Courtship, mating and egg-laying in *Tylototriton verrucosus* from the Darjeeling district of the Eastern Himalaya

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***Tylototriton verrucosus* is confined to high altitudes of the Eastern Himalaya. The present study on salamanders of Darjeeling district deals with courtship, mating and egg-laying in 46 pairs of *T. verrucosus* during May and June 1999, under natural and laboratory conditions. The animals show sexual dimorphism during the breeding season. Courtship and amplexus always take place at night. The courtship behaviour is in the form of a nuptial dance. The amplexus is ventral and the eggs are laid singly. The duration from courtship to egg-laying varies between pairs. Clutch size is positively correlated to the length and weight of the female.**

IN India, *Tylototriton verrucosus* is the sole representative of the order Caudata. It is reported from high altitudes and cold climate of the Eastern Himalaya of West Bengal, Arunachal Pradesh, Sikkim, Manipur and Meghalaya[1]. The earlier studies on *T. verrucosus* report on the habitat[2,3], breeding behaviour[4,5], larval stage[6–8], parental care[9] and endangered status[10–12]. Their biology still remains to be studied, specially in relation to breeding behaviour, reproduction mode and distribution[13].

The present study on *T. verrucosus* was taken up at 23 sites in Darjeeling district. The salamanders emerge from their hibernation with the first monsoon shower. They were found in permanent and temporary pools, shallow ditches, marshes and slow-moving streams, from late April to early September. They oviposit during summer from early May to late June.

During the breeding season, the salamander habitats were monitered for gravid females and mature males, each day from 1600 h. The mean air and water temperatures during May and June were 19.9°C ± 0.68 (range: 18.0–20.6°C) and 18.8°C ± 0.3 (range: 17.5–20.1°C), respectively, with humidity of 85.84% ± 3.83 (range: 71–92%). Soon after amplexus, the pairs were caught. The male and female were separated and brought to the laboratory. The total length (from snout to the tip of the tail) and body weight of the individual male and female were recorded. The animals were released in aquariums having 8 cm of water. Each aquarium housed one breeding pair.

Soon after the male and female were released in the aquarium, they showed rapid swimming movements. After swimming for about 12 min, the pair positioned themselves next to each other (Figure 1 *a*). The male 'nosed' the female at the tail region for more than 1 min (Figure 1 *b*). It then moved upwards to the belly region of the female and nosed the female for about 30 s (Figure 1 *c*). It then moved to the other side of the belly and nosed for about 1 min (Figure 1 *d*). The male then curved its tail and moved it rapidly, and nosed the female all over the body for about 3 min (Figure 1 *e*). The female began to move away and the male followed her (Figure 1 *f*). The male tried to get underneath the female's body by pushing with its head at the cloacal region of the female (Figure 1 *g*). The male having made room to get underneath the female's body, moved slowly towards the head region of the female from the ventral side. This took about 2 min (Figure 1 *h*). Then the male tried to grasp the female's forelimb with its forelimb (Figure 1 *i*). After about 13 s, the male succeeded in establishing a firm grip. The amplexed pair began their nuptial dance by swimming with vigorous tail movements. During the nuptial dance, the cloaca of both male and female partners swells and protrudes (Figure 1 *j*). The cloaca of the male opened for sperm sac expulsion. The first batch of sperm sac expulsion took about 15 min. The sperm sacs, after floating for a few minutes, settled at the bottom of the aquarium. While the sperm sacs floated after expulsion, the female opened her cloaca and sucked them. This took about 6 s. Once the first batch of sperm sacs was sucked, the male released more sperm sacs for about 4 s. The pair remained in amplexus for about 30 min. Then the pair separated and swam freely. The females started laying eggs after free swimming. The egg-laying was seen after about one and half hours of the sperm sac entering the cloaca of the female. The egg-laying continued for about 210 min. The total number of eggs laid was 47. The fertilized embryos could be seen clearly inside the jelly envelope (Figure 1 *k*).

This was the observation for one breeding pair. Forty-six breeding pairs were observed, timed, filmed and photographed. Courtship and amplexus always took place at night. Once the entire sequence, starting from courtship to completion of egg-laying was studied, the adults along with their fertilized eggs were released back in their habitat.

In 45 out of 46 amplexing pairs, the females were longer [178.28 mm ± 10.58 (range: 145–195 mm)] and heavier [29.68 g ± 4.03) (range: 21–40 g)] than the males [157.56 mm ± 9.76 (range: 145–176 mm) and 19.94 g ± 2.45 (range: 15–25 g)]. During the breeding season, the skin of the males was shiny and smooth in

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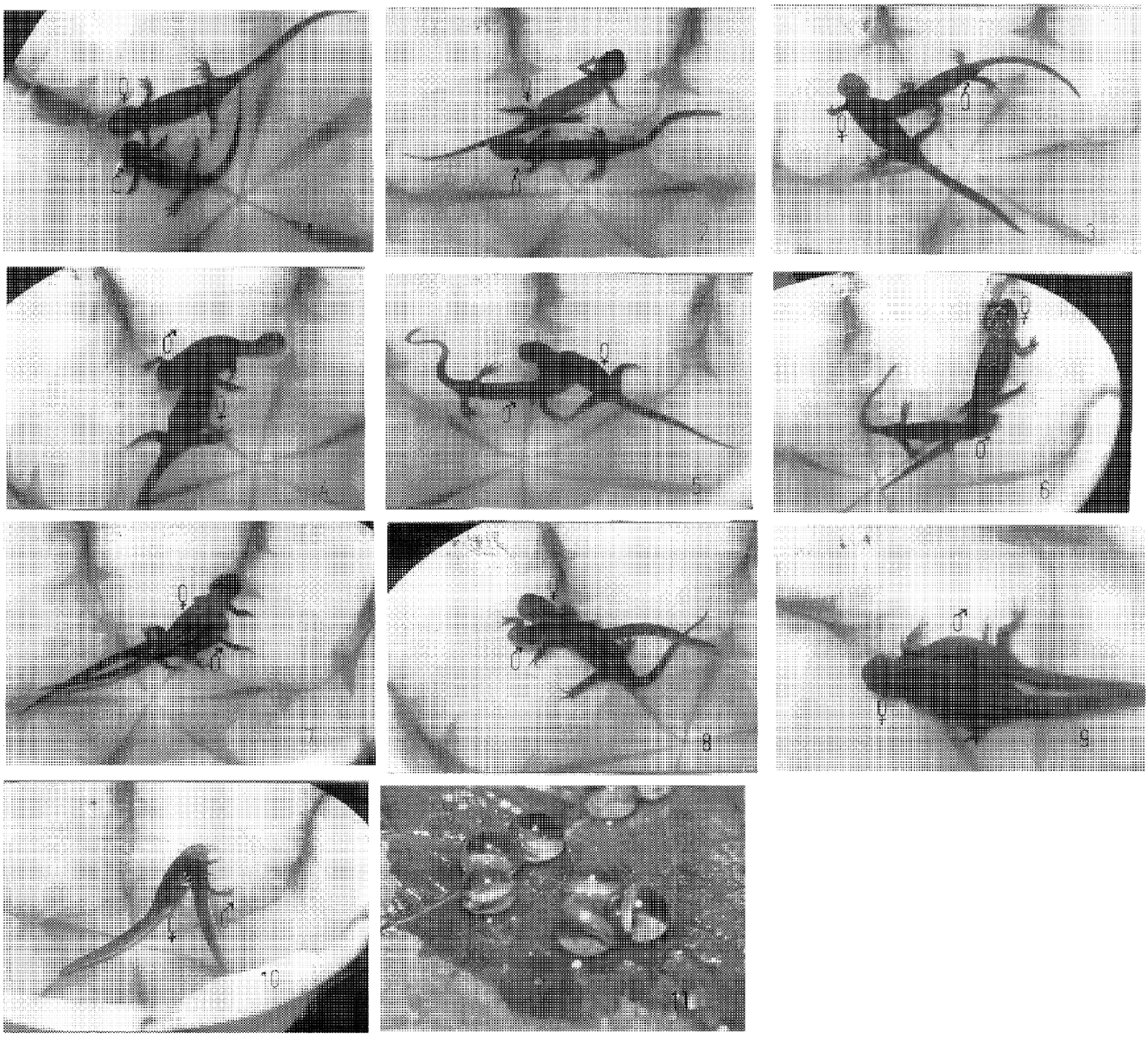

Figure 1. ***a***, The swimming male and female lie next to each other; ***b***, Male noses the tail of the female; ***c***, Male noses the belly of the female; ***d***, Male noses the other side of the belly of the female; ***e***, male with its curved tail moving rapidly, noses the female all over her body; ***f***, Female moves away from the male and the male follows her; ***g***, Male gets underneath the female by pushing with its snout from the cloacal region of the female; ***h***, Male settles underneath the female; ***i***, Male grasps the female's forelimb using its forelimb; ***j***, Swimming amplexed pair with swollen and protruded cloaca; ***h***, Fertilized embryos covered by transparent jelly envelope.

comparison with the females. The females were easily identified by their distended belly. In males, only the cloacal slit becomes orange coloured whereas in the females the entire conical-shaped cloaca becomes orange coloured.

There was a wide variation in the timing from the beginning of courtship to egg-laying, among the 46 breeding pairs. The timing of courtship was 32.42 min ± 14.15 (range: 14–77 min), amplexus 80.04 min ± 29.94 (range: 29–140 min), free swimming 447.11 min ± 252.50 (range: 48–917 min) and egg-laying 1523.95 min ± 682.90 (range: 210–3690 min).

The clutch size varied between the pairs, 116.78 ± 44.87 (range: 47–196). The clutch size was dependent on the length and weight of the female. It showed positive correlation with total length ($r = 0.81$, $n = 46$) and body weight ($r = 0.91$, $n = 46$). Under natural conditions, the eggs were laid singly and attached to grass blades by the outer sticky jelly envelope. The fertilized eggs were transparent. The developing embryos could be seen clearly in the jelly envelope. Egg-laying was observed only once for the females in all cases, while the males tried to mate several times.

The earlier study on the breeding of *T. verrucosus* was based on 4 breeding pairs and did not have in-depth analysis of the timing of courtship, mating and egg-laying[14]. The present study shows that the timing varies between pairs. Unlike in other amphibians, egg-laying in salamanders takes a long time. Although nuptial dance and ventral amplexus have been reported[15–20], the studies were not for the Indian species. They were either from Nepal[15,16] or laboratory studies conducted in Europe. The present study clearly indicates that the animals do not seem to have any alternate mating strategy as was being speculated[20].

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Middle Cretaceous carbonate build-ups and volcanic seamount in the Shyok suture, Northern Ladakh, India

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Along the Shyok suture zone in northern India, a ~ 200 m thick limestone succession has been identified as a carbonate platform margin with build-ups. This limestone succession is directly overlying volcanic rocks of island arc affinity. The partly recrystallized reefal limestone which rests on a volcanic seamount or ridge contains abundant rudists, corals, gastropods, algae and a rich orbitolinids assemblage of Late Aptian–Early Albian age. This faunal assemblage reflects a shallow-water tropical environment for the carbonate build-ups and also shows a close affinity with those recorded from the Yasin Group in north-western Pakistan. The presence of Late Aptian *Horiopleura,* Radiolitidae and different forms of *Orbitolinae* and other microfaunal assemblage in the reefal limestone, dates the underlying volcanic edifice as Middle Cretaceous or older.

Rudists, nerineids, corals and foraminifers of Lower Cretaceous age are widely distributed as a reefal framework all along the tropical and subtropical Euro–African–Asiatic regions of the northern margin of the Tethys. However, prior to our findings, the Cretaceous carbonate build-ups associated with submarine volcanism have only been reported in the Caribbean, Sicily in Italy, Yasin in Pakistan and from dredged samples from a seamount in the central Pacific region.

IN northern India, the Ladakh block is in an intermediate position between the Indian Plate in the south and the Karakoram Plate in the north. To the west, it is separated from the Kohistan Complex by the Nanga Parbat–Haramosh syntaxis and to the east, it is cut-off from the Lhasa block by the Karakoram fault (Figure 1). The Ladakh block lies along a critical geological juncture and is characterized by two suture zones – the Indus and Shyok (Figure 1) – that mark the closing of different branches of the Tethys ocean and finally the collision of India with Asia, 60–50 Ma. The Shyok suture zone lies to the north of the Indus suture zone and is interpreted as an oceanic suture[1] or the relic of a back-arc basin[2].

The rocks of the Shyok suture zone, trending north-west-southeast (Figure 1) across the Nubra–Shyok valley, occur in intensely deformed tectonic slices between the Ladakh batholith, to the south-west and the Kara-

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