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Influence of certain environmental factors on the predatory efficiency of the larvivorous fish *Macropodus cupanus*

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Synopsis

Investigations of the effect of certain environmental factors on predatory efficiency of the indigenous larvivorous fish *Macropodus cupanus* indicates the dependence, in a quantifiable way, of predation on the environmental complex surrounding the prey-predator system. Prey consumption is less at low temperatures and increases significantly with rise in temperature. Feeding under conditions of light is significantly higher than in darkness. Salinities of up to 21.83‰ do not affect predation rate, except that owing to stress conditions, prey intake at 21.83‰ is lower than at 0.12‰. Considering fish size, in terms of unit body weight, predation declines significantly as size increases. However, when total body weight is considered, predation increases with increase in fish size. Environmental factors do not alter the time course of predation regularly or significantly, perhaps owing to haphazard intake subsequent to satiation and/or a 'learning' factor. The higher predation rate of this fish when compared to the conventional larvivore *Gambusia affinis* indicates its potential as a biocontrol agent of mosquito larvae.

Introduction

The rapidity of development of insect resistance to pesticides, coupled with a growing concern about environmental pollution has revived interest in other mosquito control techniques, notably biological ones. Although larvicidal fishes such as *Gambusia affinis* and *Poecilia reticulata* have been utilised in mosquito abatement programmes (Sasa et al. 1964, Mallars & Fowler 1970, Bay & Self 1972), indiscriminate releases of these exotics have led to their monopolization of certain habitats, threatening the survival of valuable aquatic fauna (Myers 1965, Bay 1973, Menon 1977). This has promoted an interest in indigenous larvivorous fishes such as *Macropodus cupanus* (Cuv. & Val.).

An essential part of investigating the biocontrol potential of this fish is determining the influence of environmental factors on prey intake, since mosquito larval habitats are beset with wide fluctuations in physico-chemical factors such as temperature and light (Rajagopalan et al. 1976), which in turn may affect predation. A knowledge of the influence of salinity on predation rate of the fish is important in the event of its introduction into brackish water tracts and drains and canals in such areas. However, such information is lacking on indigenous larvivorous fishes, apart from the work of Jacob et al. (1982) on *Aplocheilus lineatus*.

Although attempts have been made (Ivlev 1961) to construct models for predicting the course of predation processes based on assumptions derived from analogies with the kinetic theory of gases or monomolecular reactions, behavioural studies provide more realistic and precise assumptions for models of the predation process (Reddy 1973), and hence these have been utilised in this investigation.

Materials and methods

M. cupanus collected from streams and water bodies in the Trivandrum area (Kerala, South India) were acclimated to laboratory conditions in aquaria filled with well water at a temperature of 28 ± 1° C, pH of 7.1 ± 0.3, and oxygen at near air saturation. The fish were fed once a day on fourth instar *Culex* larvae (reared in the laboratory) for 9 periods of 10 minutes duration each. After being accustomed to this regular feeding schedule, the fish were divided into batches of 10–15 each and acclimated to the desired environmental conditions.

The range of temperature experimented with was that which might be encountered in the habitat (Rajagopalan et al. 1976) – i.e. 22.5 ± 0.5° C to 32.5 ± 0.5° C. In the case of salinity, since the fish survives salinities of up to 21.83‰, predation efficiencies were investigated at salt concentrations ranging from 0.12‰ to 21.83‰ (0 to 60% of sea water salinity of 36.2‰). The effect of light on feeding was determined by allowing the fish to predate under both light (supplied by a 30 cm long 40 W fluorescent tube, providing illumination of the intensity of 28 lux, over each tank) and dark conditions. Since predation is modified by environmental conditions, all factors, except the one dealt with were kept constant to show the influence of each factor separately. All tests were carried out with medium-sized fish (0.53 ± 0.07 g in weight; 26.5 ± 1 mm in standard length); in addition, the influence of fish size on predation was also investigated.

Prior to the investigation, the fish were starved for an uniform period of 24 hours. Each was then fed for 9 periods of 10 minutes duration each. Since at no time were the fish observed to consume more than 70 larvae per individual, in the initial feeding period this prey number was supplied. In the subsequent feeding periods, prey offered were reduced to 20 on the basis of preliminary observations on feeding. Larvae offered at the beginning of each feeding period were removed at the end, with the minimum of disturbance to the fish. Q_{10} relations were calculated following Welsh et al. (1968) and Nagabhushanam & Kodarkar (1978).

Results and discussion

The tests reveal that predation is dependent in a quantifiable way on the considered variables of the environmental complex surrounding the prey-predator system. However, predation in the periods subsequent to the initial one did not show significant differences (Fig. 1–4). This may be explained by the fact that once satiated, further intake is haphazard. Also, a 'learning factor' (Hoar 1942) may be involved in feeding in a confined space, as recorded by Reddy (1973) in *G. affinis*.

Influence of temperature on predatory efficiency

The results (Table 1, Fig. 1) show that predatory efficiency increases at a statistically significant rate with rising temperature, till an optimum is reached. Predation is minimal at low temperatures of 22.5 ± 0.5° C (20.6 ± 4.9 larvae per individual). It increases to 34.9 ± 4.2 larvae per individual as temperature rises to 27.5 ±0.5° C and then to 45.2 ± 3.9 larvae per individual at 32.5 ± 0.5° C. One reason for this result could be that maintenance rations increase with rising temperature exponentially (Elliott 1975). Again, as claimed by Rozin & Mayer (1961), food intake could be adjusted approximately the same amount that metabolic rate is affected by temperature shift. However, data comparison is hindered since the high and low temperatures reported in most investigations (Brett 1979) relate to temperate conditions; for instance, the four distinct temperature ranges suggested by Elliott (1975) as affecting meal size – 4–7° C, 7–13° C, 13–18° C and 18–22° C – do not apply under tropical conditions. However, it must be mentioned that Maglio & Rosen (1969), Reddy (1973) and Jacob et al. (1982) reported the feeding behaviour of other larvicidal fishes such as

G. affinis, *P. reticulata* and *A. lineatus* to be in direct response to water temperature. The predatory efficiency of *M. cupanus* is higher than that reported by Reddy (1973) for *G. affinis* in tropical waters, at 20° C (12.6 larvae per individual), 25° C (16.0 larvae per individual) and 30° C (20.5 larvae per individual), but is lower than that reported by Jacob et al. (1982) in *A. lineatus* at 22.5° C, 27.5° C and 32.5° C (47.3, 61.2 and 69.7 larvae per individual).

The Q_{10} value for *M. cupanus* for the 22.5–32.5° C temperature range is 2.194, indicating the degree to which predation is influenced by temperature. This value, however, is slightly lower than that expected when computed from the increase in the rate process from 22.5–27.5° C, even when the fish is tested within its 'biokinetic' (Fry 1947) range. This is in conformity with the findings of Vivekanandan & Pandian (1977) that in the tropics, feeding rate in *Ophiocephalus striatus* levelled off at 32° C. Gerald (1976b) also states that at 33° C, overall rate of food uptake in *Ophiocephalus punctatus* is reduced in varying degrees. Loss of appetite has been reported at relatively high temperature in the temperate regions in the salmon and the brown trout (Brett et al. 1969, Elliott 1975).

Table 1. Effect of temperature on the predatory efficiency of *M. cupanus* (n = 15).

Between temperatures	32.5 ± 0.5° C	27.5 ± 0.5° C	22.5 ± 0.5° C
32.5 ± 0.5° C	—	t = 8.93	t = 20.33
27.5 ± 0.5° C	—	—	t = 11.58

All t values are significant at the 1% level

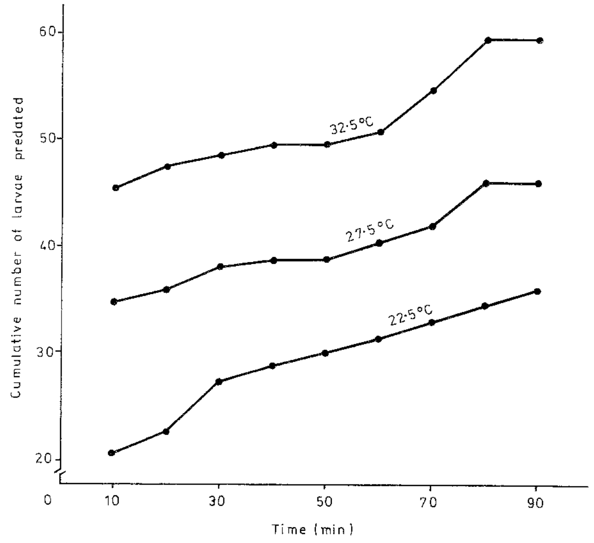

Fig. 1. Influence of temperature on the time course of predation in *M. cupanus*.

Thus in *M. cupanus* the process of prey capture proceeds in accordance with the temperature of the immediate environment; since its predatory efficiency is slightly impaired around 32° C, caution should be exercised in its introduction into waters where temperature may rise to high levels.

Influence of light on predatory efficiency

Available light influences feeding, there being a highly significant difference between predation efficiencies under light and dark conditions (Table 2, Fig. 2). Predation under conditions of light (57.4 ± 5.3 larvae per individual) is higher than that under conditions of darkness (34.2 ± 5.6 larvae per individual). The predatory efficiency of *M. cupanus* is considerably higher than that reported by Reddy (1973) in *G. affinis*, similarly feeding under conditions of light (17.4 larvae per individual) and darkness (15.8 larvae per individual), but is lower than that of *A. lineatus* under conditions of light (72 larvae per individual) and darkness (55.5 larvae per individual) (Jacob et al. 1982).

That in visual species (such as *M. cupanus*, Jacob 1981) the relationship between predator and prey depends on available light has been supported by laboratory experiments involving controlled manipulation of food supply and light conditions (Blaxter 1970) and models with different stimulus characteristics (De Groot 1969). Extensive research into feeding periodicities based on diel changes in

Table 2. Effect of illumination on the predatory efficiency of *M. cupanus* (n = 15).

Between regions	Light	Dark
Light	—	t = 21.12

t value significant at the 1% level

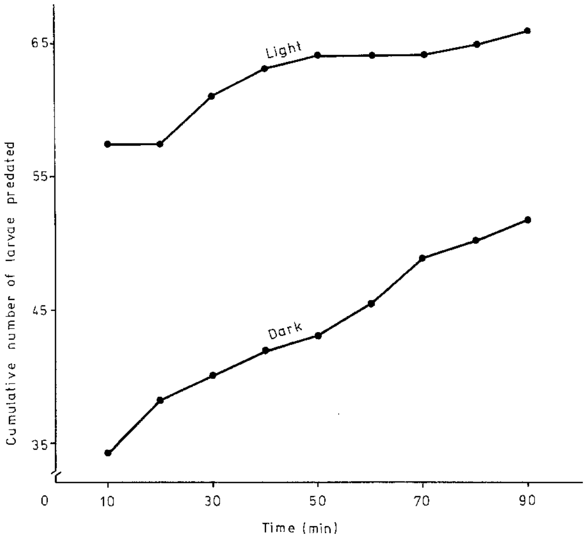

Fig. 2. Influence of light on the time course of predation in *M. cupanus*.

stomach contents has also proved this point (Woodhead 1966).

Blaxter (1970) claims that visual feeders cease predation once the light intensity falls below a threshold value; around this threshold value there is a gradual reduction in behavioural performance. However, in *M. cupanus*, under these experimental conditions feeding intensity, though lowered under conditions of darkness, is still present. This corresponds to the findings of Reddy (1973) in *G. affinis*. It may be attributed to a 'learning' factor (Hoar 1942) operating within the confined space of the experimental vessel; alternatively, other factors including prey movement and olfactory cues (Herrick 1924, Peters 1979) may assume importance below the visual threshold. Although feeding in the dark under tank conditions is not necessarily evidence of nocturnal feeding (Blaxter 1970), the fact that such predation exists at all is an indication of the larvivorous potential of the fish in covered wells for example, where light conditions similar to the ones encountered in this test may exist.

Influence of salinity on predatory efficiency

The results (Table 3, Fig. 3) show that while predation efficiencies at salinities of 0.12‰, 7.38‰ and 14.52‰ (29.0 ± 6.6, 27.6 ± 6.2 and 27.0 ± 6.3 larvae per individual, respectively) do not reveal significant differences, predation at 21.83^{0}/$_{00}$ (26.2 ± 5.9 larvae per individual) is significantly lower than that recorded at 0.12‰. Thus, above a certain salinity, stress conditions begin to operate, altering predation. Nevertheless, when the time course of predation is considered, owing to haphazard intake in the periods subsequent to the initial one, the 0% and 60% functions cross at the 5th period, leading to a higher cumulative consumption of larvae at 21.83‰ than at 0.12‰. The prey intake of the fish in the different salinities is thus an indicator of its functional adaptation to salinity.

Table 3. Effect of salinity on the predatory efficiency of *M. cupanus* (n = 15).

Between salinities	0.12‰ (0%)	7.38‰ (20%)	14.52‰ (40%)	21.83‰ (60%)
0.12‰ (0%)	—	t = 1.18	t = 1.67	t = 2.38*
7.38‰ (20%)	—	—	t = 0.51	t = 1.21
14.52‰ (40%)	—	—	—	t = 0.69

* Significant at the 5% level
Other t values are not significant

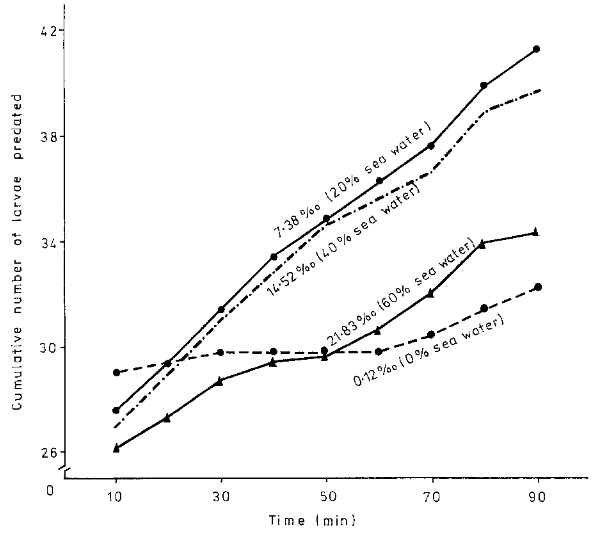

Fig. 3. Influence of salinity on the time course of predation in *M. cupanus*.

Influence of size on predatory efficiency

A significant difference in the predatory efficiencies of the three size groups of *M. cupanus* is apparent (Table 4, Fig. 4). Predation rate, per individual, is least in the small-sized group (13.0 ± 0.02 g weight; 17 ± 0.5 mm standard length), being 7.6 ± 3.7 larvae per individual. It increases as the fish grows, reaching 28.6 ± 4.5 larvae per individual in the medium-sized group (0.53 ± 0.07 g in weight; 26.5 ± 1.0 mm in standard length) and 53.0 ± 4.4 larvae per individual in the large-sized group (1.23 ± 0.12 g in weight; 35 ± 2 mm in standard length). In terms of fraction of body weight, however, the small-sized group preyed more effectively. With increase in fish size efficiency decreased from 58.46% to 50.18% and 43.09% of the body weight in small-, medium- and large-sized groups, respectively. This finding that feeding rate is inversely related to size, in terms of unit body weight, is in conformity with the results of Gerald (1976a) in *O. punctatus*; that prey intake shows a consistent increase with increasing size when total body size is considered is supported by Otto's (1971) work on *O. kisutch*.

It has been theorized (Peters 1979) that food intake and body weight are regulated relative to some 'set-point', as in mammals. The mechanism of alteration of the set-point, i.e. whether a change in food intake is the initiator of a change in body weight set-point or whether the set-point is altered first and then food intake is changed in a supportive role, is however unknown.

In conclusion, the manner in which predation efficiencies are altered by the ecophysiological factors of the habitat can be linked to data on other biological processes; altogether they permit an evaluation of the suitability of introducing the fish into specific habitats.

Table 4. Effect of fish size on the predatory efficiency of *M. cupanus* (n = 15).

Between sizes	Small (0.13 ± 0.02 g)	Medium (0.53 ± 0.07 g)	Large (1.23 ± 0.12 g)
Small (0.13 ± 0.02 g)	—	t = 17.97	t = 38.92
Medium (0.53 ± 0.07 g)	—	—	t = 20.02

All t values are significant at the 1% level

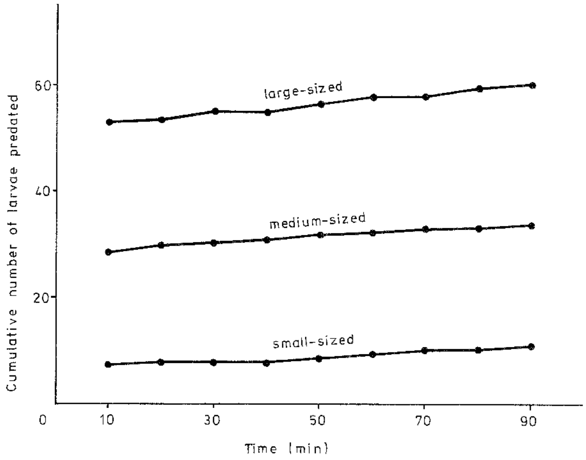

Fig. 4. Influence of fish size on the time course of predation in *M. cupanus*.

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