

**ON SOME ASPECTS OF REPRODUCTIVE BEHAVIOUR IN
CHLORONEURA QUADRIMACULATA (RAMBUR) (ZYGOPTERA:
PROTONEURIDAE)**

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The observations were carried out at a hill stream, Sagar District, Madhya Pradesh, India. Territoriality was strongly demonstrated by males which also exhibited precopulatory courtship by "wing display" before assuming the tandem position. Intra-male sperm transfer occurred after the seizure of the female and lasted for 18.8 sec. The copulatory wheel was formed in the perched condition and was maintained for 4.1 min, during which insemination took place. After disruption of the wheel position, the tandem pair performed postcopulatory exploratory flights which lasted for 20.8 min. The sensory styles of the ovipositor valvulae helped in the exploration of suitable sites and materials. Oviposition occurred in tandem and lasted for 20.3 min. The eggs were laid irregularly and exophytically among the algal mass and were covered by a gelatinous investment.

INTRODUCTION

A survey of literature, including recent reviews by CORBET (1980) and BICK & BICK (1980), revealed a lack of information on reproductive behaviour among the members of the Protoneuridae, which are confined in India to heavily wooded areas of montane tracts at altitudes between 500-2330 m. The present paper provides some information on the reproductive activity of *Chloroneura quadrimaculata* occurring widely in Sagar, India.

METHODS

The observations on behaviour were made between 18 April and 25 June, 1982. The adult damselflies were caught with the help of a butterfly net carrying a 2 m long handle. Marking of

insects took place on 24 April, 9 May and 27 May, 1982. The insects were individually marked laterally on the thorax and abdomen with white Asian enamel paint and were immediately released again. A careful watch was kept on the damselflies visiting the biotope from early morning till 15.00 h (sunrise 05.45 h, sunset 18.50 h) in the afternoon, often using field binoculars. All activities of *C. quadrimaculata* were observed and noted daily in a notebook. At times, damselfly pairs in tandem and in the wheel position were captured for verification of markings. The duration of various events given herein were recorded with the help of a stop watch. In the test, the symbol \bar{X} indicated mean value and N = number of observations.

DESCRIPTION OF BIOTOPE

The biotope comprised a small hill stream called Bewas near Chittora village in Sagar district, Madhya Pradesh, India at 23° 50'N and 78° 35'E. The river bed at the investigation site was covered with black soil and pebbles. It lacked macrophytic vegetation, but some plants of *Ipomoea aquatica* and trees (*Terminalia arjuna*) were growing on the river bank. Fallen and rotting leaves and twigs of these plants covered the shallow water surface along with thick algal mats comprising mostly *Spirogyra* filaments. The water showed slight alkalinity (pH range 7.5-8) and the ambient and water temperature measured in shade by Celsius mercury thermometer (0-250° C) at about 12.00 h ranged between 31.5-34° C and 24.5-30.5° C respectively during the period of observations.

OBSERVATIONS AND DISCUSSIONS

TERRITORIALITY

Chloroneura quadrimaculata males arrived at the biotope (09.00-10.00 h) earlier than the females (10.00-10.30 h) and established base perches along the river bank at high spots on *Ipomoea aquatica* plants or on smooth rocky projections above the water surface. The head always faced towards the sun and the abdomen rested nearly parallel to the surface when the male perched on the base. Males remained on the base perch for 20-25 min during which period they made short and regular patrol flights, usually down-stream or over the river bank. While perched, the male guarded a territory within a radius of 1.5-2.0 m. DREYER (1978) and FURTADO (1972) reported the territorial area within a radius of 0.5 m or less for most Zygoptera while, according to UTZERI et al. (1983), it ranged between 1.0-1.5 m only in *Coenagrion lindeni*. The territorial area happened to be larger in Calopterygidae (3-4 m long, KUMAR & PRASAD, 1977) and is the largest in Anisoptera (10 m or more, PARR, 1983). If any conspecific male intruded into the territory, the resident male abandoned his perch and sallied towards the intruder, who immediately flew away from the area. The male *Chloroneura quadrimaculata*, thus, showed territoriality and aggressive behaviour similar to "flight towards intruder" behaviour (BICK & BICK, 1965).

In *C. quadrimaculata*, the intruder was never chased beyond the territory and harmed physically unlike the behaviour observed in *Pseudagrion decorum* (BABU, 1983). In case of heterospecific intruders (*P. rubriceps*, *Copera*

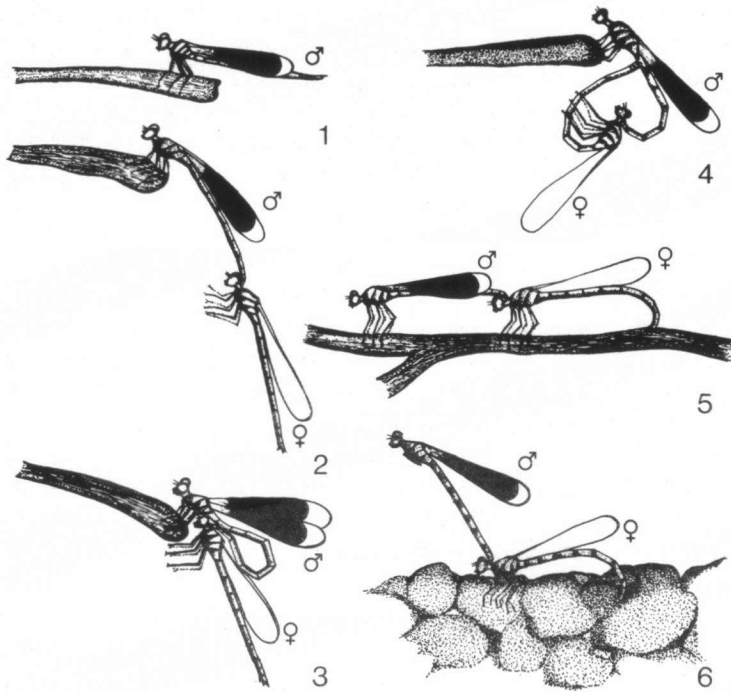
marginipes) traversing through the territory, the resident male *C. quadrimaculata* exhibited no reaction, so that small damselflies belonging to *Rhinocypha* sp. often remained perched close to it. When heterospecific males, however, approached the base perch, the resident male showed aggressive behaviour by raising up and displaying the abdomen, an observation similar to that of FURTADO (1972). It is evident from this account that *C. quadrimaculata* male shows strong territoriality and the aggressive behaviour was displayed predominantly towards conspecific males, a view also expressed by CORBET (1980).

Territoriality has been stated to be absent in Platynemididae (BUCH-HOLTZ, 1956; HEYMER, 1966), most Lestidae and many Coenagrionidae (BICK et al., 1976; FINCKE, 1982), although Calopterygidae and the Anisoptera exhibit it strongly (CORBET, 1980). From this view point, territorial behaviour seems to be significant and possibly phylogenetically related, indicating perhaps an evolutionary specialization in the group. If shown by all members, the Protoneuridae may rank close to the Calopterygidae in respect of territorial display.

PRECOPULATORY COURTSHIP

As soon as a female arrived in the area, the male left its perch to court her and performed flights above, below and laterally to the female damselfly. The precopulatory courtship was, therefore, exhibited by males who prominently displayed the blackish-brown spots of their wings, like many members of Euphaeidae (PINHEY, 1951) and Calopterygidae (KUMAR & PRASAD, 1977). The female, when receptive, responded by staying in the territory, otherwise she escaped by flying swiftly away. The male caught hold of the female prothorax by its anal appendages and thus established a tandem link with her in the air. CORBET (1980) stated presence of the precopulatory courtship typically in Calopterygidae and ROBERT (1958) in certain Coenagrionidae. *Chloroneura quadrimaculata*, among the Protoneuridae, showed it characteristically and seems to be similar to Calopterygidae in the occurrence and method of display of precopulatory courtship.

In tandem, pairs of damselflies performed a short precopulatory flight over the water surface and river bank, searching for a suitable site for intramale sperm transfer. BICK (1966) stated in *Ischnura verticilis* that unaccompanied females exhibited threat display by wing-warning and ventral abdominal curving (WWAC). In *C. quadrimaculata*, however, the females in tandem showed abdominal curving to signal rejection of approaching territorial males. This behaviour seems to be correlated to sex ratio where males outnumbered females in a population (PARR & PALMER, 1971).



Figs 1-6. Reproductive behaviour of *Chloroneura quadrimaculata*: (1) Male on base perch; — (2) Male and female in tandem link; — (3) Intramale sperm transfer; — (4) Tandem wheel position; — (5) Exploratory oviposition in tandem, both partners providing support; — (6) Oviposition female with male in upright tandem.

INTRAMALE SPERM TRANSFER

The pair alighted on a plant, usually similar to the base perch, where only the male provided support by resting its legs on the vegetation and the female remained suspended down-wards. The abdomen of the male curved forward so that the gonopore on the ninth abdominal segment was brought against the opening of the vesicula spermalis located on the second abdominal segment. In this process, the head of the female was held very close to the secondary copulatory apparatus of the male. Intramale sperm transfer thus occurred in the perched condition and the whole process lasted for 11-27 sec ($\bar{X} = 18.8$ sec, $N = 5$). Thereafter the male relaxed, extended abdomen and rested for 20-30 sec before entering into the wheel position. The reproductive behaviour of *Chloroneura quadrimaculata* deviates from that of *Erythromma viridulum* (BUCHHOLZ, 1950) and *Hetaerina americana* (JOHNSON, 1961), where translocation occurs

prior to seizure of the female and attaining tandem link. CORBET (1980) stated that except in certain Calopterygidae, translocation occurs immediately after assumption of the tandem link. In *C. quadrimaculata*, however, translocation did not take place immediately after establishing of tandem position as it was preceded by a short period of precopulatory flight. Moreover, it occurred without interruptions in the perched condition and not during flight as reported by UTZERI et al. (1983) in *Coenagrion lindenii*.

COPULATORY WHEEL POSITION

Anisopteran dragonflies mostly assume the wheel position during flight (ROBERT, 1958; NEVILLE, 1960), whereas the Zygoptera usually assume it when perched (ROWE, 1978). In *Chloroneura quadrimaculata* also, the tandem pair adopted the copulatory wheel position while settled at the same place where translocation had occurred. The abdomen of the female curved ventrally and forward in the direction of male accessory genitalia, swinging for at least 5-7 times before interlocking successfully with them. Contrary to this, BICK et al. (1976) reported formation of copulatory wheel by female *Chromagrion conditum* in her first attempt only.

BICK & BICK (1963) reported in *Enallagma civile* that the female during copula clasped all her legs ventrally on III, IV & V abdominal segments. In *C. quadrimaculata*, all the legs of the female hung free as indicated by uncurved tarsi.

After wheel formation, copulation in *Chloroneura quadrimaculata* occurred under two conditions, settled and in flight. Rhythmic movements in the abdominal wheel were also noticed when settled. Usually long and varying copulatory durations have been reported in Zygoptera: 16 min in *Argia apicalis* (BICK & BICK, 1965), 23-58 min in *Enallagma cyathigerum* (DOERKSEN, 1980), 62-84 min in *Ischnura erratica* (PAULSON & CANNINGS, 1980) and 2-30 min in *Coenagrion lindenii* (UTZERI et al., 1983). In *Chloroneura quadrimaculata*, the copulatory period lasted for 3-8 min ($\bar{X} = 4.1$ min, $N = 13$), which is notably short in comparison to recorded ones. KUMAR & PRASAD (1977) reported copulation to last 3-4 min in *Neurobasis c. chinensis* also.

On the basis of dual function of the damselfly penis, sperm removal and transfer (WAAGE, 1979), it has been argued by CORBET (1980) that sperm removal by the penis from the spermatheca needed a very long duration of the wheel position (10-20 min in *Ischnura aurora*) and sperm transfer was carried out in 2 min only (ROWE, 1978). We, however, view it slightly differently and believe that long copulatory durations observed by different workers were, no doubt, necessary for removing the sperms from the spermatheca but from damselflies which had already mated and were engaged in copulation again. The spermatheca of a virgin damselfly needs no cleaning and hence insemination

occurs directly, requiring a short period only. The copulatory duration, therefore, seems to be directly proportional to the time used up during sperm removal from the spermatheca. The penis forms basically a sperm transference organ and the function of sperm removal acquired by it must have been a secondary specialization in the group. Thus, the comparatively short duration of copulation observed in *C. quadrimaculata* may be explained if it involved mating only with virgin females. The long copulatory durations recorded by various workers seemingly involved females which had mated earlier.

POSTCOPULATORY EXPLORATORY FLIGHT

At the end of copulation the pair rested for one or two minutes before starting intermittent postcopulatory flights in tandem above the water surface to explore suitable sites of oviposition. The male maintained a perpendicular posture over the female during in tandem flight and both the partners provided support when settled. The female explored among the fallen rotting leaves, twigs and algal mat on the water surface by touching these objects with her ovipositor. A morphological study of the ovipositor by light microscopy revealed the presence of a fine setose surface at the tip of the styli of the ovipositor valvulae (Fig. 7). We regard these setae as forming special sensory organs, as reported by SRIVASTAVA & SRIVASTAVA (1983). The postcopulatory exploratory flight in *C. quadrimaculata* lasted for 16-28 min ($\bar{X} = 20.8$ min, $N = 5$) during which period neither the eggs were laid nor the punctures made similar to many Coenagrionidae (BICK, 1972).

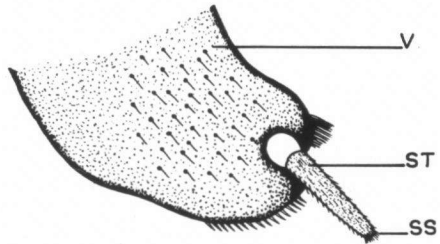


Fig. 7. *Chloroneura quadrimaculata*: style of ovipositor valvula, showing sensory setae (SS).

OVIPOSITION

Oviposition in *C. quadrimaculata* occurred intermittently in tandem among the filamentous algal mass growing on the surface of water. The female guided and controlled the oviposition process while the male escorted her. The eggs were laid singly at different spots in the mass of algae by the female extending her abdomen and changing the direction of her ovipositor. The pair remained settled and oviposited at one site for 2-3 min before moving off to other sites. The total period of oviposition, including interruptions, lasted for 18-30 min ($\bar{X} = 20.33$ min,

N = 9). The eggs were laid irregularly and were covered by a gelatinous investment.

The oviposition behaviour of *C. quadrimaculata* is interesting because it is completed in company with the male and the eggs are inserted singly among the filaments of the algae on the water surface, unlike the typical endophytic oviposition reported in other Zygoptera (FURTADO, 1972).

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