INTEGRATED MOSQUITO MANAGEMENT IN DHAKA CITY: PROMISING NON-CHEMICAL COMPONENTS

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Abstract - Environmental alteration, habitat manipulation, introduction of predators appear as promising interventions for integrated mosquito management for Dhaka city. A survey of mosquito breeding grounds in 1994 showed 86.4% less larvae in drains with flowing water than stagnant drains, and 77.7% less in drains with guppy fish *(Poecilia reticulata)* than those without them. Lakes and ponds stocked with various fish species, had low average larval density (22 and 399/ m^2) compared to others (3,140-23,421/m^2). A 1996 survey of 2,456 larval habitats showed an average habitat index of 12.4, and on an average 10.7 larvae per positive habitat. Six fishes consumed on an average 10-700 larvae per individual in 24 hours; *Clarias batrachus* and *Oreochromis niloticus* consumed 2,180 and 398 larvae in only 2 hours. Among insects, 10 odonate nymphs consumed on an average 33 larvae and *Naucoris, Nepa* and *Ranatra* on an average 25 larvae in 24 hours. The vegetation cover in breeding grounds influenced larval population. A 25% cover with water hyacinth and duckweeds showed 62.7% less larvae in the former than the latter. Experiments with duckweeds showed a 40-100% reduction in oviposition due to duckweed cover. A decline in hatching, survival of immature stages, and adult emergence (16-52%) compared to the controls (57-69%) was observed; in case of full cover no larvae survived beyond second instar. A 6 week programme of clearing drains, seeding with guppy and use of Malariol oil B gave control for 3 months.
Key words - Habitat manipulation, fish predation, insect predation, duckweed

INTRODUCTION

Species diversity of mosquitoes in Dhaka city, the capital of Bangladesh, has decreased from 27 species in 1970 to only 5 in 1997, but the population of *Culex quinquefasciatus* Say has increased dramatically. Its proportion in the total mosquito population of Dhaka city increased from 18.2% in 1970 to 57.2% in 1979 and 69.6% in 1997 (Ameen and Moizuddin, 1973; Ameen *et al.*, 1982, 1984; Nazneen, 1997). The city with a population of nearly 7 million people dwelling in a 225-km^2 area (Dept. Geography, Univ. of Dhaka, 1994) has grown rapidly with an imbalanced city planning. Absence of a proper and/or adequate disposal of wastes, bad sanitary and drainage systems, haphazard city growth combined with resource constraints have contributed to the creation of many ideal mosquito breeding grounds, and consequent to it a very high density of mosquito populations. The water of these breeding grounds are becoming increasingly polluted, where *C. quinquefasciatus* breeds well but many other species cannot survive and therefore have been eliminated.

A laboratory study in Dhaka showed that at 27±1 ºC *C. quinquefasciatus* completes its life cycle in a little less than 10 days (Ameen and Moizuddin, 1975). Considering the lower temperature in the winter it was estimated that the species could complete 32 generations in a year in Dhaka city. However, actually 28 generations were obtained in a year (1984-85) in the laboratory of National Institute of Preventive and Social Medicine, Dhaka (Ameen, 1985). This indicates the great growth potential of the population of this species in urban centres of tropical and sub-tropical regions.

The Dhaka City Corporation spends about one million US dollar annually to purchase mosquito adulticides and larvicides. The total institutional sales of anti-mosquito insecticides in the country is estimated at 1.5 million US dollars. In addition to this, the annual sales of aerosols and mosquito coils to private citizens in the country is estimated at 14.2 and 79.6 million US dollars, respectively (M.A. Chowdhury, unpublished document). However, these have not resulted in adequate control and mosquito biting nuisance continues in spite of the huge spendings. Reluctance to acknowledge the fact that mosquito problem is essentially an environmental and ecological problem, the propensity to ignore the impor-

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Table 1. Comparison of mosquito larval density in contrasting conditions of the drains of Dhaka city during Oct.-Nov., 1994. (Source: Ameen *et al.*, 1994).

Drain type	No. observed) (% of total	No. sampled	Average density (no./m^2)	% proportion of the densities the contrasting conditions	% reduction of density between
Flowing and stagnant drains					
Flowing	515 (54.4%)	462	1,354	13.6%	86.4%
Stagnant	379 (40.1%)	325	9,926	100%	
Dry	52 (5.5%)				
Total	946	787			
Drains with and without guppy *(Poecilia reticulata)*					
With guppy	124 (15.8%)	124	1,067	22.3%	77.7%
Without guppy	663 (84.2%)	663	4,785	100%	
Total	787	787			

Table 2. Mosquito larval density in different types of permanent breeding ground in Dhaka city during Oct.-Nov., 1994 (Source: Ameen *et al.*, 1994).

Type of breeding ground	No. sampled	Estimated area covered (ha)	Density (no./m^2)	
			Average	Range
Derelict pond	260	93.9	11,283	0–286,950
Fish pond	166	54.6	391	0–5,165
Borrow pit	69	5.7	5,399	0–45,452
Beel	58	173.1	5,494	0–46,443
Lake	5	143.3	22	0–258
Housing plot	223	22.5	3,140	0–20,543
Shallow water	48	22.9	5,370	0–68,868
Others (Dolai Khal*)	25	14.6	23,421	0–261,698
Total	854	530.6		

* Remnant of a canal of this name; most of it now filled up.

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tance of mosquito bionomics, sole dependence on insecticides for mosquito control, and at the same time insufficient knowledge about their susceptibility status seem to be responsible for the failure of mosquito control programmes in the city (Ameen, 1994; Ali *et al.*, 1999).

Different studies in Dhaka showed that environmental alteration to reduce mosquito breeding grounds and introduction of predatory biocontrol agents like larvivorous fishes into breeding grounds are promising interventions for inclusion in an Integrated Mosquito Management (IMM) programme for Dhaka city. A review of these and some new works, and their possible role in mosquito control in urban centres like Dhaka city are presented and discussed in this paper.

MATERIALS AND METHODS

Surveys

A survey of mosquito breeding grounds of Dhaka city was undertaken during Oct.-Nov. 1994, which covered all the 90 Wards of the Dhaka City Corporation (DCC). All the mosquito breeding grounds were located and the larval habitats classified broadly into two groups: drains and other water bodies. The drains were further grouped as stagnant or flowing, and with or without guppy fish *(Poecilia reticulata* Peters). Larval habitats other than drains were classified into eight types (Table 2). Size of the water bodies and proportion of aquatic vegetation (floating and emergent, such as water hyacinth, duck-weed, *Ipomaea,* grasses, etc.) cover were recorded by eye estimation. A total of 946 drains and 854 water bodies were sampled during this survey covering a total water surface area of 530 ha (nearly 2% of the DCC area at the time of survey). Another monthly survey of the temporary breeding grounds in five areas of Dhaka city was conducted during Jan.- Dec. 1996; seven different types of temporary habitats were encountered (Table 4).

Larval sampling

Mosquito larvae from the permanent breeding grounds were collected following the standard method (Service, 1976) ; each sampling consisted of three dips; the average number of larvae per dip was converted to number per m^2. When the larval density was very high only one dip was taken. As for the temporary habitats, the accumulated water and larvae therein were collected in plastic jars except for plant pots and tree holes. The larvae from these two habitats were siphoned into the collection jars.

Larval rearing and predation

To ensure a steady supply of larvae during experiments on the effect of plant cover of the water surface and feeding by predators, colonies of *C. quinquefasciatus* were maintained in the laboratory following Ameen and Moizuddin (1975). Experiments were conducted to assess the rate of consumption (predation) by various larvivorous fishes and predatory aquatic insects. A single predator was placed in a glass jar (30 cm x 15 cm x 13 cm) half-filled with tap water. Counted number of *C. quinquefasciatus* larvae of different instars (1st to 4th) were introduced into the jars. The number was always more than what the predator could consume during the observation period. The predator was allowed to feed upon the mosquito larvae for 24 hours. However, in the case of the cat fish, *Clarius batrachus* (L.) and the nile tilapia, *Oreochromis niloticus* (L.), predation was observed for only 2 hours on each occasion because of their very high rate of consumption. Any dead larvae in the jar was not counted as consumed. A fresh supply of larvae was given for the following 24 hours. The test was thus repeated for five consecutive days. There were four replications for each predator.

Nuruzzaman (1988) experimented with three fishes , viz., guppy, *Nilotica* and *Channa punctata* (Bloch), where each of the four larval instars at densities varying from 5 to 320 were taken in test containers, covered with net to prevent the fish from jumping out. The consumption of larvae at each density level was observed for 1, 2, 3 and 24 hours; *Nilotica* and *Channa* for 1, 3 and 24 hours only. There were three replications, but five for guppy for each density. In another set of tests larvae of all the four instars were mixed and put together at densities of 20, 40 and 80 with three replicates for each. Five, 10 and 20

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Table 3. Mosquito larval density in breeding grounds with different aquatic vegetation cover. (Source: Ameen *et al.*, 1994).

Type of aquatic vegetation cover	Total area (ha)	Average density (no/m^2)	% proportion of the densities
With at least 25% cover of water hyacinth	161.4	4,282	100%
With at least 25% cover of duckweed	13.1	1,598	37.3
With less than 5% cover of floating vegetation	321.3	2,946	68.8

Table 4. Consolidated mosquito larval collection data from temporary habitats of five localities of Dhaka city during Jan.- Dec. 1996. (Compiled from Jasim Uddin, 1998).

Habitat	C.t.	C.s	E.p.	T.c.	P.p.	G.r.	T.h.*	Total
Total no. searched	264	60	144	960	900	47	81	2,456
No. positive with larva	72	12	89	77	9	12	33	304
Habitat Index (% of positive samples)	**27.3**	**20.0**	**61.8**	**8.0**	**1.0**	**25.5**	**40.7**	**12.4**
Mosquito species (no. collected)								
Aedes aegypti L.	93	17	200	182	10	39	56	597
Ae. albopictus Skuse	778	28	517	340	24	82	19	1788
Armigeres obturbans (Walker)	0	0	0	0	0	0	493	493
Culex quinquefasciatus Say	336	0	46	0	0	4	0	386
Total	**1,207**	**45**	**763**	**522**	**34**	**125**	**568**	**3,264**
% of total	37.0	1.4	23.4	16.0	1.0	3.8	17.4	
Average no. per positive habitat	16.8	3.8	8.6	6.8	3.8	10.4	17.2	10.7

C.t. = Cemented tank, C.s. = Cocoanut shell, E.p. = Earthen pot, T.c. = Tin can, P.p. = Plant pot, G.r. = Glass receptacle, T.h. - Tree hole.
* Tree holes up to shoulder height only were surveyed.

larvae of each instar were pooled together in the above densities. A control with no fish in each larval density with equal number of replicates was also maintained.

Effect of live duckweed cover on *C. quinquefasciatus* population

Effect of the extent of live duckweed cover on the water surface was assessed on two counts: oviposition and egg hatchability, survival of the immature stages and adult emergence. *Effect on oviposition***.** Four plastic bowls (12.5 cm dia.), each with 200 ml tap water were placed inside the mosquito rearing cage; 50 females were allowed to oviposit in each test. Three of the test bowls had duckweed, and the fourth without duckweed acted as control. The extent of surface cover in the three test bowls was different, one had full cover, the second half cover and the third scattered cover with duckweed. One-fourth of the quantity of a fully covered bowl was allowed to scatter in the covered bowl. The experiment was repeated seven times. The number of egg rafts laid in each of the bowls was recorded.

Table 5. Consumption of *C. quinquefasciatus* larvae by fishes. (Compiled from Hossain *et al.*, 1995-96.)

Fish species (Body length)	Average number of larvae of different instars consumed				
	I	II	III	IV	Average
2 hours predation					
Deshi magur, *Clarias batrachus* (L.) (16 cm)	3,143	2,646	1,583	1,357	2,182.3
Nilotica, *Oreochromis niloticus* (L.) (14 cm)	456	449	298	387	397.5
24 hours predation					
Climbing perch, *Anabas testudineus* (Bloch) (9 cm)	976.6	722.2	616.6	541.8	714.3
Colisha fasciata (Bloch & Schneider) (3.5 cm)	13.8	152.2	67.4	104.8	84.6
Snake heads;					
Channa striata (Bloch) (30 cm)	78.3	297.0	98.2	150.8	156.1
C. punctata (Bloch) (16 cm)	16.4	88.2	21.8	30.4	39.2
C. orientalis Schneider (=*C. gachua* Shaw & Shebbeare) (14 cm)	26.4	35.0	46.0	60.2	44.0
Mosquito fish/Guppy, *Poecilia reticulata* Peters:					
Small (0.6 cm)	25.4	9.4	4.2	0	9.8
Medium (1.8 cm)	34.6	25.2	9.8	29.5	24.8
Large (2.7 cm)	265.8	166.6	59.8	90.4	145.7

Effect on egg hatchability, survival of immature stages and adult emergence

These experiments were performed with 400 ml tap water in earthenware bowls (26.5 cm dia). Each test had one control and four treatments : full cover, three-fourths cover, half cover, and scattered cover. Five egg rafts were placed in each bowl. The number of hatched larvae, and subsequently the number of 2nd, 3rd, 4th instar larvae and pupae were also counted in each treatment and control. After pupation the pupae were transferred to the rearing cage in separate bowls. The number of adults that emerged was also recorded. There were four replication of the tests.

Duckweeds

Two duckweed species, *Lemna perpusila* Torrey and *Spirodela polyrhiza* (L.) Schlied, were used for the experiments. The duckweeds were collected from ponds, ditches and paddy fields in different areas of the city.

RESULTS

The data on mosquito larval density in the drains and permanent breeding grounds of Dhaka City are presented in Table 1 and 2, respectively. Larval density in breeding grounds with different floating vegetation cover are shown in Table 3. Table 4 shows the habitat index (percentage of habitats with mosquito larvae among the total surveyed) of the seven different temporary mosquito breeding habitats during the 1996 survey and mosquito species composition in them. Consumption data of different larval

Table 6. Consumption of different larval instars of *C. quinquefasciatus* in 24 hours by aquatic predatory insects in Dhaka (Compiled from Hossain *et al.*, 1995-96).

Species (body Length of the predator)	Average number of larvae of different instars consumed					
	I	II	III	IV	Average of the insters	Group average
Hemiptera nymph						24.9
Naucoris sp.: nymph (0.6 cm)	20.8	5.6	35.8	4.8	16.8	
Naucoris sp.: nymph (1.0 cm)	18.6	17.2	29.8	6.4	18.0	
Naucoris sp.: Adult (1.0 cm)	71.2	66.4	77.2	24.6	59.9	
Nepa sp. : (1.7 cm)	23.6	18.5	11.2	8.8	15.5	
Ranatra sp. : (4.2 cm)	22.0	20.2	10.8	4.6	14.4	
Odonata nymph :						
Zygoptera (Damselfly)						33.1
Agriocnemis sp. : (1.0 cm)	13.8	24.8	28.0	6.8	18.3	
Ischnura sp. : (1.5 cm)	51.4	45.2	33.3	20.0	37.5	
Ceriagrion sp. : (1.4 cm)	34.6	47.0	12.0	10.4	26.0	
Pseudagrion sp. : (1.6 cm)	24.4	57.6	36.6	22.8	35.4	
Anisoptera (Dragonfly)						
Pantala sp. : (1.0 cm)	48.0	46.2	30.0	20.8	36.3	
Rhodothemis sp. : (1.0 cm)	34.4	28.6	22.3	15.0	25.1	
Rhodothemis sp. : (1.7 cm)	59.0	55.4	48.2	31.7	48.6	
Neurothemis sp. : (1.2 cm)	32.5	26.6	19.9	14.2	23.3	
Neurothemis sp. : (1.4 cm)	55.3	48.2	45.8	38.2	46.9	
Urothemis sp. : (1.9 cm)	44.2	42.0	28.5	20.0	33.7	

Table 7. Effect of live duckweed cover on oviposition of *Culex quinquefasciatus.*

	Without any cover (control)	Sattered cover*	Half cover	Full cover
Lemna perpusila				
No. of egg rafts laid (Mean ± SD)	4.71 ± 1.80	1.0 ± 0.82	2.43 ± 1.62	0
PRDC	–	78.8%	48.4%	100%
Spirodela polyrhiza				
No. of egg rafts laid (Mean ± SD)	3.57 ± 1.27	1.71 ± 0.95	2.14 ± 1.46	0.2 ± 0.41
PRDC	–	52.1%	40.1%	91.9%

PRDC =Per cent reduction due to duckweed cover.
*One-fourth of the quantity of a fully covered bowl was allowed to scatter in this treatment.

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Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

instars of *C. quinquefasciatus* by aquatic predatory fishes during Jan. - Dec. 1982. experiments are presented in Table 5, and by predatory insects in Table 6. Experimental results on the effect of live duckweed cover on oviposition are presented in Table 7; and on egg hatchability, survival of immature stages and adult emergence are shown in Figs. 1 and 2, respectively for *Lemna perpusila* and *Spirodela polyrhiza*.

DISCUSSION

Mosquito larval density showed a 86.4% reduction in drains with flowing water compared to stagnant drains of Dhaka city (Table 1). Mosquito control by flushing stagnant water through landscape changes brought success in the U.S.A. in the past (Bates, 1949). Among the temporary habitats, the highest habitat index (61.8%) of mosquito larvae was found for earthen pots followed by tree holes (40.7%) and others. Contribution to the total larval population of these habitats was highest for cemented tanks (37.0%), followed by earthen pots (23.4%); other major contributors were tree holes and tin cans. The average number per positive site (habitat) was the highest (17.2) for tree holes, followed by cement tanks (16.7), glass receptacles (10.4), earthen pots (8.6), etc. (Table 4). Works of Basio (1971) in the Philippines, Soman (1977) in Banglore city, Khan (1980) in Dhaka, Ahmed *et al.* (1990) in four different areas of Bangladesh, and Schreiber (1992) in Florida, U.S.A. also showed the important contribution of the container breeding mosquitoes to the total mosquito population. Reduction of these sources is possible by 1) burying the throw away containers like earthen pots, tin cans, glass receptacles, coconut shells, etc.; 2) filling tree holes with soil and sealing them with cement; 3) replacing urban plantations with species that develops less holes, and 4) creating awareness among citizens about the danger of excess water in plant pots.

Drains with guppy showed a 77.7% reduction in larval population compared to those without guppy (Table 1). Among the permanent breeding grounds, lakes and fish ponds with a variety of fish species, had a remarkably lower larval density than that of the others (Table 2). Apparently consumption of mosquito larvae by fishes reduced the larval density. The use of fish as biological control agents for mosquitoes has been an increasingly used option (Gerberich, 1971; Chapman, 1976). Gerberich (1971) provided a bibliography key word index on the control of mosquitoes by the use of fish for the years 1904-1968. Nuruzzaman (1998) reviewed some of the works from 1919 to 1997 on predation of mosquito larvae by fish.

Some of the surface feeding fish would be good larval predators. The relative size of the larval stage, and the feeding niche of the predator would determine the efficiency of predation. Data on Table 6 support this statement. Small guppy (0.6 cm) consumed more of the 1st instar larvae ; its consumption of later instar larvae was less and nil for the 4th instar, whom it was unable to capture. As the size of the guppy increased (1.8 cm and 2.7 cm) their consumption also increased and included the 4th instar also. Nuruzzaman (1998) showed experimentally that *P. reticulata* and *O. niloticus* prefer earlier instar larvae in presence of all the other instars; *C. punctata* showed a preference for the later instars (3rd and 4th) than the earlier ones. Among the snakeheads, rate of larval consumption was more in *C. striata* (Bloch) than the other two species (Table 6). In nature *C. striata* is seen to move near the surface and feed at the surface; whereas *C. orientalis* Schneider and *C. punctata* live below the surface and near the bottom for most of the time.

Aquatic insects like the hemipteran *Naucoris, Nepa, Ranatra,* as well as damselfly and dragonfly nymphs predate on mosquito larvae and play a role in their natural control. The average of the four larval instars consumed was c. 25 (15-60) by the above aquatic bugs, and c. 33 (18-49) by odonate nymphs, respectively (Table 6).

The extent of floating vegetation cover on the water surface seem to influence mosquito larval population; c. 25% cover with duckweed had 62.7% lesser larval population than a similar cover with water hyacinth (Table 3). Experiments with duckweeds showed a reduction in oviposition by 48.4% and 78.8%, respectively due to half cover and scattered cover of *L. perpusilla*, and no oviposition in case of complete cover. Similar, but lesser reduction was observed in experiments with *S. polyrhiza* (Table 7).

The effect of duckweed cover on egg hatching and survival of immature stages was manifested in a sharp decline in survival from egg hatching to adult emergence compared to the control (without any cover); in case of full cover no larva could reach the third instar, all of them died (Figures 1 and 2).

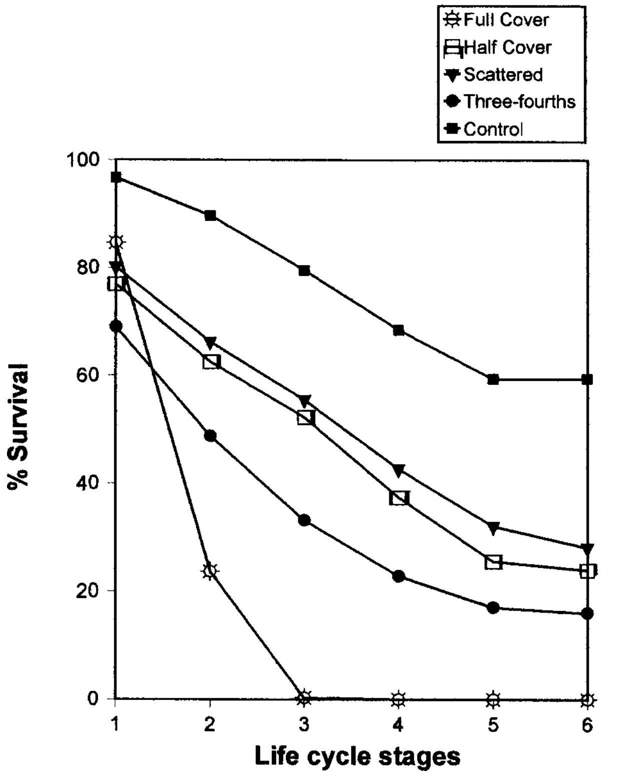

Figure 1. Line diagrams showing the effect of surface cover of *Lemna perpusila* Torrey on the hatchability, survival of immature stages and adult emergence of *Culex quinquefasciatus* Say in earthhenware bowls.

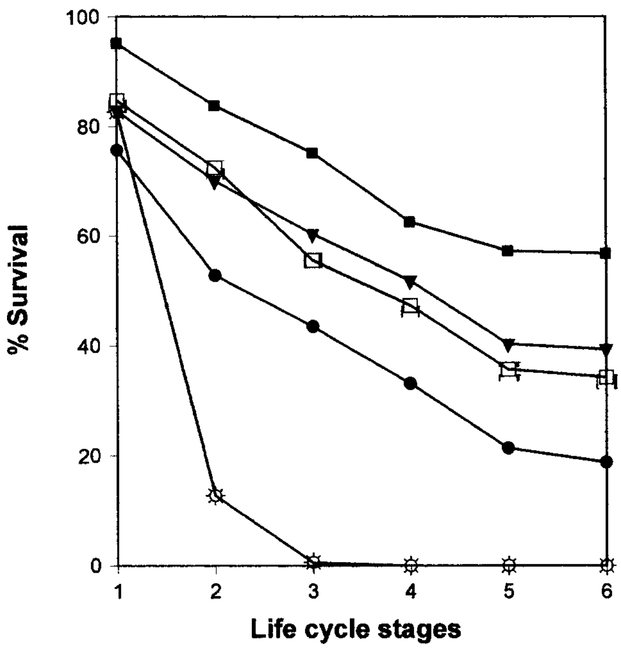

Figure 2. Line diagrams showing the effect of surface cover of *Spirodela polyrhiza* (L.) Schlied, on the hatchability survival of immature stages and adult emergence of *Culex quinquefasciatus* Say in earthhenware bowls.

Legends (X Axis)

1 - 1st instar (egg hatching), 2 - 2nd instar, 3 - 3rd instar, 4 - 4th instar, 5 - pupa, 6 - Adult emergence

An annotated list and bibliography of papers dealing with plants in relation to mosquito including plants that cover the water surface and control larvae was provided by Jenkins (1964). Other reports on duckweeds reducing mosquito population are many, e.g., Porges and Mackenthum (1963), Sjorgen (1968), Furlow and Hayes (1972), Cully and Epps (1973), Lin (1986), Rajendran and Reuben (1991), Ansari and Sharma (1991), Eid *et al.* (1992). Roy (1998) reviewed some of the related literature from 1902 to 1992.

The discussion suggests that: 1) seeding of drains and permanent water bodies with suitable larvivorus fish species, 2) removal of water hyacinth from urban water bodies, and 3) replacing them with duckweed to prevent recurrence of water hyacinth would be good control interventions in addition to the habitat manipulations, mentioned earlier, as part of IMM programme with less dependence on chemical pesticides. In Dhaka city a 6-week programme of cleaning drains, seeding them with guppy and use of Malariol B gave good mosquito control for 3 months.

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