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# BIOLOGY OF *XYLOTRECHUS BASIFULIGINOSUS* HELLER- A BORER OF KHARSU OAK TREES IN THE WESTERN HIMALAYA

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**ABSTRACT**

**Biology of *Xylotrechus basifuliginosus* (Cerambycidae: Coleoptera: Clytini) was studied on its host Kharsu oak *Quercus semecarpifolia* Smith. It has an annual lifecycle with five larval instars. Beetles emerge at the onset of the rainy season (June-July) under natural conditions at 2600-2800 m. Females soon after copulation lay up to 34 eggs in cervices and covered depressions on the bark of oak trees. The larval period is 269 days under natural conditions. The growing larvae feed in the sapwood up to December and thereafter go into hibernation (end of December-mid of March) in larval galleries. Pupation is triggered by sudden rise in temperature in spring (end of March), pupal period is ~94 days. The beetles emerge from the pupal chamber by chewing the bark and making a circular exit-hole (5 mm dia). The adult morphology (both sexes) and male genitalia, are described and compared with its congeners *X. smei* and *X. stebbingi* also known from northern India, besides the morphology of egg, larval and pupal stages.**

**Key words:** *Xylotrechus basifuliginosus*, Cerambycidae, *Quercus semecarpifolia*, Garhwal, stem borer, oak, male genitalia, seasonality, lifecycle, moist temperate forest, feeding pattern.

The genus *Xylotrechus* is Holarctic in origin and richest genus in Southeast Asia (Cherepanov, 1988) with at least 180 species of the genus *Xylotrechus* known across the globe (Ohbayashi and Niisato, 2007). The adults of this genus generally have robust form, antennae are filiform and less than the half of body length, elytra are generally tapered or rounded and femora are not distinctly spined. The larval habits and host plants preferences of *Xylotrechus* spp. are various and the major hosts include the genera *Quercus* (*Q. semecarpifolia, Q. leucotrichophora*), *Picea smithiana, Pinus* sp. and *Salix* spp. (Beeson, 1941; Linsley, 1964; Mathur and Singh, 1959). Beeson and Bhatia (1939) described the biology of certain species of genus *Xylotrechus* in Indian forest records. *X. basifuliginosus* is a black coloured beetle (15 mm), which inhabits moist temperate forests of Chakrata hills (Dehradun district) in Garhwal region of Uttarakhand state and Chopal (Shimla) and Dharamsala (Kangra) both in Himachal Pradesh state, in the Indian Western Himalaya between ~1500-3000 m. This species is a mainly borer of kharsu oak (*Quercus semecarpifolia*) which not only causes tree mortality in Western Himalaya (Singh, 2011; Kariyanna *et al*., 2017) but also considerably deteriorates the quality of timber and wood damaged by larvae is rendered totally useless for commercial purposes and hence preparing marketable timber fraught with difficulties. Previously Singh (2011) identified this species as a secondary borer causing damage to kharsu oak in Chakrata Forest Division, Uttarakhand. K.M. Heller firstly described the morphology of adults of *X. basifuliginosus* in 1926. However, the morphology of remaining life stages of eggs, larva, and pupa have yet to be described, so this study was undertaken to fill this gap. As a result, this study will serve as a foundation for interpreting and comprehending other parts of this borer's biology, as well as assisting in the management and control of this borer in the Western Himalayan region.

## MATERIALS AND METHODS

The present study was carried out from 2018-2020, in the Deoban Reserve Forest (N 30.74806; E 77.86639; 2606-2815m) of the Chakrata Forest Division, Dehradun district, Uttarakhand state in India. In order to study the biology of *X. basifuliginosus*, borer infested kharsu standing and fallen trees and logs, were marked and studied. 3-5 borer infested branches of fallen and dead kharsu oak trees were cut into logs in fortnight and chopped into pieces to record the number the larval stages and their duration period up to the formation of pupa. While during emergence in June-July in field condition, observations were taken after every week. Data was recorded on the number

and sex of the emerging beetles, copulation, mating and egg laying.

Morphological studies on *X. basifuliginosus* eggs, larvae, pupa and adults were conducted in the Forest Research Institute laboratory in Dehradun, Uttarakhand, India. Digimizer 4.0 image software and Olympus SZX16 stereoscopic microscope were used to study and measure the morphology of different developmental stages. The width of head capsules of different larval instars were measured with ocular micrometer. Final instar larva was described for the morphological study. For morphological studies of adults, the emerged adults were preserved by treating with 10% KOH for overnight to soften the chitin and dissolve the soft parts. Specimen thus treated was kept in clove oil and permanent mount in Canada balsam were prepared. The length, width and other morphological character of pupa was also studied under microscope. Besides two congeners (*X. smei* and *X. stebbing*) of *X. basifuliginosus* that also occur in the Western Himalaya having overlapping distributional ranges were compared morphologically with *X. basifuliginosus*. Male genitalia of *X. basifuliginosus* and *X. smei* were studied by following Ehara (1954) method and compared with four Japanese *Xylotrechus* spp.

## RESULTS AND DISCUSSION

### Biology

Emergence of beetles occurs during June and July when the mean temperature and relative humidity are above 22°C and 59%, respectively. Mating takes place just after the emergence during day time, with peak time being 11:00-15:00 hr on the stems on which they emerged or on the foliage exposed to bright sunlight. Copulation lasts for about 8 to 10 min with repeated copulation by the same pair. While at rest the females stretch out their ovipositors and twist them backwards and forwards for up to an hour. The next day after mating oviposition takes place in June- July. The female after mating moves continuously on the Kharsu stems searching with its ovipositor by stretching it with full length for suitable cracks and crevices in the bark of stem to lay eggs. Eggs are partially exposed to exterior and partially inserted in the bark. According to Shylesha (1992), in *Xylotrechus quadripes* under normal conditions each female deposits one or two eggs at a time but 1 to 10 eggs have been noticed by Ramaiah (1983). The maximum number of 34 eggs were laid within 24 hr during June (25.1°C, 56% RH) on the first day after emergence and the number of eggs laid steadily decline to thereafter to 2 on the 8th day after emergence. A total of 32 eggs ($\bar{x}$) are laid by single female in its lifetime whereas a total of 28 eggs were counted in single virgin female (Fig. 1a,b). Overall hatching % was 78.71%. Hatching of eggs takes 7 days in summer (June; 23.7°C, 63% RH) at Deoban, Chakrata Forest Division, Uttarakhand).


Fig. 1. Eggs inside the abdomen of a virgin female

Duration of first instar larval stage is 24-29 days (27.1 days in July). Second instar larval duration is 36-44 days (41.6 days in August-September) whereas third instar lasts for 49-57 days (56.4 days in September-October). Fourth instar larval stage duration is 66-71 days (69.9 days in November-December). 5th instar larval stage duration is 71-76 days (74.6 days from December-March). Fifth instar larva feeds in the sapwood and go into hibernation from end of December to March inside the larval gallery (2.2-10.1°C, 40-66.8%RH). With the onset of warm weather, larva becomes active and starts boring in the wood from mid-March of the following year.

Pupa takes 81-97 (94 days) with the callow adult taking 6-7 days to complete sclerotization and remains in the chamber for 3-4 days before emergence. The emergence of beetles of the next generation takes place during June-July of the following year. Adults chew a 5mm dia exit hole in the bark once the larvae have completed their development. Overall, the mean male and female ratio of 3 years was 1.7:1. The mean data of longevity of 3 years indicated that the females live moderately longer (12.53± 1.92 days) than male adults (10.06± 2.28 days).

### Taxonomy and morphology

The freshly laid eggs are elongate, elliptical in shape and milky white and one end more acutely pointed than the other (Fig. 2). Later the eggs become slightly yellowish and bloated (Fig. 3). The eggs measured 1.84± 0.05 mm long and 0.59± 0.06 mm wide. 1st instar larval length varies between 1.83-1.96 mm and width from 0.36-0.52 mm and whitish; while 2nd instar

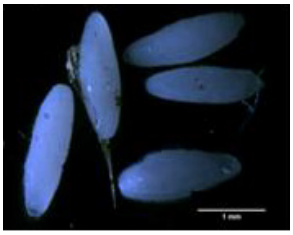

Fig. 2. Eggs

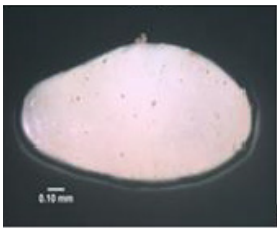

Fig. 3 Egg before hatching

measured 3.80-4.41x1.10-2.00 mm, with colour being pale to whitish-yellow, robust and thick; 3rd instar measured 5.0-9.20x 2.8-3.91 mm and yellow, while 4th instar larva is cylindrical, winkled and yellow, measuring 12.0-17.2x 4.0-5.0 mm; 5th instar was 19.4-24x 4.50-5.50 mm and yellow; all are apodous. The width of head capsules ranges from 0.61± 0.07 to 4.16± 0.11 from I to V larval instars. Just before pupation, the larva contracts, causing the intersegment skin to wrinkle and the abdominal segment to progressively taper, with the tapering most noticeable in the 4th and 5th segments. The 5th instar has its head trapezoidal, glabrous, depressed, and creamish with rounded edges; its mouth frames are dark brown and strongly pigmented (Fig. 4c,d), and mandibles black, short, robust, and have gouge-like cutting edges with a dark brown basal apical portion and a row of setae (Fig. 4e). Head capsule is with occipital foramen which is divided into small anterior and large posterior portion by tentorial bridge. Prothorax is thick with yellow pigmentation having distinct proalar plates and short hairs on the lateral region. The dorsal surface consist of large, rectangular, sclerotised plate called pronotum which is anteriorly shinning, glabrous or velvety pubescent. Abdomen ten-segmented, with its first six to seven segments of tergal and sternal areas similar in appearance; these usually have rounded structure called 'ampullae' which are broad, fleshy oval protuberance and are parallel in dorsal and ventral surface (Fig. 4a,b). These help larva in moving along inside the gallery. The anal region is trilobite with short fine hairs (Fig. 4f).

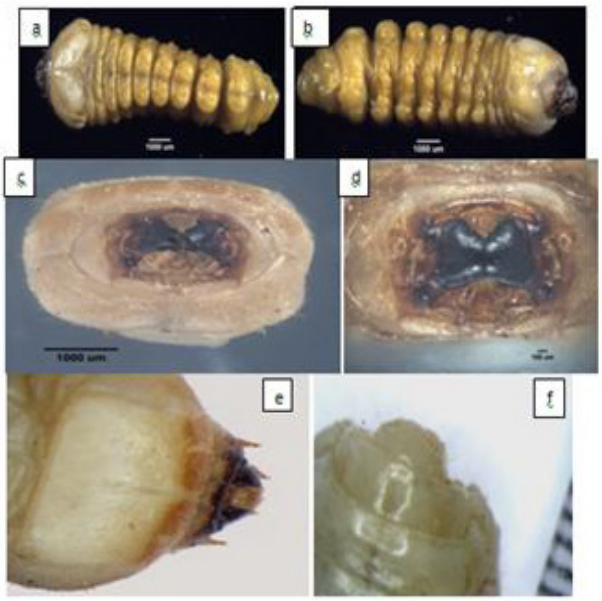


Fig. 4. V instar larva of *X. basifuliginosus* (a) Ventral view (b) Lateral view (c) Frontal view (d) Mouth parts (e) Ventral view of mouth parts (f) Last abdominal segments

Pupa is exarate type, closely resembling adult both in shape and size; and measuring 17.75± 0.95 mm long and 5.25± 0.50 mm wide, yellow, with head round, abruptly hooked at their apex and above carinate along the cutter side, pubescent at the base, labrum longitudinally striate, with short recumbent setae, clypeus transversally striate, pubescent at sides, forehead with V-shaped carina, the tip of which reaches the level of lower margin of the eyes and the ends exceed the level of antennal supports forming an oval-elongate flat tubercle and reaches the hind margin of the head (Fig. 5a). Antennae are pale yellowish in colour, short, and situated on the lateral side of the body, reaching up to the metanotum where they terminate above the elytra and wing (Fig. 5b). Mesonotum and metanotum are glabrous, shining and have a pronounced scutellar groove (Fig. 5e). The abdomen is fairly elongate, inflated, regularly narrowed and bowed towards the tip, widest at segment IV; sternites lack spinules, whereas 1st-7th tergites have several sparsely acicular black and short spinules (Fig. 6d); spines are stout, more strongly curved on the 7th to 9th abdominal tergites (Fig. 5c, d). 6th-7th acicular spinules are transversely arranged along

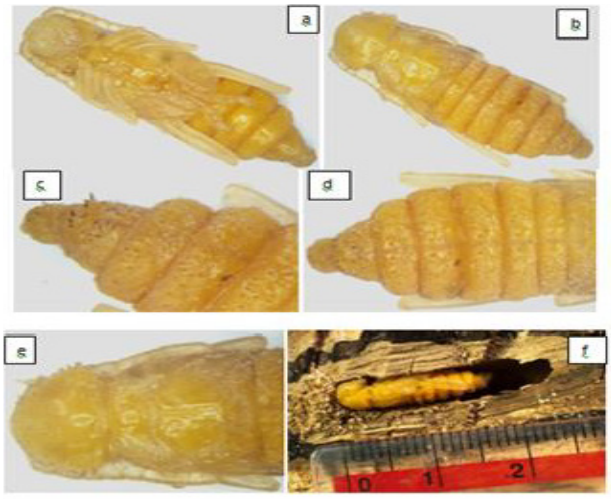


Fig. 5. Pupa of *X. basifuliginosus* (a) Ventral view (b) Dorsal view (c) Tergite with spinules (d) Abdominal tergites with spines (e) Dorsal view of pronotum and thorax (f) Pupa inside pupal chamber

the centre and 5th acicular spine is transversely disposed along the hind margin. The apex of the 8th tergite is somewhat inflated, with four tiny spines towards the rear border. The pupal chamber in 38 mm long, 6 mm wide, free of frass and formed at a short depth in the sapwood (Fig. 5f).

Heller described the adult *X. basifuliginosus* in 1926, mainly by comparing it with the genus *Perissus* (Cerambycidae: Clytini) i.e. *P. quercus* occurring in the same area with which it was perceived by him to be confused. Heller's (Heller, 1926) morphological description of *X. basifuliginosus* is not comprehensive and difficult to interpret because of the terminology used. The distinctive characters include: colour varies from black to dark brown with grey pubescence on the head, thorax and abdomen region. Elytra are dark brown and covered with grey pubescence, with three creamish coloured transverse bands in male, while these bands are yellow in female (Fig. 6, 7). These bands are present on the subbasal, median and sub-apical area of elytra, while the elytra is tapered at the end. Mandibles are triangular, black, short, pointed and posses short brown setae. Head and pronotum is seperated by pale band. Antennae is 11 segmented in both the sexes, filiform type, black in male and brown coloured in female, inserted in the middle of the frons and measures less than the half of the body length. The antenna are attached to the head capsule by a large basal membrane which is often regarded as the 'basal segment'. Pronotum is dark brown colour and densely covered with brownish pubescence. Abdominal sternites are densely covered with white and yellow alternate bands in female and white-black bands in males which are covered with long erect hairs. Legs are hairy, dark brown in colour, strong and moderate size. Femur of foreleg and midleg is stout and longer than tibia. Shape of hind leg is slender and slightly shorter than tibia. Fore, mid and hind tibia have tibial spurs. Spur of hind tibia is long. Tarsus is four segmented. First meta-tarsomere is longer than the total length of remaining tarsomere and twice as long as 2nd and 3rd combined of remaining tarsomeres. The last tarsal segment has pair of claws. Hind femora nearly reaches but does not exceed the elytral apics.

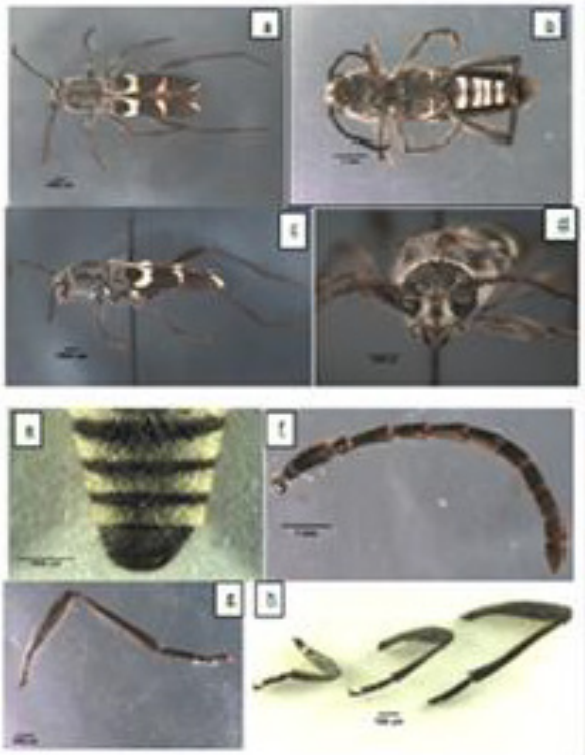

Fig. 6. Male *X. basifuliginosus* (a) Dorsal view (b) Ventral view (c) Lateral view (d) Frontal view (e) Abdominal sternites (f) Antennae (g) Hindleg (h) Foreleg, Midleg and Hindleg

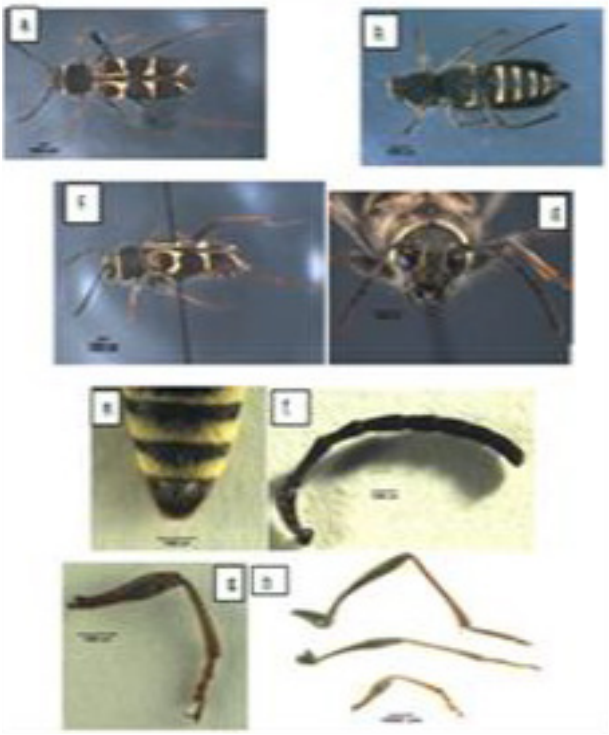

Fig. 7. Female *X. basifuliginosus* (a) Dorsal view (b) Ventral view (c) Lateral view (d) Frontal view (e) Abdominal sternites (f) Antennae (g) Hindleg (h) Foreleg, Midleg and Hindleg

A comparison of adults of *X. basifulginiosus* with congeners *X. smei* and *X. stebbingi* revealed the following: these are distinguished by the body length, spots on pronotum, colour pattern on elytra, prothorax and underside of the abdomen (Fig. 8); *X. stebbingi* is largest (12-18 mm) followed by *X. basifuliginosus* (10.5-19 mm) and *X. smei* (10-17mm), respectively in

body length. Pronotum is without spots on the disc in *X. basifuliginous* (Fig. 8a) while *X. smei* has two spots (Fig. 8b) and *X. stebbingi* has four spots (Fig. 8c). *X. basifuliginous* has three distinct creamish transverse bands on the elytra, while the size of the three bands are narrow and short in *X. smei* and are interrupted and broken in *X. stebbingi*. Prothorax of *X. basifuliginosus* is black, reddish in *X. smei* and grey with brown spots in *X. stebbingi*. While on the ventral side of abdomen these three species show variation in the transverse bands which are alternately white and black in *X. basifuliginosus* , pale coloured spots or bands in *X. smei* and are ashy white spots in *X. stebbingi* instead of bands. Legs and antennae are black and densely covered with grey hairs in male of *X. basifuliginosus* whereas it is reddish brown and densely covered with grey hairs in male of *X. stebbingi* and *X. smei*.

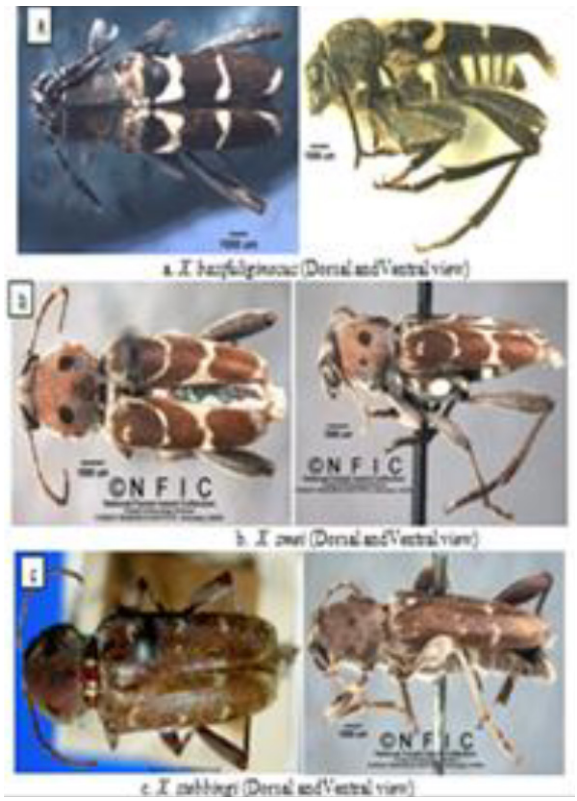


Fig. 8. Comparison of morphology of adult of three species of *Xylotrechus* (a) *X. basifuliginosus* (b) *X. smei* (c) *X. stebbingi*

Male genitalia- *X. basifuliginosus* vs. *X. smei;* In *X. basifuliginosus* the tegmen (Fig. 9a) measures 1.5x 0.98, with lateral lobes 0.13x 0.08 mm, narrowest at the apical and gradually constricted towards the apex, sparsely covered with short and fine brown setae near apex, with long and thick dark brown setae 0.49 mm long apically' tegmental ring 0.96x 0.58 mm, wide and slightly narrow or V- shaped towards the base; lateral


Fig. 9. Male genital parts of *X. basifuliginosus* (a) Tegmen (b) Median lobe (c) 8th Sternite (d) 8th Tergite

lobes smaller than the roof and apex is rounded. Median lobe (Fig. 9b) is slightly curved, relatively long, 2.08x 0.49 mm, with median orifice slightly projected or pointed, exposing the reflexed apical part of the ventral plate. Median struts are slightly curved and longer than median lobes and separated from each other. 8th sternite (Fig. 9c) measures 0.67x 0.98 mm wide, semicircular, densely covered with long brown setae present at apical half. Spiculum gastrale 1.23 mm long, Y-shaped, slender and longer than the 8th sternite. 8th tergite (Fig. 9d) 1.43x 1.26 mm, densely covered with short and brown-coloured setae which are long apically. In contrast, *X. smei* the tegmen is 1.44x 0.61 mm (Fig. 10a); lateral


Fig. 10. Male genital parts of *X. smei* (a) Tegmen (b) 8th Tergite (c) 8th Sternite (d) Median lobe (e) Spiculum gastrale

lobes 0.15x 0.08 mm, narrowest at the apical gradually constricted towards the apex, covered with short and fine brown setae near apex, with long and thick dark brown, 0.34 mm long setae apically. Tegmental ring 0.65x 0.48 mm, somewhat U-shaped towards the base. Lateral lobes larger than the roof and apex is rounded. Median lobe 1.83x 0.45 mm, strongly curved with median orifice slightly projected or pointed, exposing the reflexed apical part of the ventral plate (Fig. 10d). Median struts strongly curved and longer than median lobes and separated from each other. 8th tergite 1.25x 1.14 mm wide, sparsely covered with short and brown coloured setae (Fig. 10b). 8th sternite (Fig. 10c) 0.97x 1.9 mm, semicircular, sparsely covered with long brown setae present at apical half. Spiculum gastrale 1.38 mm long, Y-shaped, slender and longer than the 8th sternite (Fig. 10e).

Ehara (1954) studied the male genitalia of four Japanese spp. of genus *Xylotrechus* (*X. chinensis, X. clarinus, X. cuneipennis* and *X. pyrrhoderus*) and concluded that these differ in median lobe. Five genitalia characters (length, curvature of median lobe with median struts, length between median lobe and median struts, structure of edge of median orifice and length between lateral lobes and roof) were selected as given in Ehara (1954). These were analysed in 6 species (*X. basifuliginosus, X. smei* and four Japanese spp.). These analyses revealed that length of male genitalia of *X. basifuliginosus* is largest (3.39 mm) amongst all; curvature of median lobe with median struts, it is slightly curved in *X. basifuliginosus* and *X. chinensis, X cuneipennis* and *X. pyrrhoderus* whereas it is moderately curved in *X. clarinus* and strongly curved in *X. smei*; structure of edge of median orifice is slightly projected in *X. basifuliginosus* and *X. smei* whereas in Japenese species it is weakly projected; and length between lateral lobe and roof, lateral lobe is smaller in *X. basifuliginosus, X. chinensis* and *X. pyrrhoderus* whereas it is larger than roof in *X. smei, X. clarinus* and *X. cuneipennis*.

The lifecycle of *X. basifuliginosus* was found to be different in some respect from *X. stebbingi* which also attacks other Western Himalayan oaks i.e. *Q. leucotrichophora* and *Q. floribunda* growing in the vicinity of *Q. semecarpifolia* but separated along the altitudinal gradient. *Q. semecarpifolia* is timberline species while the latter two occur at lower altitudes in the temperate zone. *X. stebbingi* which infests *Q. floribunda* oak logs and stumps, the beetles emerge in June-July and has an annual life cycle (Beeson and Bhatia, 1939) whereas according to Stebbing (1914), the larval stage of *X. stebbingi* is about 270 days, however the pupal stage lasts from 42 days to 2 months on *Q. floribunda* and emergence takes place at the end of July or August in north west Himalaya while in *X. basifuliginosus* pupal duration ranges from 81-97 days during March-May. *X. smei* is also another congener of *X. basifuliginosus* which attacks *Q. leucotrichophora*. The longest oviposition period is 6 days in April. Eggs are laid in crevices and covered depressions on the surface of bark in large clusters and egg hatches in 4-5 days in the months of April. The shortest larval period of *X. smei* on sal logs (*Shorea robusta*) is 52 days in April-May and 18-19 days of the pupal period in Dehradun (Beeson and Bhatia, 1939). The shortest life cycle of *X. smei* overwintering broods is about 6 months and the longest might be 16 months (Beeson and Bhatia, 1939). Emergence of *X. smei* (in Dehradun) begins at the end of March from overwintered broods and is at its peak in May-June and continues to the end of the November (Beeson, 1941).

Male genitalia of Cerambycinae are distinct from the other subfamilies of Cerambycidae by having quite well developed 'roof part' while 'lateral lobes' shows variation within the groups (Sabanoglu and Sert, 2018). The length of male genitalia of *X. basifuliginosus* is largest amongst all. The main difference amongst *Xylotrechus* spp. is in the length of 'lateral lobes', and 'roof' of tegmen which is the highly variable in shape in this species and enumerated as a valuable character for differentiation in this species. Cerambycid borers are one of the main factors responsible for the mortality and decline of *Q. semecarpifolia* oak trees in the temperate zone of the western Himalaya and *X. basifuliginosus* also deteriorates the quality of wood and timber. Therefore, understanding the lifecycle of this stem borer in this intricately balanced oak forest ecosystem can help us in better conservation and management of Kharsu oak forests.

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**AUTHORS CONTRIBUTION**

GCR and APS conceived and designed research; GCR gathered data and conducted experiments under guidance of APS; GCR and APS analyzed data; GCR prepared draft of manuscript and A.P.S. reviewed the manuscript.

**CONFLICT OF INTEREST**

The authors declare no conflicts of interest in preparing this manuscript.

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