COMPOSITE FISH CULTURE FOR MOSQUITO CONTROL IN RICE FIELDS IN SOUTHERN INDIA

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Abstract. Composite culture of edible fishes (common carp, *Cryprinus carpio*; silver carp, *Hypopthalmithys molitrix*; grass carp, *Ctenopharyngodon idella*; catla, *Catla catla*; rohu, *Labeo rohita*; and mrigal, *Cirrhinus mrigala*) in rice fields in the Cauvery delta of Tamil Nadu, southern India, resulted in 81.0% reduction in the immature mosquito population of anophelines and 83.5% of culicines. Analysis of fish feces for mosquito larval head capsules showed that common carp and silver carp are effective larvivores. The selective feeding of common carp on culicines and silver carp on anophelines is correlated to their trophic niches. Net profit in the fish-cum-rice fields was 2.5 times greater than fields in which rice alone was cultured. Hence, rice-cum-fish culture can be recommended to the farming community in this area.

INTRODUCTION

The use of fish as biological control agents to control ricefield breeding mosquitos has on numerous occasions given promising results in reducing mosquito vector populations. The mosquitofish, *Gambusia affinis*, has been widely tested for mosquito control in paddy fields in Louisiana (Craven and Steelman, 1968), in California (Hoy and Reed, 1971), in USSR (Zainiev and Muminov, 1983) and in north India (Das and Prasad, 1991). However, mass culture of *Gambusia affinis* is difficult due to low fecundity and some stress-related intolerance during transportation (Cech and Moyle, 1983; Hoy, 1985). A more practical approach for mosquito control in rice fields is to promote rice-cum-edible fish culture which is economically beneficial to the farming community. In China, common carp, *Cyprinus carpio* and grass carp, *Ctenopharyngodon idella* have been extensively used as biological control agents (Provincial Anti-Malaria Experimental Group, Henan, 1977; Luh, 1981; Li *et al*, 1986; Wu *et al*, 1991) and they have also been tested in USSR for their larvivorous efficacy (Shumkov, 1983).

Rice-cum-fish culture is not popular in Tamil Nadu, mainly because of the shortage of water in many areas which makes it difficult to maintain a sufficiently high water level. The primary interest of the farmers is to cultivate rice with available water and not fish. However, the scientists of Tamil Nadu Agricultural University (TNAU) are trying to popularise rice-cum-fish culture in the Cauvery delta of Tamil Nadu where a system of irrigation canals provides abundant water. The objective of the present study was to determine the effect of composite fish culture on the immature population of mosquitos, especially the vectors of Japanese encephalitis (JE), *Culex tritaeniorhynchus*, *Cx. pseudovishnui* and *Cx. vishnui,* which mainly breed in rice fields in southern India.

MATERIALS AND METHODS

Studies were conducted at the Soil and Water Management Research Institute (SWMRI) of Tamil Nadu Agricultural University (TNAU), Thanjavur District in the Cauvery delta, an extensive rice growing area. The experiment was carried out during the "Kuruvai" crop season (July to September 1993). Composite fish culture was carried out in a field measuring 1,200 m^2 with a 400 m^2 "fish trench" on one side (1 m deep and 6 m wide). The fish trench was divided into three replications by placing the screens, made of polypropylene bags in the trench. Correspondingly the main field was divided with strong dykes (15 cm high) into 3 replications each of which communicated with fish trench. Wire mesh was placed at entry points for water to prevent the escape of fishes from the rice fields. The unstocked control field, measuring 1,600 m^2, was also divided into three replicates.

Stocking of fish

The "Composite fish culture" combined three indigenous carps (catla, *Catla catla*; rohu, *Labeo rohita* and mrigal, *Cirrhinus mrigala*) with three exotic carps (common carp, *Cyprinus carpio*; silver carp, *Hypopthalmithys molitri* and grass carp, *Ctenopharyngodon idella*), since these carp are commonly preferred by the people in this area. The fingerlings were stocked at the rate of 10,000/ha in the trenches (common carp, silver carp, grass carp, catla, rohu and mrigal in the ratio of 25%, 25%, 20%, 10%, 10% and 10% respectively). The initial length (average of 10 fingerlings) of each species was noted at the time of stocking. Fingerlings were stocked in the trenches 3 days before transplanting of paddy in the fields. Supplementary feed was prepared by mixing ground-nut oil cake and rice bran and adding 10% of the total weight of the fishes to the trench.

Rice cultivation

The fields were transplanted with ADT 36 paddy variety. Basal application of fertilisers (Urea - 110.7 kg/ha, Superphosphate - 21.4 kg/ha, Potash - 82.0 kg/ha, Gypsum - 500.0 kg/ha and Phosphobacterium - 2.9 kg/ha) was done just before transplantation in both the fish stocked and unstocked control fields. 33 days after transplanting, the fields were top dressed with Urea (54 kg/ha) and Potash (39 kg/ha). Pesticide was not applied in both fish stocked and unstocked fields, since there was no pest incidence. Deweeding was done 24 days after transplanting. Water level was maintained about 13 to 14 cm in the rice fields during the study period except at the time of top dressing. Fields were irrigated by lift irrigation from wells.

Sampling of mosquito immatures in rice fields

The samples of mosquito immatures were collected using a standard 350 ml dipper. 20 dips were taken from each replication. Larval instars and pupae of anophelines and culicines and other aquatic insects were counted in each dip. The mosquito pupae were taken to the laboratory for identification after emergence. Sampling was carried out thrice a week from the 3rd day after transplantation. Earlier studies in ricefields in Tamil Nadu have shown that there is a natural decline in the population of immature mosquitos from six weeks after transplantation (Rajendran and Reuben, 1991; Sundararaj and Reuben, 1991). Hence, sampling was carried out for six weeks after transplantation only.

Analysis of gut and feces content of fishes

From each replication in the experimental field two fishes of each species were collected from the trenches on each sampling occasions. The fishes were isolated immediately after collection in individual trays (10" × 8" size) for 24 hours. (Ungureanu *et al*, 1981), before being returned to the field. The excreta were collected and stored in 70% alcohol. Any fish found dead in the trays were preserved in 70% alcohol for analysing gut contents. The excretory materials collected were examined microscopically for mosquito larval head capsules. The data from gut analysis were pooled with the data of the feces examination.

Data analysis

The Selection Index (Ivlev, 1961) was calculated to find out the food selection behavior of each species of fish.

$$\text{Selection index} = \frac{U - V}{U + V}$$

where,

U = Percentage of prey item in gut contents

V = Percentage of prey item in the field

Since the mosquito pupal remains could not be recognised in the excretory material, the selection index was not worked out for mosquito pupae. ANOVA (analysis of variance) test on the log (n+1) transformed data was performed to compare the populations of mosquito immatures and other aquatic insects between the fish stocked and control fields. Paddy yield was found out after harvest and fish yield was calculated after 7 months of stocking, since fish culture in the trenches was continued in the second crop season ('Thaladi') also.

RESULTS

Mosquito breeding was recorded only during the first 3 weeks after transplantation. The mosquito species present in the fields without fish were *Culex vishnui* (51.9%), *Cx. tritaeniorhynchus* (44.2%), *Cx. pseudovishnui* (2.5%), and *Cx. (Lut.) fuscanus* (1.3%) among culicines, and *Anopheles subpictus* (94.8%) and *An. vagus* (5.2%) among anophelines. In the fish stocked fields, culicines present were *Cx. tritaeniorhynchus* (81.5%) and *Cx. vishnui* (18.5%) and the anophelines were *An. subpictus* (94.6%) and *An. vagus* (5.4%).

There was a considerable reduction in the population of mosquito immatures in the fish stocked fields (Fig 1). There was 37.5% reduction in the population of I larval instar in fish stocked fields in comparison with the control fields. Corresponding values were 44.0% for II larval instar, 63.6% for III larval instar, 69.8% for IV larval instar and 83.5% for pupae of culicines. In the anopheline population there was a 37.0% reduction in I instar, 34.8% in II instar, 59.1% in III instar, 71.8% in IV larval instar and 81.0% reduction in pupal population. ANOVA test performed on the log transformed data from 18 sampling occasions on which mosquito breeding was observed, showed that all stages of culicine immatures were significantly reduced in the fish stocked fields (I instar: $F = 4.91$; $p < 0.05$; II instar: $F = 7.61$; $p < 0.05$; III instar: $F = 6.09$; $p < 0.05$; IV instar: $F = 8.65$; $p < 0.05$; pupae: $F = 7.24$; $p < 0.05$). Similarly, the populations of anophelines were significantly lower (I instar: $F = 5.73$; $p < 0.05$; II instar: $F = 4.68$; $p < 0.05$; III instar: $F = 5.60$; $p < 0.05$; IV instar: $F = 9.42$; $p < 0.05$; pupae: $F = 6.39$; $p < 0.05$).

Among the non-target organisms sampled, populations of chironomids ($F = 9.22$; $p < 0.05$), ephemeropteran nymphs ($F = 5.55$; $p < 0.05$), notonectids

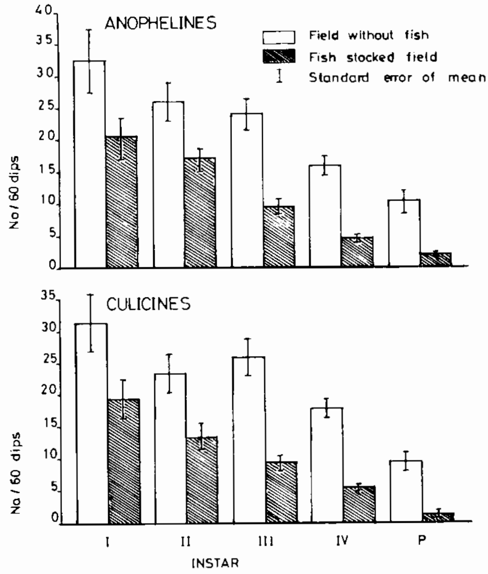

Fig 1–Effect of composite fish culture on mosquito immature population in rice fields.

($F = 6.78$; $p < 0.05$), hydrophilids ($F = 6.06$; $p < 0.05$), dytiscids ($F = 5.22$; $p < 0.05$) and coenagrionids ($F = 5.39$; $p < 0.05$) were significantly reduced in the fish stocked fields. There was no significant reduction in the populations of velids, hydrometrids, gerrids, corixids and libellulids.

The initial lengths (average of 10 fingerlings) of common carp, silver carp, grass carp, catla, rohu and mrigal at the time of stocking were 4.3 cm, 3.6 cm, 4.8

Table 1

Number of head capsules identified in fish excreta (N0./54 fishes).

Name of the fish	Culicines		Anophelines		Total	
	I/II	III/IV	I/II	III/IV	Culicines	Anophelines
Common carp	29	46	5	3	75	8
Silver carp	7	5	7	17	12	24
Grass carp	0	4	0	6	4	6
Catla	0	0	0	0	0	0
Rohu	0	1	0	0	1	0
Mrigal	1	1	0	0	2	0

Table 2

Selection Index of fishes cultured in rice fields.

Fish species	Culicines				Anophelines				Chiro-nomids	Ephemerop-terans	Noto-nectids	Cori-xids	Coenag-rionids	Libel-lulids	Hydro-philids	Dytis-cids
	I	II	III	IV	I	II	III	IV								
Common carp	–0.52	–0.14	–0.16	+0.58	–0.80	–0.93	–0.89	–0.59	+0.83	–0.48	–0.68	–0.80	–0.78	–0.42	+0.06	–1.00
Silver carp	–0.84	–0.71	–0.89	–0.39	–0.80	–0.82	–0.31	+0.01	+0.20	–1.00	–0.86	0.80	–0.78	–1.00	–1.00	–1.00
Grass carp	–1.00	–1.00	–0.89	–0.51	–1.00	–1.00	–0.70	–0.44	+0.14	–1.00	–0.93	–1.00	–1.00	–1.00	–1.00	–1.00
Rohu	–1.00	–1.00	–0.89	–1.00	–1.00	–1.00	–1.00	–1.00	–1.00	–1.00	–1.00	–0.80	–1.00	–1.00	–1.00	–0.55
Mrigal	–1.00	–0.92	–1.00	–0.80	–1.00	–1.00	–1.00	–1.00	+0.54	–1.00	–0.85	–1.00	–1.00	–1.00	–1.00	–1.00

cm, 5.2 cm, 4.2 cm and 3.0 cm respectively and at 6 weeks after transplantation they were 9.2 cm, 10.3 cm, 8.6 cm, 17.8 cm, 11.7 cm and 9.2 cm respectively. The fish excreta were analysed for head capsules of mosquito larvae. The highest number of culicine head capsules were found in the excreta of common carp and highest number of anopheline larval head capsules in the excreta of silver carp (Table 1). The head capsules of late larval instars (III/IV) of both anophelines and culicines were found in greater numbers than those of the early instars (I/II) in the excreta of silver carp and common carp respectively. The excreta of grass carp contained only a small number of mosquito larval head capsules (Table 1). None was identified in the excreta of catla and very few were found in the excreta of rohu and mrigal. The remains of aquatic insects other than mosquitos identified in the fish excreta included chironomids, ephemeropteran nymphs, notonectids, corixids, coenagrionids, libellulids, hydrophilids and dytiscids.

The preference of each fish species for available prey species was measured by calculating the Selection Index, which compares proportions of prey species in the field and in the feces (Table 2). Common carp selectively fed on IV instar culicines (+ 0.58) and not on other instars of culicines or anophelines. Similarly, silver carp was found to selectively feed on IV instar anophelines (+ 0.01) and not on other instars of anophelines or culicines. Except these two fish species, other species did not show selective feeding on mosquito immatures. Of the six fish species stocked, common carp, silver carp, grass carp and mrigal were found to feed on chironomids selectively (Table 2). Common carp is the only fish species which showed selective feeding on hydrophilids (+ 0.06). Rohu did not selectively feed on any of the insect groups present in the field. Since the excreta of catla did not contain any insect remains, selection index could not be worked out.

Total fish yield was 847.50 kg/ha after seven months of stocking. Net profit in the rice-cum-fish culture was Rs. 23, 862/ha and in the rice alone cultivated fields net profit was Rs. 9,750/ha. Paddy yield was affected in the second crop season due to flood and cyclone.

DISCUSSION

Composite fish culture in rice fields in southern India resulted in 81.0% reduction in the population of anophelines and 83.5% of culicines. In China, the combination of common carp and red carp has shown 86.3% reduction in culicine population and 59.1% in anophelines (Provincial Anti-Malaria Experimental Working Group, 1977) and there was 90% reduction in mosquito populations where common carp, *Tilapia* spp or grass carp were cultured (Wu *et al,* 1991). The higher percentage reduction in the populations of late instars of mosquitos implies that the fishes select late instars rather than the early instars. This was confirmed by finding that common carp selectively fed on IV instar culicines and silver carp on IV instar anophelines.

Of the six species of fish used for composite culture, 3 species, common carp, silver carp and grass carp are known to be efficient feeders on mosquito immatures in rice fields. The selective feeding on IV instar culicines, chironomids and hydrophilids by common carp could be due to its bottom feeding behavior as pointed out by Luh (1981). Similarly, selective feeding of silver carp on anopheline IV instar is correlated with its surface feeding behavior. Panicker *et al* (1985) have reported that catla consumed on an average of 928.2 larvae of *Culex quinquefasciatus* per day in the laboratory. However, in the present study catla showed no evidence of larvivorous behavior in rice fields. Surprisingly, grass carp, a proven effective mosquito larvivore in rice fields (Provincial Anti-Malaria Experimental Working Group, 1977; Wu *et al,* 1991), showed no selective feeding on mosquito immatures in the present study. This could have been due to the presence of efficient competitors like common carp and silver carp and it may have fed mainly on aquatic weeds.

The significant reduction in the populations of chironomids, ephemeropteran nymphs, notonectids and damselfly nymphs in the fish stocked fields are in conformity with the results of Miura *et al* (1984) in their experiments with *Gambusia affinis* in rice fields. However, these authors did not find any reduction in the populations of hydrophilids and dytiscids. Odonata appeared only 3 weeks after transplantation in rice fields when mosquito breeding had declined and therefore in this area predation pressure by odonates on mosquito immatures is undoubtedly very low.

Net profit in rice-cum-fish cultured fields was 2.5 times greater than that of rice alone cultured fields. hence, the integration of rice and fish farming, if successfully promoted to the farming community, will provide more income to farmers and can be an effective strategy in the control of mosquito vectors of JE in Cauvery delta.

ACKNOWLEDGEMENTS

We wish to thank Dr A Abdul Kareem, Director, Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu for his permission to carry out this work at Soil and Water Management Research Institute (SWMRI), Thanjavur. We also thank Mr Jayaraman, Assistant Professor, Tamil Nadu Veterinary and Animal Sciences University, Thanjavur, for his valuable technical guidance in fish culture. The help rendered by staff of SWMRI and Mr T Balaji of CRME during this study is gratefully acknowledged. The financial assistance by CSIR [9/622(1)/92-EMR-1] is gratefully acknowledged.

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