life History:* Eggs hatched in 1–2 days. The duration of the larval stages varies from 13.5 to 52 days, with an average of 34.6 days. The pupal stage averages 4 to 5 days. The duration from egg hatching to adult emergence thus falls in the region of 5 to 6 weeks (Table 1).

Paine (1934) working on *T. splendens* in Fiji found that its egg stage took 2

TABLE 1.—Life history of *T. splendens*.

Stage	No. Exptd.	Larval Length (mm)	Duration (Days) Range	Average
Egg	26	..	1– 2	1.5
Larva				
1st instar	9	1.0– 2.5	1– 3	1.5
2nd instar	14	2.5– 4.0	1.5– 4	2.4
3rd instar	6	3.8– 7.0	3– 8	4.7
4th instar	10	7.0–13.0	8–37	26.0
Pupa	12	..	4–12	4.6
Egg hatching to adult emergence			17.5–57	39.2

days, its larval stage from 16 days (minimum) to 134 days (maximum), according to food availability, and the pupal stage 6 days, with a minimum period per generation of 30 days. Paine's results thus agree with the present study. Cheong & Ganapathipillai (1964) also obtained similar results with the Malayan species.

The duration of the larval stage is undoubtedly dependent on a number of factors such as availability of food, prey searching and capturing ability, rates of feeding and digestion, amount of disturbance by prey or other organisms, light and temperature. Goma (1964), working on *T. brevipalpis conradti* (Grunb.) and *T. kaimosi* (von Som.), found that predation on *Aedes aegypti* was more intense in the light than in the dark due to greater activity of the prey in light.

2. *Occurrence in Shanghai Jars:* Random sampling of water-containing shanghai jars in the Jalan Kayu coastal area shows that, in nature, about 70 percent (30 out of 43) harbour *T. splendens* (Table 2). The majority (42 percent) contained only a single predator, mostly in the 4th larval stage; 21 percent contained from 2 to 10 individuals, averaging 3.6 per jar, and 7 percent contained more than 10 per jar. In one jar, as many as 21 immature stages (eight 1st instars, four 3rd, six 4th and three pupae) were found, and in five jars three or more full-grown larvae were observed to coexist together in low prey densities.

TABLE 2.—Occurrence in nature of *T. splendens* in 43 shanghai jars.

Predator Density	Jars		Immature Stages	
	No.	%	No.	No./Jar
0	13	30.2	..	..
1	18	41.9	18	1
2–10	9	20.9	32	3.6
10+	3	7.0	50	16.7
Total	43	100.0	100	2.3

The prey of *T. splendens* found in shanghai jars in nature fell predominantly into three groups: *Aedes, Culex* and chironomids. Out of 30 jars examined, 21 (70 percent) contained *Aedes albopictus,* 6 (20 percent) contained chironomids and only one (3.3 percent) contained *Culex.* The observed percentage of chironomids might, however, be much lower than the actual as chironomids were not easily seen in their normal habitats in green algae and mud.

The numbers of jars in which *T. splendens* was associated with *A. albopictus, Culex* spp., and chironomids, were respectively 13 (43.4 percent), 1 (3.3 percent) and 4 (13.3 percent). A large percentage (53.3 percent) of the jars containing *A. albopictus* were in the group with 1–10 prey larvae per jar. From the fact that *Toxorhynchites* species are commonly found in container habitats typical of *Aedes* (*Stegomyia*) species and their high degree of association in this study, it is concluded that the normal prey of *T. splendens* in Singapore is *A. albopictus.* This is further supported by the frequent association of the two species in rural areas observed on many other occasions.

3. *Number of Prey Eaten:* The observed number of prey eaten per day varies from 3 to 6, 2 to 10, and 3 to 12 in the first three larval instars, averaging 4.6, 4.6 and 8.0 respectively (Table 3). The 4th instar consumes more prey per day, averaging 14, with a range of 3–27.

The observed number of prey eaten during each larval stage varies widely (Table 3), with a range of 5–15, 6–12, 22–60, and 61–113 in the 1st, 2nd, 3rd and 4th instars respectively. Feeding in all instars is irregular and discontinuous, especially towards the end of the larval phase.

Muspratt (1951) working on *T. brevipalpis* Theo., found that 100–200 *Aedes aegypti* larvae were killed during the predator's entire larval life. This shows that there is essentially no difference between the feeding capacity of the two *Toxorhynchites* species (Table 3).

4. *"Killing without Eating" Behaviour:* All larval instars of *T. splendens* were found to exhibit the behaviour of killing

TABLE 3.—Number of prey (*Aedes*) eaten.

Predator stage	No. exptd.	Average prey length (mm)	Average no. prey eaten	
			Per Day	Per Stage
1st instar	13	2.7	4.6	6.7
2nd instar	11	3.0	4.6	8.5
3rd instar	10	3.8	8.0	34.0
4th instar	26	5.8	13.7	83.9
Total prey eaten in predator's life time				133.1

their prey without eating the latter, typically just before and after ecdysis (Table 4), with this propensity being more evident after moulting than before, and most pronounced just before pupation (Table 4; Fig. 1). This behaviour which includes killing its own kind, is not confined to the 4th instar only, and not necessarily 'compulsive' in the old 4th instars as generally believed (Corbet, 1963; Laird, 1965) since some never killed, without eating, other mosquito larvae or their own kind.

This behaviour was also observed to be erratic and did not depend on prey numbers. Killing was observed to occur when from 5 to 40 prey were present and was exhibited about equally often in both sexes. This behaviour is probably a protective device to offset predation by its own kind during the particularly vulnerable period just before and after moulting, as was also remarked by Corbet & Griffiths (1963) for the 4th instar.

T. splendens *as a Biological Agent for* Aedes *Vectors: T. splendens* has several characteristics of a good biological agent. Its ability to destroy in the 4th instar an average of about 14 full-grown *Aedes* larvae per day, in an average-sized container, means that a whole population of *Aedes,* averaging 75 eggs per batch for *A. aegypti* (Macdonald, 1956), can be destroyed in less than a week.

The protective killing behaviour prior to and just after moulting, especially just before pupation, is equivalent to the effective use of insecticide on a pest population since it normally results in total or near total kill of the prey. This behaviour at the same time ensures that at least one individual survives the hazard of moulting and thus enables the predator species to maintain populations at a higher level than if it did not occur (Brinkhurst in Laird, 1965).

Another good quality of the predator is its ability to withstand hunger over long periods. As long as 30 days have been observed for full-grown 4th instars in the laboratory (pers. observations). This is long enough for three or four generations of the prey to elapse.

TABLE 4.—"Killing without Eating" behaviour in *T. splendens.*

Predator stage	No. exptd.	No. showing behaviour			Average no. *Aedes* larvae killed	
		Total	BM [a]	AM [a]	BM	AM
1st instar	14	4	1	3	1	1
2nd instar	15	4	1	3	1	1.3
3rd instar	15	11	2	10	6	1.6
4th instar	35	31	15	27	2.3	15.7

[a] BM=Before moult (0–3 days)
AM=After moult (0–3 days)

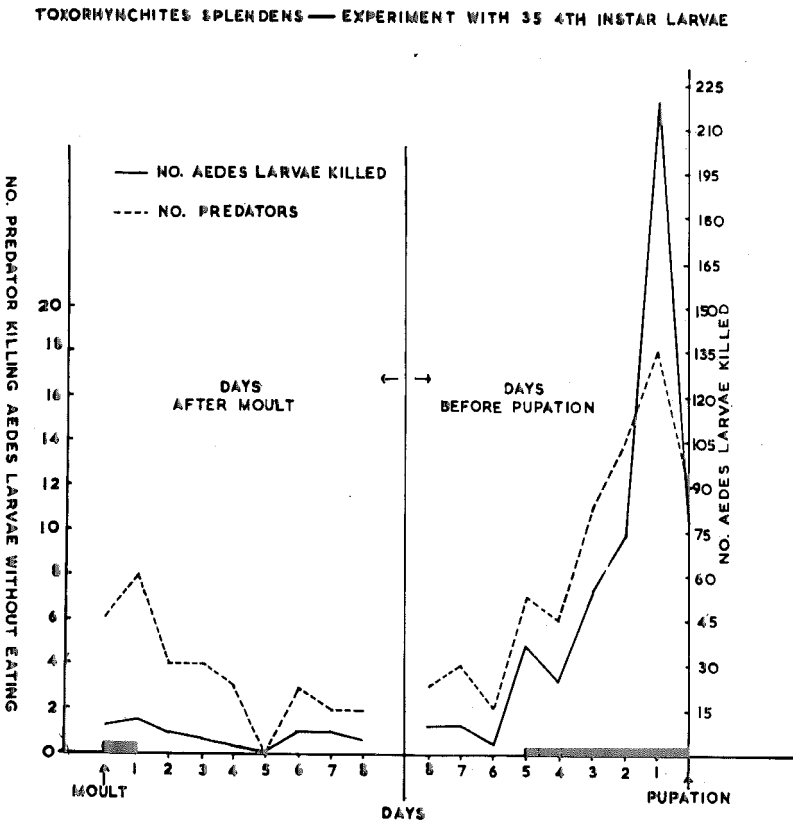

FIG. 1.—Graph showing "killing without eating" behaviour in *T. splendens*.

Yet another good quality of the predator is its lack of prey specificity. The ability to switch on to other kinds of prey when the normal prey is depleted or absent, is undoubtedly an important factor advantageous to the survival of the predator. Barr & Chellappah (1963) found the following mosquito genera to be associated with *T. acaudatus* (Leicester) in Singapore in *Nepenthes* cups: *Tripteroides, Aedes, Uranotaenia, Armigeres* and *Culex*. Undoubtedly most *Toxorhynchites* species have a similar wide range of prey.

From considerations of larval and adult biology, *T. splendens* can probably be most effectively utilized for the control of *Aedes albopictus* in rural areas and probably ineffective for *A. aegypti* in urban areas since it rarely occurs in populated areas due to its shy nature and dependence on nectar of wild flowers not normally found in urban areas.

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