Odonatologica 6 (3): 163-171 *September 1, 1977*

REPRODUCTIVE BEHAVIOUR IN *NEUROBASIS CHINENSIS CHINENSIS* (LINNAEUS) (ZYGOPTERA: *CALOPTERYGIDAE*)

A. KUMAR and M. PRASAD

Northern Regional Station, Zoological Survey of India,
13 Subhas Road, Dehra Dun - 248001, India

Received August 20, 1976 / Revised March 28, 1977 / Accepted May 31, 1977

The reproductive behaviour of *N. c. chinensis* has been studied in the field (Dehra Dun, India), and compared with that of the holarctic *Calopteryx* species. Save for minor details, it is essentially similar to that recorded in other members of the family. Courtship is well marked and the ♂♂ demonstrate "territorialism" over small, shaded streams. Copulation lasts 3-4 min and is performed perching on vegetation or exposed rocks near the stream. Oviposition is endophytic and the eggs are laid by unattended ♀♀ in submerged vegetation. They are cylindric, covered by a thin, gelatinous investment.

INTRODUCTION

Dragonflies demonstrate well developed complex behavioural patterns. Of special significance are the ethological specialisations achieved by the *Calopterygidae*, which family is considered to have attained an optimal level of behavioural specialization. HEYMER (1972, 1973), in his excellent and extensive ethological studies on the palearctic *Calopteryx* species, has described in detail the territorial and reproductive behaviour and its significance in the behavioural evolution of the Order, and reviewed the earlier work on the ethology of the holarctic members of the family (WILLIAMSON, 1905; BUCHHOLTZ, 1951, 1955; WALKER, 1953; ROBERT, 1958; ZAHNER, 1960; CORBET, 1962; JOHNSON, 1962). Recently, PAJUNEN (1966), KLÖTZLI (1971), WAAGE (1971, 1972, 1973, 1975) and AITA (1974), among others, contributed much to our knowledge of calopterygid behaviour.

The behavioural patterns of the holarctic *Calopterygidae* are well understood, chiefly due to extensive observations on the genus *Calopteryx*. However, almost

no investigations have been made on the ethology of the tropical representatives of the family, like *Neurobasis, Mnais, Matrona*, etc. In the present paper we report our observations on reproductive behaviour in *Neurobasis chinensis chinensis* (Linn.), the beautiful small stream breeding calopterygid of the Dehra Dun Valley (alt. ca. 650 m, 77°35'-78°20' EL and 29°57'-31°20' NL), India. Its range extends throughout India except in desert areas, generally between the altitudes of 600-1200 m, and Nepal (FRASER, 1934; ST. QUENTIN, 1970).

PHYSIOGRAPHY, CLIMATE AND DESCRIPTION OF THE BIOTOPES

The Dehra Dun Valley is an irregular parallelogram. On the South, the Siwalic Hills present a steep face scarred by frequent precipices; on the North, a long gentle declivity slopes inward and forms a longitudinal shallow valley, terminated by the outer ranges of the Himalaya. The mean altitude amounts to approximately 650 m and the valley gradually slopes towards the rivers Ganga and Jamuna, on its eastern and western sides, with a gradient of 6 m/km. There is a total fall of about 300 m on either side. The drainage occurs in the eastern or in the western direction respectively. The climate is of the tropical monsoon type; the mean annual temperature varies from 3°C to 40°C; the annual average rainfall amounts to about 2500 mm, 85% of which falls in the period June-September.

The biotopes used by *N. chinensis chinensis* as breeding places are slowly running streams or artificial water channels which are present in the relatively level region in the middle of the valley (Fig. 13). These are generally tributaries of large rivers or artificially prepared shaded channels to water mills (locally called "Gharat") or agricultural fields, passing through the grassy areas, and are about a meter in width and 30-50 cm deep, with dense overhanging and submerged vegetation. The water flow is slow (20 to 50 cm/sec). Their bottom comprises sand and gravel, sometimes it is muddy and contains debris and decaying leaves. The pH values amount to 8.2-9.0 and the water temperature quickly changes with the atmospheric temperature.

MATERIAL AND TECHNIQUES

The observations were made at Sulphur Spring, Kalsi and Maldevta.

The adults were captured, marked, released and recaptured at a selected stretch of a stream. Since there were not too many adults it was not very difficult to follow and recognise a marked individual.

OBSERVATIONS

FRASER (1934) recorded that *N. chinensis* breeds in montane and submontane streams and it shows a predilection for certain streams. ZAHNER (1959) has also shown that the males of *Calopteryx splendens* and *C. virgo* avoid streams which are less than 60 cm wide. KUMAR (1977), while studying the distribution of adult Odonata around a fresh water lake in the Western Himalaya, noted that adults of *N. c. chinensis* were present only around channel-like streams (about 1.5 m. wide) and never at the lake shore.

Adults are sun-loving and flutter lazily over the water surface and amidst the vegetation in the late forenoon. They are generally confined to their larval habitats and are only rarely observed away from the channels. They are common around the streams twice in a year, viz., March-June (dry summer, average temperature 15°-35°C) and October-November (autumn and early winter, average max. temp. 20°-30°C) when emergence also occurs (KUMAR, 1973).

Males demonstrate territorial behaviour, similar to that in other *Calopterygidae* (cf. CORBET, 1962; HEYMER, 1972). A male selects a small area of the stream, approximately 3-4 m long, and defends it against the intrusion of other males, but tries to court all the females (2 to 3) which may be present in his territory. This territory may be defined as "territory of defence" (CORBET, 1962), within which the male selects an overhanging plant as a "settling base" from which he makes regular short flights on either side. Two to three females have been observed resting or ovipositing within the "territory of defence" of one male. However, aggressive display and duels with other intruding males are not uncommon during the breeding season. Invariably the male intruding from the adjacent territory is immediately chased away, both males hover in rapid circles over the water surface, which eventually results in one male leaving the territory. This behaviour is similar to that of the males of European *C. haemorrhoidalis* (HEYMER, 1972).

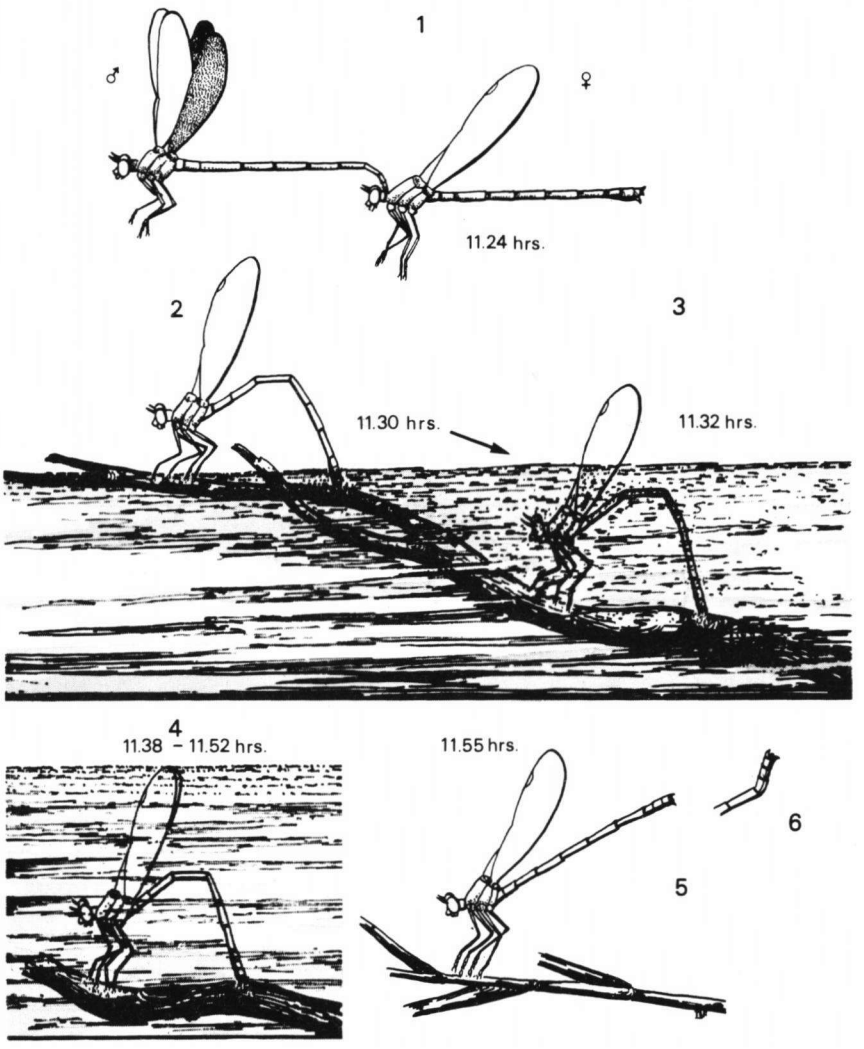
The male tries to "court" the females flying through his territory. This involves the display of the strikingly coloured hind wings and abdomen. Like European *Calopteryx* (HEYMER, 1972), the males of *N. chinensis* have terminal abdominal segments with a conspicuous contrasting coloration ("tail lights"). The hind wings of the male are also partly coloured with brilliant metallic green and blue. The males of *N. chinensis* are frequently observed diving down to the water surface, under the overflying females and alight there briefly. During the process only the fore wings are used while the emerald green hind wings, which are motionless and obliquely spread, and the metallic green curved abdomen with white terminal segments flash brilliantly. The male even floats in this posture on the water current for 20-30 cm. Immediately after, it takes off and comes over the female and attempts to get hold of her prothorax with its anal appendages. Almost similar is the courtship behaviour of European *Calopteryx splendens* (cf. CORBET, 1962; HEYMER, 1973). However, during the peak reproductive season, some males were observed trying to molest the ovipositing female which already has her abdomen turned up, flutters her wings briefly and further curls her terminal abdominal segments (Figs. 5, 6). ROBERT (1968) observed similar behaviour in the female of *Calopteryx virgo* and HEYMER (1973) in other West European *Calopteryx* species. BUCHHOLTZ (1955) has demonstrated variations in pre-copulatory behaviour of *C. splendens* in which the male may directly pounce on the female. The same may be the case in pre-copulatory behaviour in *N. chinensis*.

Once the male gets hold of a receptive female, he leads her, flying "in tandem" (Fig. 1), to the vegetation at the banks. The female stays passive and the male literally tows her before coitus. After settling down in tandem on the vegetation or on boulders, the male curls and jerks its abdomen. The female now curls her abdomen too and forms the "copulation wheel" with the male. This is considerably different from observations of HEYMER (1972) on West European *Calopteryx*, where the transfer of sperm always takes place after attachment of the pincers. In the case of *N. chinensis* the copulation follows immediately after the attachment of pincers. Copulation is of medium duration and the coitus continues for 3-4 minutes approximately (in four instances it was observed to last from 11.11-11.15 hrs, 11.18-11.21 hrs, 11.24-11.28 hrs and 11.58-12.01 hrs).

In one case, when a pair was in coitus on the vegetation, another male was observed to be repeatedly trying to get hold of the copulating male by its anal appendages while hovering over the pair, probably mistaking it for a female (since the wings of the male are generally closed over its body while in coitus, it flutters them only 10-12 times during the period). HEYMER (1973) reported an almost similar type of alighting behaviour of males over females in the case of *Calopteryx haemorrhoidalis*. This eventually compelled the copulating pair to fly away in tandem to settle again on a nearby bush. The pair in tandem does not easily separate if disturbed. On one particular morning the wind was strong in a small valley and a pair was observed in tandem making several unsuccessful attempts to settle down for coitus on a stone. In between they made a few short flights in tandem to perch on the vegetation also. This continued for about 6-7 min until eventually they copulated.

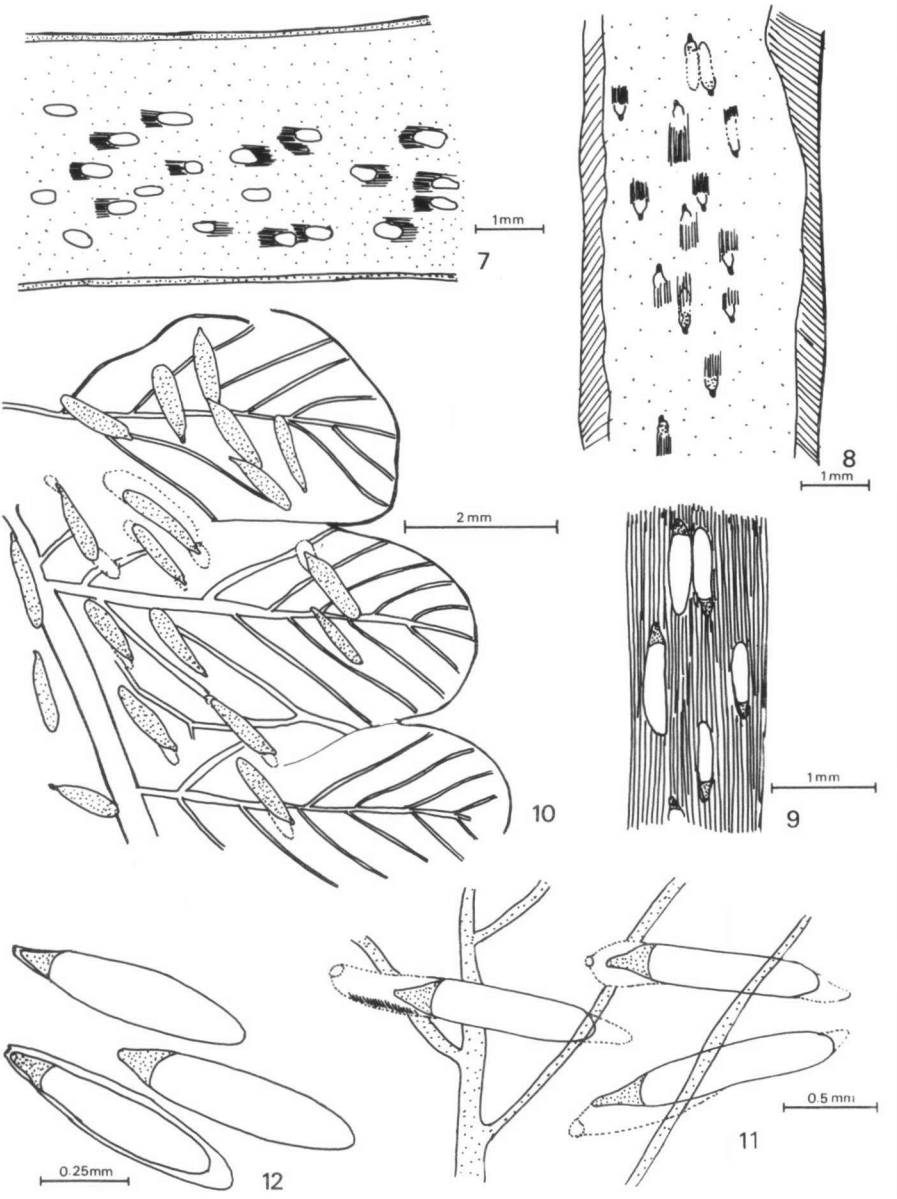
Following coitus the male suddenly abandons the female and flies away. Subsequently, the female perches on the vegetation for a few minutes with her abdomen turned up (Fig. 5). Soon afterwards she makes a short flight and settles down at a sheltered site for oviposition on submerged vegetation. In this respect *N. chinensis* shows a different behaviour than the *Calopteryx* species, where the male leads the female to the selected ovipositional site (cf. CORBET, 1962; HEYMER, 1973).

Oviposition has been observed closely in the field and it was noticed that the female, which oviposits unattended by the male, may lay eggs while partially or completely submerged. In one case two females were observed ovipositing close to each other, one staying above the water (except for the tip of her abdomen), the other submerging completely. The first female started ovipositing at 11.22 hrs and continued until 11.28 hrs, when a male arrived at the scene and repeatedly tried to molest her, which compelled her to leave the ovipositional site at 11.29 hrs. She then perched on vegetation with upwardly directed abdomen. Another female arrived on the same spot from which the former had flown at around 11.30 hrs and started laying eggs (Fig. 2). By 11.32 hrs head, thorax and



Figs. 1-6. Reproductive and oviposition behaviour of *Neurobasis chinensis chinensis* (Linn.): (1) Precopulatory tandem; – (2) Female starting oviposition; – (3) Partially submerged ovipositing female; – (4) Completely submerged ovipositing female; – (5) Perching female; – (6) Curled terminal abdominal segments of a female molested by a male.

abdomen were submerged except the apical portion of wings (Fig. 3). This female was completely submerged at 11.38 hrs and laid eggs in this position till 11.52 hrs (Fig. 4), when she rapidly came to the surface, took a short flight and perched on the vegetation (Fig. 5). WALKER (1953) observed the same type of



Figs. 7-12. Reproductive and oviposition behaviour of *Neurobasis chinensis chinensis* (Linn.): (7) Stem of a submerged plant with ovipositional punctures; – (8) Eggs inserted in cortex of the same (epidermis removed); – (9) Arrangement of eggs in cortex; – (10) Portion of a fern leaf with inserted eggs; – (11) The same, enlarged; – (12) Eggs.

behaviour in *Calopteryx aequabile* where the female stayed submerged for 30 minutes. In the meantime a male was also perching at his "settling base", from where it would make short flights and would try to alight over and molest the nonsubmerged female. Every time the male would alight over the ovipositing female, she would stop laying eggs and would raise her abdomen in resistance. An interesting feature noted was that the submerged female was left alone by the male. Thus the post-copulatory behaviour of the male of *N. chinensis* is quite different from those of *Calopteryx* species, where the male not only leads the fmeale to the site of oviposition but also guards and protects her either from leaving his territory without laying eggs or from molestation by other intruding males while she is ovipositing.

The submerged female lays eggs vigorously and moves regularly forward against the water current in the process. She may even be swept from side to side when the current is swift. Though a large number of submerged fern leaves with numerous eggs have been collected, *N. chinensis* does not seem to have a preference for a specific type of vegetation.

Eggs are laid endophytically either in the leaf lamina or in the cortex of submerged twigs. Females may lay eggs at short intervals on various leaves or twigs. Oviposition is quite extensive in fern leaves (Fig. 10) and on two occasions the numbers of eggs counted on these leaves were found to be 830 (on a leaf with 13 leaflets, total leaf surface area 55 cm^2), and 494 eggs (9 leaflets, total area 37 cm^2). However, it is not known with certainty whether these eggs were laid by a single female or by a number of females.

The eggs are laid obliquely at the upper leaf surface (Figs. 10, 11). A number of ovipositor punctures are also found on the leaf surface. In soft plant tissue they are completely inserted in the cortex, though the ovipositional holes could be seen over the stem surface (cf. Figs. 7 & 8). The eggs do not seem to be laid in a definite pattern since the female keeps changing her position regularly while ovipositing. In fern leaves eggs are sometimes laid parallel though often in opposite directions (Fig. 10). In cortex the eggs were laid parallel to the longitudinal fibers of the cortex tissue (Fig. 9).

The eggs are elongate, cylindrical in shape (measuring 0.73-78 mm) with a narrowed interior pole (Fig. 12). When freshly laid, they are white with dark brown anterior pole but they gradually become creamish. Eggs are covered with a gelatinous investment. The narrow anterior pole is only partially covered with epidermis, in some cases it was even found to be protruding. Hatching did not occur in the laboratory. In the first week of June larvae in various instars (size 10-45 mm) were collected from a stream at Robber's cave, Dehra Dun (Fig. 13). Oviposition and emergence were also recorded during the same period.

Fig. 13. The biotope of *Neurobasis chinensis chinensis* (Linn.) at Dehra Dun, Uttar Pradesh, India.

ACKNOWLEDGEMENTS

We are much indebted to Dr. B.S. LAMBA, Deputy Director, and Dr. ASKET SINGH, Suptdt. Zoologist, Northern Regional Station, Zoological Survey of India, Dehra Dun, for permission to conduct the study, various facilities and reviewing the work, and to Dr. B. KIAUTA, Department of Animal Cytogenetics, University of Utrecht, The Netherlands, for various helpful suggestions.

REFERENCES

AITA, M. 1974. [Reproductive behaviour of Calopteryx virgo japonica]. *Nature and Insects* 9 (13): 28-30. (In Japanese).

BUCHHOLTZ, C., 1951. Untersuchungen an der Libellengattung Calopteryx Leach unter besonderer Berücksichtigung ethologischer Fragen. *Z. Tierpsychol.* 8: 273-293.

BUCHHOLTZ, C., 1955. Eine vergleichende Ethologie der orientalischen Calopterygiden (Odonata) als Beitrag zu ihrer systematischen Deutung. *Z. Tierpsychol.* 12: 364-386.

CORBET, P.S., 1962. A biology of dragonflies. Witherby, London.

FRASER, F.C., 1934. Fauna of British India. Odonata Vol. 2. Taylor & Francis, London.

HEYMER, A., 1972. Comportements social et territorial des Calopterygidae (Odon. Zygoptera). *Ann. Soc. ent. Fr.* (N.S.). 8 (1): 3-53.

HEYMER, A., 1973. Etude du comportement reproducteur et analyse des mécanismes déclencheurs innés (MDI) optiques chez les Calopterygidae. (Odon. Zygoptera). *Ann. Soc. ent. Fr.* (N.S.). 9 (1): 219-255.

JOHNSON, C., 1962. Breeding behaviour and oviposition in Calopteryx maculatum (Beauvois) (Odonata: Zygoptera). *Am. Midl. Nat.* 68: 242-247.

KLÖTZLI, A.M., 1971. Zur Revierstätigkeit von Calopteryx virgo L. (Odonata). *Mitt. schweiz. ent. Ges.* 43 (3-4): 240-248.

KUMAR, A., 1973. Description of the last instar larvae of Odonata from the Dehra Dun Valley (India), with notes on biology I (Suborder Zygoptera). *Oriental Ins.*, 7 (1): 83-118.

KUMAR, A., 1977. Some field notes on the Odonata around a fresh water lake in Western Himalaya (Renuka: Himachal Pradesh). *J. Bombay nat. Hist. Soc.* (in press).

PAJUNEN, V.I., 1966. Aggressive behaviour and territoriality in a population of Calopteryx virgo L. (Odonata: Calopterygidae). *Ann. Zool. fenn.* 3: 201-214.

ROBERT, P.A., 1958. Les libellules (Odonates). Neuchâtel, Delachaux et Niestlé S.A.

ST. QUENTIN, D., 1970. Odonata aus Nepal. *Khumbu Himal* 3 (3): 389-411.

WAAGE, J.K., 1971. Aspects of the reproductive behaviour and ecology of Calopteryx maculata (Beauvois) (Odonata: Calopterygidae) and a study of its reproductive isolation from C. aequabilis Say. Ph.D. Thesis, Univ. Michigan.

WAAGE, J.K., 1972. Longevity and mobility of adult Calopteryx maculata (Beauvois, 1805) (Zygoptera: Calopterygidae). *Odonatologica* 1 (3): 155-162.

WAAGE, J.K., 1973. Reproductive behaviour and its relation to territoriality in Calopteryx maculata (Beauvois) (Odonata: Calopterygidae). *Behaviour* 47 (3-4): 240-256.

WAAGE, J.K., 1975. Reproductive isolation and the potential for character displacement in the damselflies, Calopteryx maculata and C. aequabilis (Odonata: Calopterygidae). *Syst. Zool.* 24 (1): 24-36.

WALKER, E.M., 1953. The Odonata of Canada and Alaska Vol. I. Toronto Univ. Press.

WILLIAMSON, E.B., 1905. The dragonflies (Odonata) of Burma and Lower Siam. I. Subfamily Calopterygidae. *Proc. U.S. nat. Mus.* 28: 165-187.

ZAHNER, R., 1960. Über die Bindung der mitteleuropäischen Calopteryx-Arten (Odonata, Zygoptera) an den Lebensraum des strömenden Wassers. II. Der Anteil der Imagines an der Biotopbindung. *Int. Rev. Hydrobiol.* 45: 101-123.