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Developmental mode in white-nosed shrub frog *Philautus cf. leucorhinus*

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Direct development in amphibians bypassing intermediary tadpole stage has behavioural evolutionary and ecological significance. This paper presents direct development in *Philautus cf. leucorhinus*, while comparing with other congeners of the Western Ghats.

Keywords: Amphibians, direct development, *Philautus cf. leucorhinus*, shrub frogs, Western Ghats.

AMPHIBIANS exhibit remarkable variations in development from egg to adult. One such extreme modification is direct development, wherein free-swimming tadpole stage is completely eliminated and eggs hatch into baby frogs, resembling the adults except for their size. Species adapted completely to terrestrial living generally exhibit direct development. The advantage of being adapted to such development includes avoidance of predation, which is prevalent in aquatic media, parental care and more importantly, dependency on water body for development and complex metamorphic processes¹.

Direct development bypassing an aquatic, free-swimming tadpole stage in amphibians seems to be the fastest reproductive mechanism adapted in vertebrates and specifically among anamniotes^{2,3}. Based on site of egg development, as many as 29 breeding types have been recorded in amphibians². Nevertheless, direct development has an evolutionary significance in adapting to non-aquatic habitats, resembling oviparous development of birds and reptiles.

The Western Ghats, a hill range on the west coast of India, with rich biodiversity harbours as many as 137 amphibian species. Among these, *Philautus* genus (Anura: Ranidae: Rhacophorinae), commonly known as Oriental shrub frog has direct development from egg to adult.

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About 90 *Philautus* species have been recorded throughout the world and over 30 species have been described from India, among which 23 are from the Western Ghats⁴⁻⁸. Rao⁹ has reported tadpole stages in '*Philautus leucorhincus*' or '*Philautus leucorhyncus*', *P. hypomelas*, *P. nassutus*, *P. pulcher* and *P. variabilis*. Later, Patil and Kanamadi³ provided a detailed description of direct development in *P. variabilis*. Similarly, Bossuyt and Dubois⁴ rejected the tadpole descriptions in *P. hypomelas* by Rao⁹, which is supposed to be of the genus *Nyctibatrachus*. Subsequently, direct development was reported in *P. glandulosus*^{10,11} and later in *P. bobingeri*, *P. bombayensis*, *P. graminirupes*, *P. nerostagona*, and *P. tinniens*^{4,6,7,12,13}. The present communication reports direct development in white-nosed shrub frog, *Philautus* cf. *leucorhinus* Lichtenstein and Martens, 1856, is contrary to earlier reports of tadpole stage in its development^{9,8} and only the third species from the Western Ghats to be described completely.

Philautus cf. *leucorhinus* is a small-sized arboreal shrub frog, coloured pale to dark brown on the dorsum with varied black patches, and resembles the earlier description of the species^{8,14-16}, (S. K. Dutta, pers. commun.). It has a hexagonal white spot on the snout tip and a dark band between eyes passes through a distinct tympanum till the shoulder. Prominent supratympanic fold. Throat speckled with brown in male. Toes half-webbed. Calling male of *P.* cf. *leucorhinus* (SVL: 28.9 mm; Figure 1 a) was observed from a tree trunk at a height of 2 m facing down, whereas the female (SVL: 33.7 mm; Figure 1 b) was observed less than a metre away at 0.3 m from the ground on a *Myristica malabarica* tree stilt root. This was observed at 2015 h IST on 14 June 2004 with incessant rain (air temperature: 28.8°C and relative humidity:

97%) from Yenneholé, Sagar taluk, Shimoga (563 m amsl; 13°57'54"N, 74°43'37"E). Pairs got amplexed axially at 2315 h (Figure 1 c) and female carried the male to ground level. All eggs were laid on a leaf of *Hopea ponga* less than 10 cm from the ground, between two rocky boulders by morning (0600 h). Male and female got separated after the spawning process. Later eggs were collected ($N = 51$) and developmental stages were observed in the laboratory (Figure 1 d) at an interval of 24 h.

Diameter of eggs was 3.5 ± 0.16 mm, with a thin gelly coat. Eggs were unpigmented with uniform cream colouration. Pole differentiations followed by the process of cleavage, gastrulation and neurulation were observed within 24 h. Neural folds were seen at 24 h (Figure 2 a). Neural fold and neural plate elongated and formed into neural tube and at 72 h, head and tail buds were formed at the anterior and posterior ends of the neural tube respectively (Figure 2 b). Hind limb and forelimb buds were seen as embedded beads on the surface of the egg near the neural tube attachment region. Head, tail and limb buds elongated and were more pronounced at 96 h and eyespots as a bulged region on the lateral positions on the head were observed (Figure 2 c). Tail was curved to the left in all the eggs. Pigmentation was observed on the mid-dorsal line at 120 h and it spread initially along the neural tube, then on upper and lower portions of the abdomen during the entire developmental process (Figure 2 d). At 144 h, head and tails further elongated and pigmentation intensity also increased. Tail was translucent, flat and membranous. During the same period, pigmentation of iris and heart beats were also observed. Tail and head region differentiated further during 168 h. Hindlimb bud elongated, with recognizable differentiation of femur, tibia and foot. At 240 h, mouth-

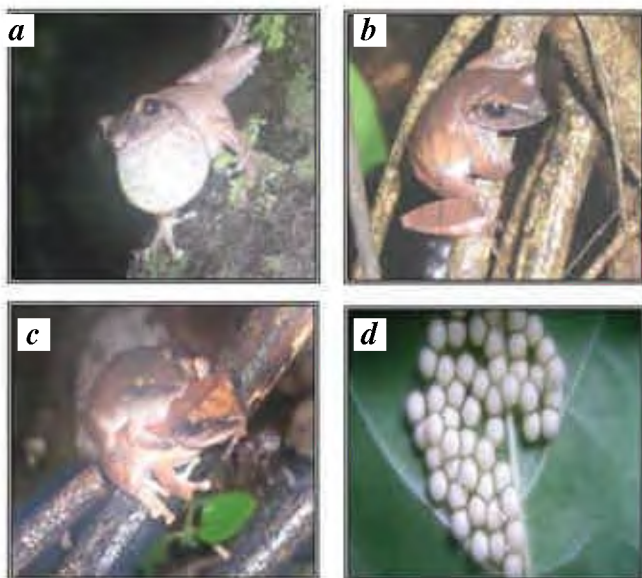


Figure 1. Amplexus and egg deposition of *Philautus* cf. *leucorhinus*. a, Male (SVL: 28.9 mm); b, Female (SVL: 33.7 mm); c, Amplexed pair and d, Egg clutch (3.5 ± 0.16 mm, $N = 51$).

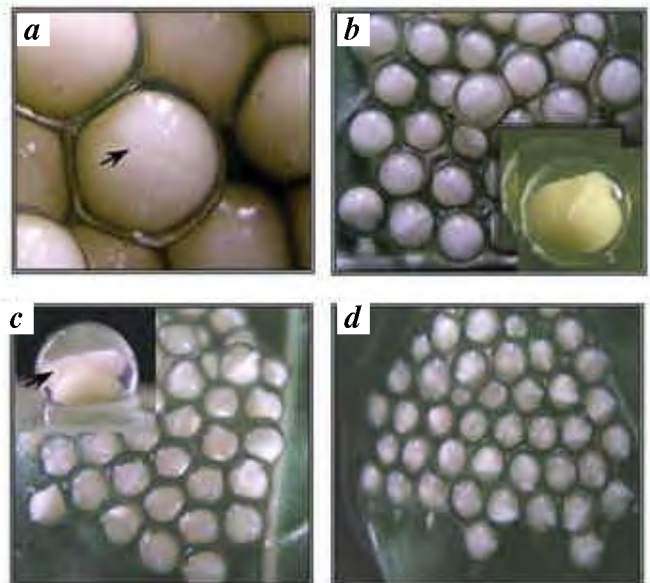


Figure 2. Developmental stages of *P.* cf. *leucorhinus* till day 5. a, Neural fold at 24 h; b, Head, limb bud and tail differentiation at 72 h; c, Curved tail bud, bead-like limb buds at 96 h and d, at 120 h.

Table 1. Various features of direct developmental pattern in *Philautus* of the Western Ghats

Species	SVL (mm)	Eggs	Days to hatch	Mode*	Habitat	Parental care	Egg diameter (mm ± SD) (N)	Locality	Geographic coordinates	Observation	Reference
<i>Philautus cf. leucorhinus</i>	♀: 33.7 ♂: 28.9	51	19	20	Above ground, (10 cm) on wet leaves, between rocks	Pair separates after spawning	3.5 ± 0.16 (51)	Yenneholé, Sharavathi River, Karnataka	13°57'54"N, 74°43'37"E, 563 m asl	14 June 2004	Present study
<i>P. glandulosus</i>	♀: 25; 24.5–26# ♂: 21; 20.4–22.9#	12–18; 48#	22; 28#	20	Above ground (1.5–3 m) on wet leaves	Pair separates after spawning	4.9 ± 0.9 (14); 4.4 ± 0.2 (48)#	Kudremukh, Karnataka; Kalpatta, Waynaad, Kerala#	13°10'–13°26'N, 75°05'–75°10'E, ~600 m asl; 11°38'N, 76°08'E, 1000 m asl#	12 August 2000 28 June 1997#	10, 11#
<i>P. variabilis</i>	♀ and ♂: 30.0 ± 4.5	54–62	12	20	Above ground	Eggs beneath abdomen of female, chasing intruding males	4.1 ± 0.2 (30)	Dharwad, Karnataka	15°17'N, 75°03'E, ~780 m asl	June–August 1994–96	3
<i>P. nerostagona</i>	♀: No report ♂: 30.1–34	41	20	20	In ~10 cm deep tree hole, 10 m above ground	–	4.5 ± 0.3 (41)	Kalpatta, Waynaad, Kerala	11°38'N, 76°08'E, ~1000 m asl	20 July 2000	6
<i>P. tinniens</i>	♀: 25 ♂: No report	–	–	17	On ground	–	–	Nilgiri hills, Tamil Nadu	11°24'N, 76°42'E, ~1800+ m asl	–	4, 18
<i>P. bombayensis</i>	♀: No report ♂: No report	26–27	–	20	Above ground, wet leaves	–	–	Sakleshpur, Karnataka	12°59'N, 75°43'E, ~850 m asl	29 July 1996	12
<i>P. bobingeri</i>	♀: 23.5–26 ♂: 21.3–24.8	24	18	20	Acacia tree, 4 m from ground	–	3.9 ± 0.4 (24)	Ponmudi hills, Kerala	8°45'N, 77°08'E, 1000 m asl	July 1999	7
<i>P. graminirupes</i>	♀: 27.3–29.4 ♂: 21.4–22.6	30–38	24	17	On ground, grass clump, rocky crevice	–	4.9 ± 0.5 (38)	Ponmudi hills, Kerala	8°45'N, 77°08'E, 1000 m asl	7 July 2000	8

*Based on Duellman and Trueb².

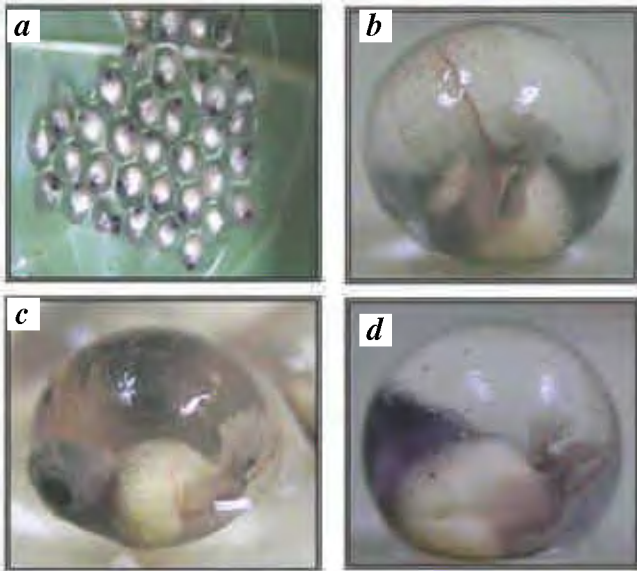


Figure 3. Developmental stages of *P. cf. leucorhinus* till day 13. *a*, Mouth differentiation at 264 h; *b*, Toe demarcation, translucent tail at 264 h; *c*, Toe digit differentiation at 288 h and *d*, Elongation of toe at 312 h.

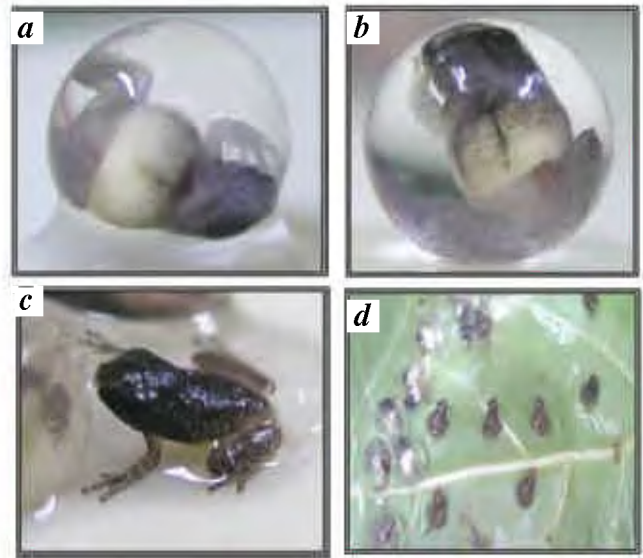


Figure 4. Developmental stages of *P. cf. leucorhinus* till day 19. *a*, Finger differentiation, limb bends at 384 h; *b*, Tiny froglet, with reduced tail at 408 h; *c*, Hatched froglet at 432 h and *d*, Froglets at 432 h.

parts were observed, but prominently into upper and lower lips during 336–384 h. Forelimb buds elongated during this period. Intermediate developmental stages are illustrated in Figures 3 and 4. Considerable reduction in yolk and proportional enlargement of head and elongation of hindlimb was observed. Toes emerged at 312 h, and differentiated by 336 h. By 384 h, fingers clearly differentiated and movements inside the jelly were observed. Tail and yolk got remarkably reduced during 432 h and tiny froglets measuring 4.54 ± 0.07 mm emerged out after 19 days (Figure 4 *c* and *d*).

Analysis of the intra group developmental stages of *P. cf. leucorhinus* with *P. glandulosus* and *P. variabilis* from the Western Ghats, shows that within 144 h, major developmental stages like demarcation of head, mouth, eye, fore limbs and hind limbs take place and the remaining period (that varies from species to species) is utilized for differentiation of fingers, toes, mouth parts, eyes and overall morphology of the body with utilization of yolk and regression of tail, which supposedly has a respiratory function¹⁷. Except for the variation in hatching periods, developmental pattern remains the same. However, the significant differences observed between these three species in female sizes, number of eggs and hatching periods might be attributed to the influence of environmental factors associated with their microhabitats. Table 1 compares the pattern of direct development in various *Philautus* species available in the Western Ghats. It was observed that the number of eggs in a clutch depends on the size of the female ($r = 0.85$, $P < 0.05$). Size of female, egg diameter and period of hatching are negatively influenced by each other; however, they are not statistically significant. All these

observations were made during June to August (the period of the southwest monsoon in this region) highlighting the breeding period of the species.

There is an urgent need to look into the molecular, developmental and evolutionary aspects in detail to understand the phylogeography of the species from the Western Ghats, considering frequent reporting of new species in *Philautus* genus (since 2001, six species out of eight anurans were discovered from the Western Ghats).

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