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FOOD PREFERENCE OF GOLDFISH (*CARASSIUS AURATUS* (LINNAEUS, 1758)) AND ITS POTENTIAL IN MOSQUITO CONTROL

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Abstract: Ornamental fishes are the most popular pets in present day world. Among these ornamental fishes, gold fish (*Carrasius auratus* (Linnaeus, 1758)) is the most admired ornamental fish through out the world and also in India.
Most of the fish farmers associated with ornamental fish trade in India are engaged in captive culture of gold fishes. Supply of suitable food during culture period is the most vital factor to achieve good growth and survival of gold fish, but proper knowledge regarding the most preferable food of gold fish is lacking. On the other hand, age-specific food preference in some fishes has been reported earlier. So, in the present study gold fish was selected to determine its food preference and experiment was also conducted to discern any age-specific food preference of gold fish. Previous works have considered gold fish as consumer of mosquito larvae but its potential as mosquito biocontrol agent has not been studied so far. So, the potential of gold fish as mosquito biocontrol agent was also studied.
From the experiment, it has been observed that gold fish has significantly higher preference for live food than artificial food, more preferably for chironomid larvae. Gold fish has significantly higher mosquito larvae consumption rate than same aged guppy and *Aplocheilus sp*. under same hydrological parameter was also observed.
So, from this study it can be concluded that supply of live food more preferably the chironomid larvae could be beneficial to get good growth and survival of gold fish in captive culture. As from this study it has also been observed that gold fish has significantly higher mosquito larvae consumption rate than popular larvivorous fishes, so in near future gold fish can not only be used as ornamental fish but also as an efficient mosquito biocontrol agent.

Key Words: Gold fish – different age groups – food preference – mosquito biocontrol
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Introduction

Ornamental fishes are attractive and colorful species of fishes with peaceful nature (Jayasankar, 1998; Mukherjee *et.al.* 2000; Singh and Ahmed, 2005) and they are the most popular pets in present day world (Singh, 2005). Ornamental fish keeping is emerging as one of the most popular hobbies across the world next to photography (Nayar, 1996; Kurup, 2003; Das *et.al.* 2005; Singh and Ahmed, 2005). Among these fishes, gold fish (*Carassius auratus*, Linnaeus) is the most popular one throughout the world and also in India.

Food is the most important and vital factor for the growth and survival of the living beings on the face of the earth (Islam, 2004) and feeding is the dominant activity of the entire life cycle of fish (Royce, 1972). The success on good scientific planning and management of fish species largely depends on the knowledge of their biological aspects, in which food and feeding habits include a valuable portion (Joadder, 2006). Proper knowledge about food preference, especially the first food of fish larvae is vital for achieving good survival rates during fish culture (Ghosh *et.al.* 2003). In general, literature on the food habits of fishes is scanty (Mitra *et.al.* 2006) and thus scientific information regarding food preference of gold fish is also lacking.

The use of larvivorous fishes is the oldest and presently the most popular biological method for eliminating or reducing mosquito larvae population (Hess & Tarzwell, 1942; Krumholtz, 1948; Hoy *et al.*, 1971,1972; Hurlbert *et al.*, 1972; Chapman, 1974; Tabibzadeh *et al.*, 1977; W.H.O., 1980, 1982; Nasir, 1979a, b; Walter & Legner, 1980; Wurtsbaugh *et. al.*, 1980; Zaman, 1980; Pant *et. al.*, 1981; Ahmed & Isfaq, 1982; Haas, 1984; Haas & Pal, 1984; El Safi *et al.*, 1985; Gratz and Pal, 1988; Blaustein, 1989, 1992; Castleberry & Cech, 1990; Fletcher *et al.*,1993; Homski *et al.*, 1994; Morgan and Buttemer, 1996; Frenkel and Goren, 1997, 2000; Raghavendra and Subbarao, 2002; Mohamed, 2003; Ghosh *et.al.* 2005; Yildirim and Karacuha,2007) and more than 253 fish species have been considered for mosquito biocontrol (Gerberich and Laird, 1985). Among these larvivorous fishes, mosquito fish (*Gambusia sp.*) and guppy (*Poecilia sp.*) are most popular throughout the world and even for more than 100 years mosquito fish has been used as a mosquito biocontrol agent throughout the world (Walton, 2007). In India, mosquito fish and guppy have been successfully utilized as the mosquito biocontrol agent for a long time (Menon and Rajagopalan, 1978; Rao *et. al.* 1982; Das and Prasad, 1991; Haq *et. al.* 1991; Gupta *et. al.* 1992; Prasad *et.al.* 1993; Dua and Sharma, 1994; Hati and Saha; 1994; Sharma, 1994; Rajnikant *et.al.* 1996; Chatterjee and Chandra, 1997; Singaravelu *et.al.*1997) and to some extent *Aplocheilus sp.* has also been used for this purpose (John, 1940; Job, 1941, Kumar *et.al.* 1998). Earlier works (Chatterjee *et.al.* 1997; Chandra *et.al.* 2008) have considered gold fish as a good consumer of mosquito larvae.

Information regarding age specific food preference of gold fish on different food items and the potential of gold fish as mosquito biocontrol agent is deficient.

Therefore the first part of our work destined to study about the age specific food preference of gold fish between live and artificial food. This study will not only provide the information about food preference of gold fish but will also suggest which food item will be beneficial for gold fish culture in captivity. The second part of our work designed to know the potential of gold fish as an effective mosquito biocontrol agent comparative to the common larvivorous fishes utilized so far in India.

Materials and Methods

Collection and Acclimatization of Fish

Goldfish of three different age groups [2 months (29-36 mm); 3 months (41-46 mm) and 4 months (58-62 mm) old] were collected from Joynagar Fish Farm and then were taken to the laboratory using oxygen packs. Three age groups were kept separately in 5 L glass tanks at a density of 6 fish/tank with proper aeration, similar photoperiod (14 L: 10 D) and temperature (27 ± 2º C). They were then acclimatized to laboratory condition for one week and were supplied with commercial feed.

As earlier works (Arthington and Lloyd 1989; Meffe and Snelson 1989; Rupp 1996; Gratz *et al.* 1996; Morgan and Buttemer, 1996) have revealed the negative impacts of mosquito fish on non-target organisms and natural ecosystems, so mosquito fish was not considered rather guppy and *Aplocheilus* sp. were selected to compare the mosquito biocontrol efficiency of gold fish in our experiment. For this purpose Guppy (29-33 mm) and *Aplocheilus* sp. (32-35 mm) of 4 months old were taken from our lab-reared batch and they were also kept in separate 5 L: glass tanks at a density of 6 fish/ tank with the same laboratory condition as provided to the gold fishes.

Collection of the Foods

The larvae of *Culex sp.* were collected from sewage drain near the University campus and then to collect the stage IV instar (5.2-6.3 mm), the heterogeneous larval population was repeatedly sieved with tap water. They were then kept in enamel trays and supplied with proper amount of food *ad libitum*. By dredging the bottom mud from the same sewage drain the chironomid larvae (*Chironomous* sp.) were collected and then the collected larvae were kept in enamel trays. Chironomid larvae of stage IV instar (10-12 mm) were collected from the lot. Standard artificial food (Tokyu, granulated form, diameter 1.3 ± 0.37 mm) was brought from the local aquarium shop for feeding experiment.

Experimental Setup

Experiment I: Age specific food preference of gold fish between live and artificial food.

This experiment was conducted in three parts.

The first part of the experiment was designed to know the age specific preference of gold fish for individual food item when foods were supplied separately. For this experiment, individual gold fishes of each of the three different age groups were kept separately in 5 L glass tanks at the density of one fish /tank. The fishes were held in the tanks for 24 hours prior to the commencement of the experiment and were kept without food to standardize hunger level. Each of these fishes was then provided daily with 300 mosquito larvae for the first seven days, with 300 chironomid larvae for next seven days and with 300 Tokyu granules for the last seven days. For each day, after one hour of supply of the food item, the remaining amount of each food item was counted. This experiment was conducted in three replicates for each set up. Figure 1 summarizes the result. Results have been represented as mean ± SD.

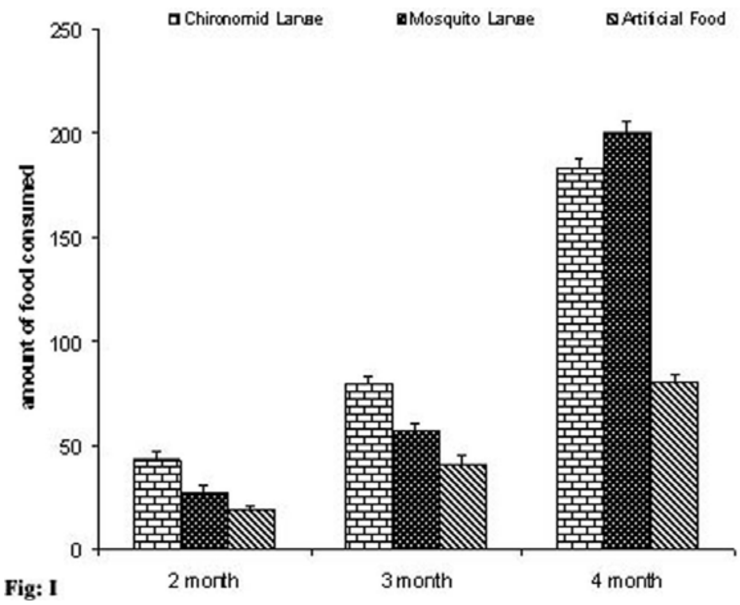

Figure 1: Food consumption rate of three different age groups of gold fish for three different food items when supplied separately.

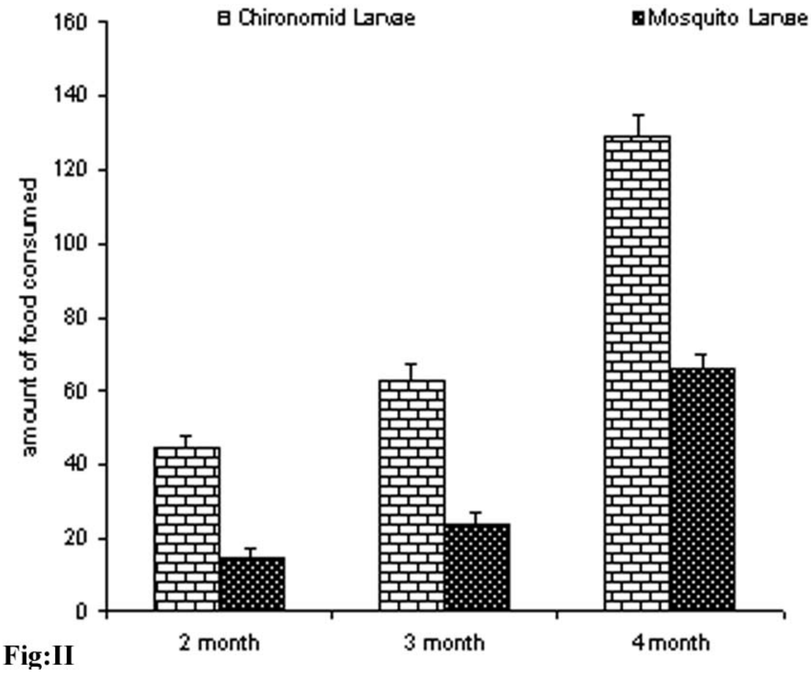

Fig:II

Figure 2: Food preference between Chironomid larvae and Mosquito larvae among three different age groups of gold fish when food items were supplied together at the same time.

The second part of the experiment was designed to know the age specific preference of gold fish between the two live food items (mosquito larvae and chironomid larvae) when the two food items were supplied together. For this experiment, individual gold fishes of each of the three different age groups were kept separately in 5 L glass tanks at the density of one fish /tank. The fishes were held in the tanks for 24 hours prior to the commencement of the experiment and were kept without food to standardize hunger level Each of these fishes were then supplied with equal amount (300 in number each) of mosquito larvae and chironomid larvae together at the same time. After 1 hour, the remaining amount of each food item was counted. This experiment was conducted in three replicates for one week. Figure 2 summarizes the result. Results have been represented as mean ± SD.

The third part of the experiment was designed to know the age specific preference of gold fish between the most preferred live food (as observed in the second part of the experiment) and artificial food. For this experiment, individual gold fishes of each of the three different age groups were kept separately in 5 L glass tanks at the density of one fish /tank. The fishes were held in the tanks for 24 hours prior to the commencement of the experiment and were kept without food to standardize hunger level. Each of these fishes was supplied with equal amount (300 in number each) of chironomid larvae and Tokyu granules together at the same time. After 1 hour, the remaining amount of each food item was counted. This experiment was conducted in three replicates for one week. Figure 3 summarizes the result. Results have been represented as mean ± SD.

Experiment II: Comparative study on mosquito larvae consumption rate between gold fish and two other larvivorous fishes.

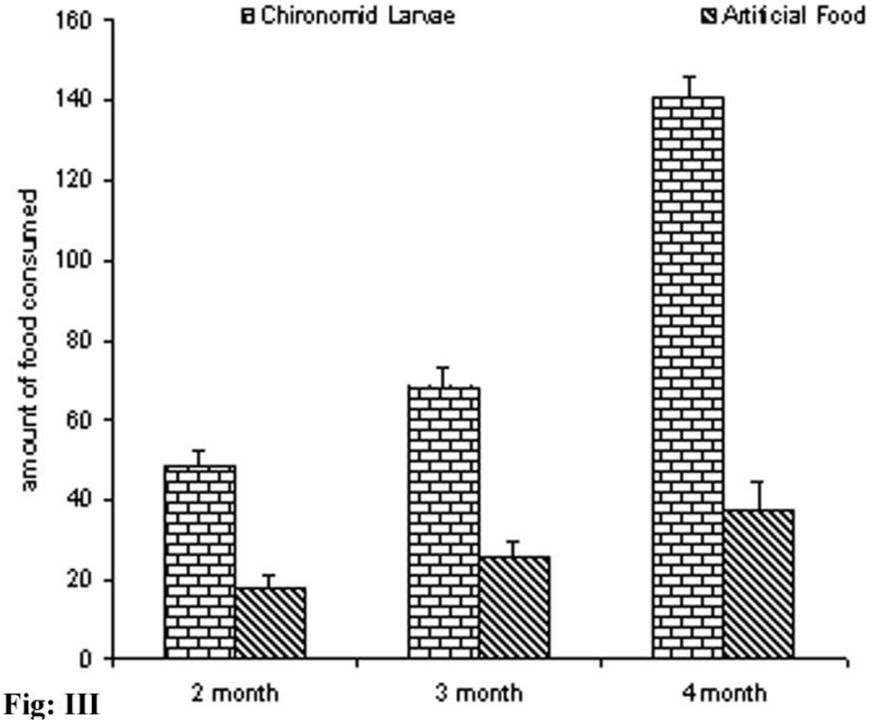

Fig: III

Figure 3: Food preference between Chironomid larvae and Artificial food among three different age groups of gold fish when food items were supplied together at the same time.

Gold fishes of 4 months old and 4 months old lab reared wild guppy and *Aplocheilus* sp. were kept separately in 5 L glass tanks at the density of one fish /tank. The fishes were held in the tanks for 24 hours prior to the commencement of the experiment and were kept without food to standardize hunger level. Each of these fishes was then provided with 300 mosquito larvae at the same time. After 1 hour, the remaining amount of unconsumed mosquito larvae was counted. This experiment was conducted in three replicates for one week. Table 1 and Figure 4 summarize the result. Results have been represented as mean ± SD.

Statistical Analysis

For the first experiment, two-way ANOVA was followed for two source of variance viz. age of gold fish and food types for each day of observation. Pooled ANOVA technique repeated over days was also followed to describe in detail about the age of gold fish vs means of food item consumed if found significant. Such comparison was made using LSD test at 1% level of significance.

For the second experiment, day wise and indifferent of days the mean consumptions along with standard error of means were calculated. One-way ANOVA for each day of study and pooled ANOVA repeated over days for mean comparison were followed with post hoc test viz. Duncan’s test at 5% level of significance.

Results and Discussion

The first experiment was conducted to know about the age specific food preference of gold fish between live and artificial food.

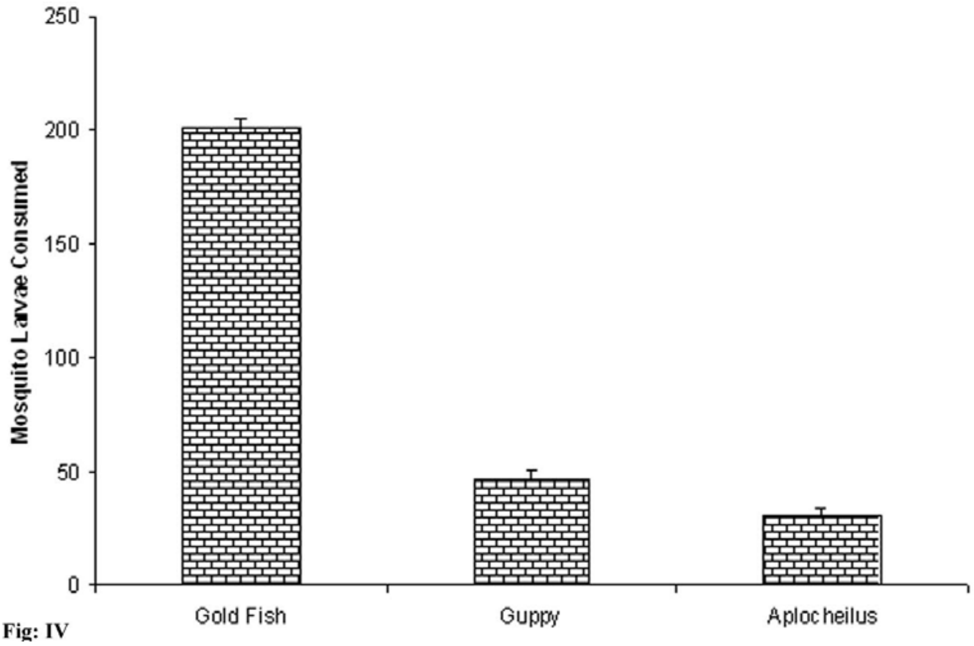

Fig: IV

Figure 4: Mean consumption rate of mosquito larvae in one hour by same aged gold fish, guppy and *Aplocheilus* sp.

Name of the Fish	Daily Consumption Rate (mean ± SD)						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Gold Fish	197 ± 5.29 [a]	203 ± 5.29 [a]	201 ± 3.00 [a]	210 ± 7.21 [a]	198 ± 2.64 [a]	201 ± 2.64 [a]	196 ± 1.73 [a]
Guppy	51 ± 2.64 [b]	45 ± 2.64 [b]	48 ± 3.00 [b]	52 ± 2.64 [b]	42 ± 2.00 [b]	45 ± 4.58 [b]	43 ± 3.00 [b]
Aplocheilus sp.	35 ± 2.64 [c]	29 ± 4.00 [c]	33 ± 4.00 [c]	27 ± 4.58 [c]	30 ± 2.64 [c]	32 ± 4.36 [c]	33 ± 4.58 [c]

Table 1: The mean daily consumption rate of mosquito larvae by three different fishes. Values (mean ± SD) with different subscripts in the same row are significantly different at the 5% level.

In the first part of the experiment, when the three types of food items were supplied separately to three different age groups of gold fish, 2 months and 3 months old gold fish always showed significantly ($P < 0.01$) higher preference for chironomid larvae and mosquito larvae than artificial food. On the other hand, although 4 months old gold fish showed significantly ($P < 0.01$) higher preference for mosquito larvae than chironomid larvae but overall it's preference for live food was significantly ($P < 0.01$) higher than artificial food. (Figure 1).

In the second part of the experiment, when chironomid larvae and mosquito larvae were supplied together to the three different age groups, all the three age groups showed significantly ($P < 0.01$) higher preference for chironomid larvae than mosquito larvae (Figure 2).

In the third part of the experiment, when chironomid larvae and artificial food were supplied together to the three different age groups, all the three age groups showed significantly ($P < 0.01$) higher preference towards chironomid larvae than artificial food (Figure 3).

So from the first experiment it is comprehensible that all the three age groups of gold fish have significantly higher preference for live food than that of the artificial food. Hence, during captive culture, the supply of live food will be more beneficial than the artificial food to get better growth and survival of the gold fish. Among the two live food supplied in the experiment, chironomid larvae was consumed with significantly higher preference than mosquito larvae by both the 2 months and 3 months old gold fish The 4 months old gold fish also has shown significantly higher preference for chironomid larvae when supplied along with mosquito larvae. So, all the three age groups have shown high preference for chironomid larvae. Nibbling behaviour is very common for gold fish and they mainly prefer to take food from benthic environment. Meanwhile, chironomid larvae are benthic in nature, (Real *et.al.* 2000; Bat and Akbulut, 2001; Titmus and Badcock, 2006; Őzkan, 2006) whether mosquito larvae are surface breather, most of the times stay at water surface and have fast wriggling behaviour than chironomid larvae. Thus it is easier for gold fish to prey on chironomid larvae than mosquito larvae. On the other hand, Őzkan (2006) has reported that chironomid larvae contain good amount of protein and are easily and quickly digestible. So, supply of chironomid larvae will be more beneficial than mosquito larvae during the captive culture of gold fish.

Result of the second experiment (Table 1; Figure IV) has revealed that indifferent of day and even for each day, gold fish has significantly ($P< 0.05$) higher consumption rate for mosquito larvae than the same aged guppy and *Aplocheilus* sp. under same hydrological parameters [Temperature 27 ± 2 ºC; pH 7.3; DO 4.42 ±1.37 mg/L]. Previous works (Job, 1941a, Menon and Rajagopalan, 1978, Elias *et.al.* 1995, Chatterjee and Chandra, 1997) have revealed that the consumption rate of mosquito larvae for adult guppy is in between 32-53.1 larvae/ day and for *Aplocheilus* sp. is about 136 larvae/day. So, the present work is illustrating the suitability of gold fish as a mosquito biocontrol agent comparative to the two popular mosquito biocontrol agents of India.

Meanwhile biological control of mosquito by larvivorous fishes has proven to be successful in stable water bodies, usually in good water quality condition (Nasir, 1979a, 1979b; Ahmed & Isfaq, 1982), however the problem of mosquito nuisance is mainly associated with polluted water with almost anoxic condition and with toxic metabolites (Mortenson, 1982; Schaefer *et al.,* 1985; Carlson *et al.,* 1986; Houston *et al.,* 1989). The three major criteria for a fish to be used as mosquito biocontrol agent are – first of all it should be with high predation efficiency of mosquito larvae, secondly, should be resistance to anoxic condition including high tolerance to insecticides and last but not the least it should have high reproductive potential (Pant *et.al.* 1981). Gold fish is extremely tolerant to environmental stress (Abramenko *et.al*. 1997), including high levels of turbidity and fluctuations in pH and temperature (Spotila *et.al.* 1979; Balon, 2004). Moreover, the species is highly tolerant to water pollution (Abramenko *et.al.*1997) and can cope up with low levels of dissolved oxygen, even for prolonged periods (several months at 2 °C) of total anoxia (Walker and Johansen, 1977; Van den Thillart, 1983). It has high tolerance to heavy metals or organochlorine insecticides (Szczerbowski and Szczerbowski, 2002). On the other hand, gold fish have high fecundity (Kuznetsov, 2004). Thus, earlier observations suggesting the suitability of gold fish to be used as mosquito biocontrol agent even in polluted water bodies. Most of the common larvivorous fishes are not with attractive appearance; so people are less interested to keep these fishes in their home ornamental pools or waterlogged places to control mosquito population, but as gold fish has a high preference as an ornamental fish, in near future it can be popularize as an efficient mosquito biocontrol agent throughout the world.

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References

Abramenko MI, Kravchenko OV, Velikoivanenko AE (1997) Population genetic structure of the goldfish *Carassius auratus gibelio* diploid-triploid complex from the Don River Basin. *Journal of Ichthyology*. **37**: 56–65.

Ahmed YA, Isfaq A (1982). Field trial on the impact of *Oreochromis spilurus spilurus* on malaria transmission in northern Somalia. W.H.O. EM/MAL/191 EM/SOM/MPD/OO1/ RB, 25 pp.

Arthington AH, Lloyd LN (1989). Introduced poeciliids in Australia and New Zealand. In: Meffe GK, Snelson FF Jr., eds. Ecology and evolution of livebearing fishes (Poeciliidae). Englewood Cliffs, NJ: Prentice Hall. p 333–348.

Balon EK (2004) About the oldest domestics among fishes. *Journal of Fish Biology*. **65** (Supplement A): 1–27

Bat L, Akbulut M (2001). Studies on sediment toxicity bioassays using *Chironomous thumni* K., 1911 larvae. *Turkish Journal of Zoology*. **25**: 87-93

Blaustein L (1989) Spatial distribution of *Anopheles freeborni*, *Gambusia affinis* and *Lepomis cyanellus* in experimental rice plots. *Journal of American Mosquito Control Association*. **5**: 254-257.

Blaustein L (1992) Larvivorous fishes fail to control mosquitoes in experimental rice plots. *Hydrobiologia*. **232**: 219- 232.

Carlson DB, Vigliano RR, Wolfe GL (1986) Distribution of mosquitoes in different wastewater stages of secondarily treated domestic effluent and untreated citrus wastewater. *Journal of American Mosquito Control Association*. **2**: 516-521.

Castleberry DT, Cech JJ (1990) Mosquito control in wastewater: a controlled and quantitative comparison of pupfish (*Cyprinodon nevadensis amargosae*), mosquito fish (*Gambusia affinis*) and guppies (*Poecilia reticulata*) in Sago pondweed marshes. *Journal of American Mosquito Control Association*. **6**: 223-228.

Chatterjee SN, Chandra G (1997) Laboratory trials on the feeding pattern of *Anopheles subpictus*, *Culex quinquefasciatus* and *Armigeres subalbatus* larvae by *Gambusia affinis*. *Science and Culture*. **63:** 51-52.

Chatterjee SN, Das S, Chandra G (1997) Gold fish (*Carrasius auratus*) as a strong larval predator of mosquito. *Transactions of the Zoological Society of India*. **1**(1): 112-114.

Chandra G, Bhattacharjee I, Chatterjee SN, Ghosh A (2008) Mosquito control by larvivorous fish. *Indian Journal of Medical Research*. **127**: 13-27

Chapman HC, (1974) Biological control of mosquito larvae. *Annual Review of Entomology*. **19**: 33-59.

Das MK, Prasad RN (1991) Evaluation of mosquito fish *Gambusia affinis* in the control of mosquito breeding in rice fields. *Indian Journal of Medical Research;* **72:** 214-217.

Das M, Sarma S, Das AK (2005) Status of Ornamental Fishes of Assam. *Fishing Chimes*.**25** (3): 13-15

Dua VK, Sharma SK (1994) Use of guppy and *Gambusia* fishes for control of mosquito breeding at BHEL industrial complex, Hardwar (U.P.). In: Sharma VP, Ghosh A, editors. *Larvivorous fishes of inland ecosystems*. *Proceedings of the MRC-C/CFRI workshop,* New Delhi, 27–28 September 1989. Delhi: Malaria Research Centre (ICMR), p. 35–45.

Elias M, Islam MS, Kabir MH, Rahman MK (1995) Biological control of mosquito larvae by guppy fish, *Bangladesh Medical Research Council Bulletin*. **21**(2): 81-86

El Safi SH, Haridy AAM, Rabaa FMA (1985) The food of the larvivorous fish *Gambusia affinis* (Baird and Girard) and *Oreochromis* (formerly Tilapia) *niloticus* (Linnaeus) in Gezira irrigation canals. *The Journal of Tropical Medicine and Hygiene*. **88**: 169-174.

Fletcher M, Teklehaimanot A, Yemane G, Kassahun A, Kidane G, Beyene Y (1993) Prospects for the use of larvivorous fish for malaria control in Ethiopia; search for indigenous species and evaluation of there feeding capacity for mosquito larvae. *The Journal of Tropical Medicine and Hygiene*. **96**: 12–21.

Frenkel V, Goren M (1997) Some environmental factors affecting the reproduction of *Aphanius dispar* (Rűppell. 1828). *Hydrobiologia*.**347**: 197–207.

Frenkel V, Goren M (2000) Factors affecting growth of killifish, *Aphanius dispar*, a potential biological control of mosquitoes. *Aquaculture*. **184**: 255–265.

Gerberich JB, Laird M (1985) Larvivorous fish in the biocontrol of mosquitoes, with a selected bibliography of recent literature. In: Laird M, Miles JW, eds. Integrated mosquito control methodologies. Vol. 2. Biocontrol and other innovative components and future directions. London: Academic Press. p 47–76.

Ghosh A, Mahapatra BK, Datta NC (2003) Ornamental Fish Farming- Successful Small Scale Aqua Business in India. *Aquaculture Asia*. **VIII** (3): 14-16

Ghosh SK, Tiwari SN, Sathyanarayan TS, Sampath TR, Sharma VP, Nanda N. Joshi H, Adak T, Subbarao S (2005) Larvivorous fish in wells target the malaria vector sibling species of the *Anopheles culicifacies* complex in villages in Karnataka, India. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. **99**: 101-105.

Gratz NG, Pal R (1988) Malaria vector control: larviciding. In: Wernsdorfer WH, McGregor I, editors. *Malaria: Principles and practice of malariology*. Edinburgh, UK: Churchill Livingstone; p. 1213-1226.

Gratz NS, Legner EF, Meffe GK, Bay EC, Service MW, Swanson C, Cech JJ Jr., Laird M (1996) Comments on ''Adverse assessments of *Gambusia affinis.'' Journal of American Mosquito Control Association*. **12**:160–166.

Gupta DK, Bhatt RM, Sharma RC, Gautam AS, Rajnikant (1992) Intradomestic mosquito breeding sources and their management. *Indian Journal of Malariology*. **29**: 41-46.

Haq S, Prasad H, Prasad RN (1991) Culture of Gambusia affinis with food fishes. *Indian Journal of Malariology*. **28**:201–206.

Haas R (1984) Guide for preliminary identification of some larvivorous fish. W.H.O. VBC/84.1, 44 pp.

Haas R, Pal R (1984) Mosquito larvivorous fishes. *Bulletin of Entomological Society of America*. **30:** 17-25.

Hati AK, Saha DC (1994) *Poecilia reticulata* as a predator of *Culex quinquefasciatus* larvae in surface drains in Calcutta outskirts. In: Sharma VP, Ghosh A, editors. *Larvivorous fishes of inland ecosystems*. *Proceedings of the MRCCICFRI workshop,* New Delhi, 27–

28 September 1989. Delhi: Malaria Research Centre (ICMR), p. 196–203.

Hess AD, Tarzwell CM (1942) The feeding habits of *Gambusia affinis affinis* with special reference to the malaria mosquito, *Anopheles quadrimaculatus*. *American Journal of Hygiene*. **35**: 142-151.

Homski D, Goren M, Gasith A (1994) Comparative evaluation of the larvivorous fish *Gambusia affinis* and *Aphanius dispar* as mosquito control agents. *Hydrobiologia*. **284**: 137–146.

Houston BN, Dancer BN, Learner MA (1989) Control of sewage filter flies using *Bacillus thuringiensis var. israelensis* I. Acute toxicity tests and pilot scale trials. II. Full scale trials. *Water Research*. **23**: 369-385.

Hoy JB, O'Berg AG, Kauffman EE (1971) The mosquito fish as a biological control agent against *Culex tarsalis* and *Anopheles freeborni* in Sacramento Valley rice fields. *Mosquito News*. **32**: 146–152.

Hoy JR, Kauffman EG, O'Berg AG (1972) A large-scale field test of *Gambusia affinis* and Chlorpyrifos for mosquito control. *Mosquito News*. **32**: 161-171.

Hurlbert SH, Zedler J, Fairbanks D (1972) Ecosystem alteration by mosquitofish (*Gambusia affinis*) predation. *Science*. **175**: 639-641.

Islam MN (2004) Eco-biology of Freshwater Gobi, *Glossogobius giuris* (Hamilton) of the River Padma in Relation to its Fishery: A Review. *Journal of Biological Sciences*. **4**(6): 780-793.

Jayasankar P (1998) Ornamental fish culture and trade: current status and prospects. *Fishing Chimes*. **17**(12): 9-13

Joadder MAR (2006) Food and feeding habits of *Gagata youssoufi* (Rahman) from the river Padma in Rajshahi. *University Journal of Zoology. Rajshahi University*. **25**: 69-71

Job TJ (1941a) Efficiency of the killi fish, *Aplocheilus panchax* (Ham.) in the control of mosquitoes. *Proceedings of the National Institute of Sciences of India*. **7**(3): 317-350

John CC (1940) Observations on the Utility of *Aplocheilus lineatus* (Cuv. And Val.) for Mosquito Control. *Journal of the Malaria Institute of India*. **3**: 67-80.

Krumholtz R (1948) Reproduction in the western mosquitofish *Gambusia affinis* and its use in mosquito control. *Ecological Monographs.* Durham, North Carolina. **18**: 1-43.

Kumar A, Sharma VP, Sumodan PK, Thavaselvam D (1998) Field trials of biolarvicide *Bacillus thuringiensis* var. *israelensis* strain 164 and the larvivorous fish *Aplocheilus blocki* against *Anopheles stephensi* for malaria control in Goa, India. *Journal of American Mosquito Control Association.* **14:** 457-462.

Kurup BM (2003) Popularization of Aquarium Keeping and Promotion of Ornamental Fish Culture and Marketing: Kerala Model of Development. *Fishing Chimes*, **23**(9): 31-34

Kuznetsov VA (2004) Changes in the population structure and biological indices of the goldfish Carassius auratus gibelio in the Volga Stretch of the Kuibyshev Reservoir under conditions of intense anthropogenic load on the ecosystem. *Journal of Ichthyology*. **44**: 167–174.

Meffe GK, Snelson FF Jr. (1989) An ecological overview of poeciliid fishes. Chap. 2 In: Meffe GK, Snelson FF, Jr., eds. Ecology and evolution of livebearing fishes (Poeciliidae.). Englewood Cliffs, NJ: Prentice Hall. p 13–31.

Menon, P.K.B. & Rajagopalan, P.K. (1978). Control of mosquito breeding in wells by using *Gambusia affinis* and *Aplocheilus blochii* in Pondicherry town. *Indian Journal of Medical Research*. **68**:927–933.

Mitra K, Suresh VR, Vinci GK, Mazumdar NN (2006) Food habits of the soft-fin barb, *Puntius sophore* (Ham. -Buch.) in a floodplain wetland, West Bengal. *Journal of the Inland Fisheries Society of India*. **38**(2): 73-76

Mohamed AA (2003) Study of larvivorous fish for malaria vector control in Somalia 2002. *Eastern Mediterranean Health J*. **9** (4): 618–626.

Morgan LA, Buttemer WA (1996) Predation by the non-native fish *Gambusia holbrooki* on small *Litoria aure*a and *L. dentata* tadpoles. *Australian Zoologist*. **30** (2): 143–149.

Mortenson EW (1982) Mosquito occurrence in wastewater marshes: a potential new community problem. *Proceedings and Papers of the Annual Conference of the California Mosquito and Vector Control Association*. **50**: 65-67.

Mukherjee M, Chattopadyay M, Datta SK, Biswas S (2000) Problems and prospects of aquarium fish trade in West Bengal. *Fishing Chimes*. **20**(1): 90-93

Nasir AS (1979a) History of the use of larvivorous fish for larval control in Somalia. W.H.O. EM/TR. SMR. LRV. FSH. MSQ. CTR/ Somalia, 3 pp.

Nasir AS (1979b) Important species of fish used for larval control in the Anti Malaria Program in Somalia, with special reference to *Tilapia zilli* and *Nothobranchius palinquisti*. W.H.O. EM/ST. SMR. FSH. MSQ. CTR/7.3 Somalia. 9 pp.

Nayar S (1996) Ornamental Fishes-A Booming Trade. *Fishing Chimes*.**16** (9): 17

Pant CP, Rishikesh N, Bang YH, Smith A (1981) Progress in malaria vector control. Bull. W.H.O. **59**: 325-333.

Őzkan N (2006) The larval chironomidae (Diptera) fauna of Bozcaada (Tenedos). *Gazi University Journal of Science*. **19** (1): 57-67

Prasad H, Prasad RN, Haq S (1993) Role of biological agents for the control of mosquito breeding through *Gambusia affinis* in rice fields. *Indian Journal of Malariology*. **30**: 57-65.

Raghavendra K, Subbarao SK (2002) Chemical insecticides in malaria vector control in India. *ICMR Bulletin*. **32**: 1-7.

Rajnikant, Pandey SD, Sharma SK (1996) Role of biological agents for the control of mosquito breeding in rice fields. *Indian Journal of Malariology*. **33:** 209-215.

Rao BUS, Krishnamoorthy K, Reddy CBS, Panicker KN (1982) Feasibility of mosquito larval control in casuarina pits using *Gambusia affinis*. *Indian Journal of Medical Research*; **76**: 684-688.

Real M, Rieradevall M, Prat N (2000) Chironomous species (Diptera: Chironomidae) in the profundal benthos of Spanish reservoirs and lakes: factors affecting distribution patterns. *Freshwater Biology*. **43** (1): 1-18

Royce WF (1972) Introduction to the Fishery Science. Academic Press. New York.

Rupp HR (1996) Adverse assessments of Gambusia affinis: An alternative view for mosquito control practitioners. *Journal of American Mosquito Control Association*. **12**:155–166.

Schaefer CH, Miura T (1985) Mosquito breeding in a cat tail marsh used for treatment of secondary sewage effluent. In B. Tabraham & J. Coates (eds.) Mosquito Res. Control Board Annual Report. Univ. Calif. Division of Agriculture and Natural resources, Berkley CA.: 80-82.

Sharma VP (1994) Role of fishes in vector control in India. In: Sharma VP, Ghosh A, editors. *Larvivorous fishes of inland ecosystems*: *Proceedings of the MRC-CICFRI workshop,* New Delhi, 27–28 September 1989. Delhi: Malaria Research Centre (ICMR), p. 1–19.

Singaravelu G, Mahalingam S, Jaya Bharati K (1997) Predatory efficiency of larvivorous fish *Gambusia affinis* on the mosquito larvae of *Aedes aegypti* and *Anopheles stephensi*. *Current Science*. **72***:* 512-514.

Singh AK, Ahmed SH (2005) Ornamental Fish Culture in Bihar: Prospects as a Cottage Industry. *Fishing Chimes*. **25**(6): 9-18

Singh T (2005) Emerging trends in world ornamental fish trade. *Infofish International*, **24**(3): 15-18

Spotila JR, Terpin KM, Koons RR, Bonati RL (1979) Temperature requirements of fishes from eastern Lake Erie and upper Niagara River. *Environmental Biology of Fishes*. **4**: 281–307.

Szczerbowski JA, Szczerbowski AJ (2002) *Carassius carassius* (Linnaeus, 1758). In Bănărescu, P. M. and Paepke, H. -J., editors. *The Freshwater Fishes of Europe, Cyprinidae 2, Part III*, Wiebelsheim: AULA-Verlag. p. 43–77.

Tabibzadeh I, Behbehani G, Nakhari R (1977) Use of *Gambusia affinis* in the Malaria Eradication Programme of Iran. Bull. WHO. **43**: 623–626.

Titmus G, Badcock RM (2006) Distribution and feeding of larval Chironomidae in a gravel-pit lake. *Freshwater Biology*. **11** (3): 263-271

Van den Thillart G, Van Berge Henegounen M, Kesbete F (1983) Anaerobic metabolism of goldfish, Carassius auratus: ethanol and CO2 excretion rates and anoxic tolerance at 20, 10, and 5 degrees C. *Comparative Biochemistry and Physiology*. **76**: 295–300.

Walker R, Johansen P (1977) Anaerobic metabolism in goldfish, *Carassius auratus*. *Canadian Journal of Zoology*. **55**: 304–311.

Walter LL, Lenger EF (1980) Impact of the desert pupfish, *Cyprinodon macularius* and *Gambusia affinis* on fauna in pond ecosystems. *Hilgardia*. **48**: 1-18.

Walton WE (2007) Larvivorous fish including *Gambusia*. In Floore, T., editor. *Biorational control of mosquitoes*. *Journal of American Mosquito Control Association*. 23 :(2: Suppl.) Mount Laurel, NJ American Mosquito Control Association. 184–220.

W.H.O. (1980 (1979)). Report of the travelling seminar on the use of larvivorous fish for mosquito control in anti malaria campaigns. Golden Sands Bulgaria/Tbilisi Georgian Republic, SSR, USSR. EM/VBC/22: EM/TR.SMR. LRV.FSH.MSQ.CTR/14, 35 pp.

W.H.O. (1982) Manual on environmental management for mosquito control with special emphasis on malaria vector. World Health Organization, Publ. No. **66**, Geneva, 283 pp.

Wurtsbaugh WH, Cech JJ, Compton J (1980) Effect of fish size on prey size selection in *Gambusia affinis*. *Proceedings of 48th Annual Conference of California Mosquito Vector Control Association*. 48-51.

Yildirim O, Karacuha A (2007) A preliminary study on determination of *Aphanius chantrei*'s feeding behaviour on mosquito larvae. *Acta Tropica*.**102: 172**–175

Zaman MS, (1980) Malaria control through fish. *Pakistan Journal of Science*. **32**: 163-168.

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