Woodpecker (Picidae) diversity in borer- *Hoplocerambyx spinicornis* infested sal *Shorea robusta* forests of Dehradun valley, lower western Himalayas

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Arun P. Singh, Entomology Division, P.O. New Forest, Forest Research Institute (ICFRE), Dehradun 248006, Uttarakhand, India. Email: *ranoteaps@gmail.com; singhap@icfre.org*
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Introduction

The sal heartwood borer *Hoplocerambyx spinicornis* Newman (Coleoptera: Cerambycidae) [sal borer; **Fig. 1**] is known to cause considerable mortality of sal *Shorea robusta* trees all over the latter's distributional range in India. Explosive outbreaks of this insect, killing millions of trees over vast stretches of forests (**Fig. 2**), have been reported from time to time, from as early as 1897 (Stebbing 1899), to as recently as 2001 (Bhandari & Rawat 2001): from Assam 1906–1961; West Bengal 1931–1934; Bihar 1897; Madhya Pradesh 1905, 1923–1928, 1959–1963; Uttar Pradesh: Kalagarh (now in Uttarakhand) 1924–1925, 1934–1937; Himachal Pradesh 1948–1954 (Roonwal 1977). The sal borer generally attacks trees that are dead or practically dead, i.e., felled, victims of windfall, struck by lightning or broken by storms, or damaged, or attacked by root fungus. Healthy standing trees are not attacked unless there is an epidemic of the borers, and the beetles are so numerous that the dead trees are insufficient for them (Beeson 1941). Sal heartwood borer is today the major factor responsible for the decline of sal, besides other biotic, and abiotic factors such as intensive grazing, lopping, felling, *etc*., which hinder its natural regeneration.

Fig. 1. Specimen of a male sal heartwood borer *Hoplocerambyx spinicornis* collected from Dehradun valley.

Relationship between woodpeckers and Cerambycidae beetles

Woodpeckers (Picidae) feed on adults, grubs, and pupae of wood-boring beetles that infest tree trunks and branches in forest habitat (Ali & Ripley 1987). A notable influx of woodpeckers accompanies an epidemic of borers in natural forests (Beeson 1941; Dennis 1967; Stoddard 1969; Jackson 1988, 2002). Woodpeckers are often cited as the most important predators of wood-boring cerambycid larvae (Brooks 1923; Linsley 1961; Solomon 1968, 1972, 1974; Jackson 2002). It is possible that larvae near ground level, and near branch points within the canopy, are less vulnerable to woodpecker predation than those in a clearly exposed small-diameter tree trunk. Similarly, adult beetles on the exposed trunk may be more vulnerable to woodpecker predation while ovipositing, which may take up to half an hour or more. Apart from small-sized beetles, and vegetable matter such as berries and seeds, cerambycid grubs form the main diet (38%–46%) of large-sized woodpeckers like the Ivory-billed Woodpecker *Campephilus principalis* in North America (Jackson 2002). Predatory woodpeckers, e.g., Three-toed Woodpecker *Picoides tridactylus*, are also known to play a significant role in regulating bark and longhorn beetle populations in coniferous forest landscapes in Europe (Fayt *et al.* 2003). A positive correlation has been established between the abundance of longhorn beetle larvae, and the brood-size of woodpeckers —the Three-toed Woodpecker nestlings' main

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Fig. 2. Extent of sal mortality caused by the sal borer.

food (Fayt *et al*. 2003). Three-toed Woodpecker is also known to show the greatest numerical response to beetle prey density, with population densities increasing up to 44.8-fold during outbreaks, relative to those supported at endemic beetle levels (Fayt *et al*. 2003). Some species of large-sized woodpeckers, like Black-backed Woodpecker *P. arcticus*, which is extremely specialized in its foraging niche, feed exclusively by excavating larval wood-boring beetles during outbreaks in dying conifers for only 2–3 years after forest fires in Alaska (Murphy & Lehnhausen 1998).

Thus, woodpeckers are important bio-agents that feed on cerambycid borer larvae and pupae in natural forests, on old aged trees, and help in suppressing population of this pest to some extent.

However, extensive study is required to establish a similar relationship between the sal heartwood borer and woodpeckers in the tropical moist deciduous sal forests of the lower western Himalayas. With this aim, the present study was carried out to evaluate the intensity of sal heartwood borer infestation in sal stands and examine the relationship of borer infestation with abundance and diversity of woodpeckers.

Study area

Dehradun valley, which covers an area of *c*. 2,000 km^2 and lies in the lower western Himalaya in the state of Uttarakhand, was selected as the study area to work on this problem. About 51–58% land area in the valley was under tropical moist deciduous sal forests (**Figs. 23, 24**) (FSI 1995). These forests have a history of sal borer outbreaks all over the valley. Here, during 1916–1924 an outbreak at Thano range covered 18 km^2, and over 80,000 trees perished. During 1952–1953, again at Thano, 8,475 badly infested trees had to be felled. In 1958–1960 an outbreak at Timli range destroyed 12,860 trees. In 1961 in Lachhiwala range a 'light' outbreak was reported. Then in 1965, once again in Thano range, 4.8 km^{2}of forest was affected with 2,379 being trees attacked, followed by 21% infestation of trees by the borer during 1976–1978 (Roonwal 1977; Singh & Mishra 1986). Recently, during 2000–2002, large-scale mortality of trees has occurred again, due to sal borer attacks in the valley (*pers. obs. of author*).

Material & methods

Selection of study sites

Topographic maps and satellite imagery (IRS-IC 1998) data of the study area, depicting the extent of sal forest cover in Dehradun valley, were procured from Forest Survey of India (FSI) and Survey of India, Dehradun for selection of study sites **(Fig. 3)**. Areas of sal forest covering more than 4 km^2, and with a canopy cover > 50%, were identified as potential sites for study. Fifteen forest ranges with large sal forest tracts were thus identified as suitable for this study. Based on the ground surveys nine sal forest sites (eight in reserve forest area and one inside Rajaji National Park) distributed all over the valley were marked and identified for sampling **(Fig. 3; Table 1)**. Field surveys were then carried out for collecting

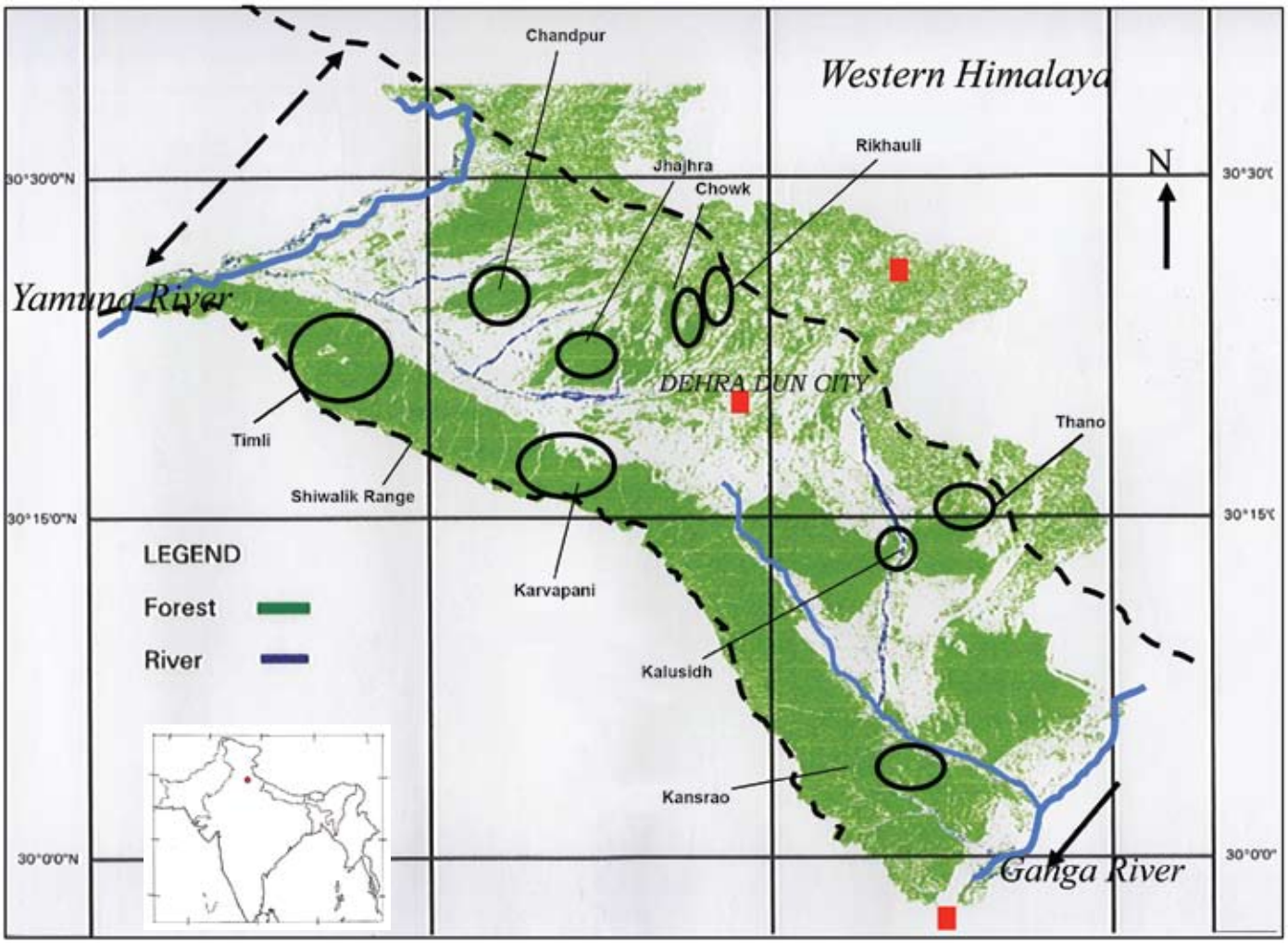

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Fig. 3. Dehradun valley: study area, the extent of sal forest cover and location of study sites as mentioned in the text.

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Fig. 4. Grey-headed Woodpecker *Picus canus*.

baseline habitat data for these study sites namely, percentage of borer-infested sal trees; tree girth at breast height (GBH); density per hectare, and tree species composition of sites. These were determined by laying down 16 vegetation plots (quadrates of 10×10m) in each site. Total numbers of sal trees were then counted in each plot, and were separated into borer-infested (including dead ones) and un-infested sal trees, to calculate percentage of borer infestation.

Woodpecker surveys

Woodpecker surveys were carried out at each site visually, using binoculars and field guides. At each site, a transect of one kilometer was marked through the forest, and walked through the vegetation plots for 60 min., at a stretch, between 0800 and 1700 hrs for sampling occurrence of woodpecker species. All woodpecker species up to 25 m on either side of transects, were identified and their numbers recorded. Nine sampling surveys were carried out at each site from May 2004 to February 2006, and February 2007, covering all the seasons.

Woodpeckers were identified with the help of various field guides (Ali & Ripley 1987; Grimmett *et al*. 1998; Kazmierczak 2000; Rasmussen & Anderton 2005). Plants in vegetation plots were identified with the help of Kanjilal (1969), and the plant taxonomist at the Herbarium, Botany Division at FRI, Dehradun.

Analysis

Relative abundance of woodpeckers, computed as average of their abundances across samples for each site, was correlated with percentage of borer-infested sal trees using Pearson's correlation coefficient. I also did regression analysis to model the relationship between woodpecker species and sal-borer occurrence. Species diversity of woodpeckers (H′) was calculated from the Shannon Index as follows (where p_i is the proportion of the ith species in the sample):

$$H' = - \Sigma\, p_i \log_e p_i$$

Shannon Index is essentially a combined measure of both species richness (i.e., number of species) and evenness of abundances (i.e., how equitably all the species are distributed in terms of their population) in a sample. In other words, species diversity will be the highest in an assemblage of woodpeckers with a large number of species and with all the species occurring in high yet equal numbers.

The structure of woodpecker assemblages and their habitat selection were studied by Principal Components Analysis (PCA), which seeks to reduce a large number of species or ecological factors into a few meaningful dimensions for easy interpretation. I first generated a 'site plot' where the sampling sites were

Table 1. Site parameters: vegetation and habitat condition of forest stands in Dehradun valley.

Sl. no.	Site/Range	Vegetation	Percentage of borer infested sal trees	Percentage of trees with GBH > 100cm	Dominant GBH class (cm)	Shannon Diversity Index of Woodpeckers*
1	Kansrao (Rajaji NP)	Pure sal and mixed patches with marshy vegetation having *Trewia nudiflora* ; *Syzygium cumini*	Low (1.7)	72	101-125	0.737
2	Karvapani RF	Mainly mixed sal patches and marshy vegetation having *Sapium somniferum*; *S. cumini*;*T. nudiflora*	High (20.3)	56	76-100	0.823
3	Timli RF	Mainly sal dominant, without water	Low (2.7)	45	51-75	0.690
4	Thano RF	Mainly sal dominant, without water	High (36.6)	59	101-105	0.919
5	Kalusidh-Lacchiwala RF	Mixed patches with marshy vegetation having *T. nudiflora*.	Low (0.5)	46	76-100	0.749
6	Chowki RF	Pure sal with mixed vegetation in nullahs and water and *S. somniferum*	Moderate (15.7)	36	51-75	0.799
7	Rikhauli RF	Pure hill sal, without water	low (0.8)	9	25-50	0.345
8	Jhajra RF	Pure and mixed patches, without water.	High (22.5)	58	101-125	0.761
9	Chandpur RF	Mainly pure sal, water in a pool, with *S. cumini*, and *S. somniferum*	High (24.7) Old infestation	47	101-125	0.647

NP=National Park; RF=Reserve Forest; * Shannon Diversity Index of woodpeckers—as determined in this study

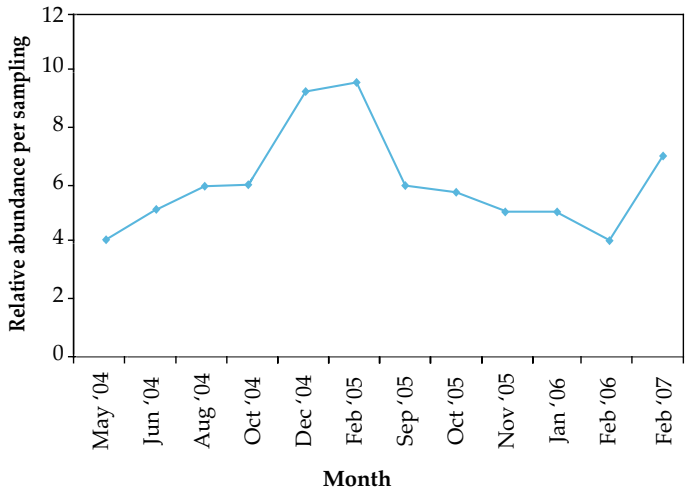

Fig. 5. Relative abundance of woodpecker per sampling through different months of the year in sal forests of Dehradun valley.

grouped according to similarity of their woodpecker species composition. Then, a 'species plot' was drawn in which all the woodpecker species were clustered on the basis of similarity of their distribution in a two-dimensional space as defined by the sampling sites in PCA. All the statistical analyses were done using the software SPSS v.11.00.

Results & discussion

Dehradun has a rich diversity of woodpeckers, as 17 species are known to exist in the district, both in the hills, and valley / plains (Singh 2000, 2002). However, except for four species, namely, Himalayan *Dendrocopos himalayensis*, Rufous-bellied *D. hyperythrus*, and Scaly-bellied *Picus squamatus* Woodpeckers, which are strictly hill species, and Brown-capped Pygmy Woodpecker *D. nanus*, which is mainly found in dry deciduous habitat in the Indian plains, the remaining 13 spp., known from the area were observed in the sal forests of Dehradun valley (below 1,000 m), the lower western Himalaya, during the survey.

Nine sites were sampled and their vegetation characteristics are given in **Table 1**.

Seasonality of woodpeckers in sal forests

It was observed that the woodpeckers, in general, were most abundant during winter (from December to February) in sal forests of Dehradun valley (**Fig. 5**).

Relative abundance

Systematic sampling of woodpeckers (**Fig. 9**) revealed that Grey-headed Woodpecker *Picus canus* (**Fig. 4**) was the most abundant species in the entire study area followed by Fulvous-breasted *Dendrocopos macei* (**Fig. 10**) and Grey-capped Pygmy *D. canicapillus* (**Fig. 15**) Woodpeckers. The least common species were Yellow-crowned *D. mahrattensis* (**Fig. 8**), Brown-fronted *D. auriceps* (**Fig. 21**), and Streak-throated Woodpeckers *P. xanthopygaeus* (**Fig. 6**).

Relationship between individual species abundance & borer infestation

Across sites, the relative abundance of woodpeckers was found to be greatest in Kansrao, followed by Thano, Jhajra, and Karvapani.

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Fig. 6. Streak-throated Woodpecker *Picus xanthopygaeus.*

Fig. 7. Black-rumped Flameback *Dinopium benghalense.*

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Fig. 8. Yellow-crowned Woodpecker *Dendrocopos mahrattensis.*

The last three sites also housed the highest proportion of borer-infested sal trees **(Fig. 12).** However, abundances of only two species namely, Greater Yellownape *Picus flavinucha* **(Fig. 13)**, and Lesser Yellownape *P. chlorolophus* **(Figs 14, 16)** were found to be positively related to sal-borer frequency.

Woodpecker communities in sal forests of Dehradun valley: the lower western Himalayas

PCA was carried out for all the sites (barring Chandpur) with respect to relative abundance of 13 species of woodpeckers. Ordination plots were generated for grouping of both, woodpecker species, and sampling sites, based on the two most important components extracted. In the analysis, the first component explained 51.6% of variation in the relative abundance of woodpeckers, while the second component contributed to 21.2

Table 2. Status, month of maximum abundance and habitat preference of woodpeckers with tropical moist deciduous forests of Dehradun valley, Uttarakhand, India

Sl. No.	Species	Residential status	Month of maximum abundance in sal forests	Preference for forest habitat
1	Greater Yellownape *Picus flavinucha*	Resident	December	Sal dominant
2	Lesser Yellownape *P. chlorolophus*	Resident	August	Sal dominant and mixed patches
3	Grey-headed Woodpecker *P. canus*	Resident	December	Sal dominant
4	Streak-throated Woodpecker *P. xanthopygaeus*	Resident	January	Mixed patches with sal
5	Greater Flameback *Chrysocolaptes lucidus*	Resident	December; February	Mixed patches with sal
6	Himalayan Flameback *Dinopium shorii*	Resident	December; February	Sal dominant
7	Black-rumped Flameback *D. benghalense*	Resident	September	Mainly mixed patches
8	Fulvous-breasted Woodpecker *Dendrocopos macei*	Resident	October-December	Sal dominant and mixed patches
9	Grey-capped Pygmy Woodpecker *D. canicapillus*	Resident	October-February	Mixed patches with sal
10	Brown-fronted Woodpecker *D. auriceps*	Winter Migrant-Vagrant Vagrant	February	Sal dominant
11	Yellow-crowned Woodpecker *D. mahrattensis*		November	Mixed patches (mainly non-sal)
12	Rufous Woodpecker *Micropternus brachyurus*	Uncommon resident Resident	May	Mixed patches with sal
13	Speckled Piculet *Picumnus innominatus*		February	Mixed patches with sal

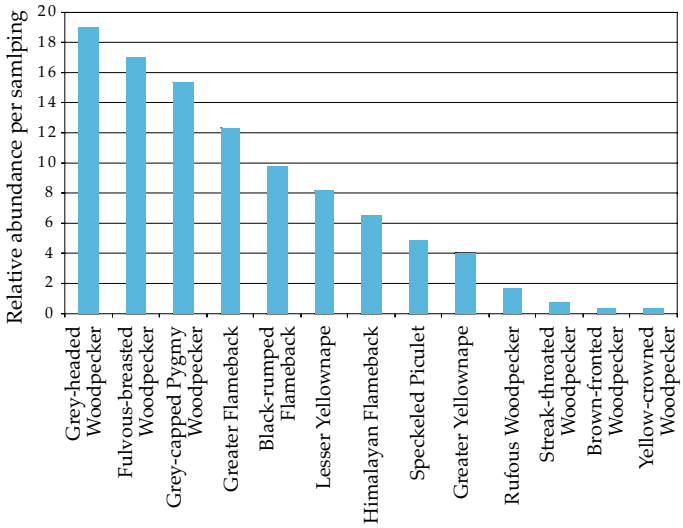

Fig. 9. Relative abundance per sampling of individual species of woodpeckers in sal forests of Dehradun valley

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Fig. 11. Himalayan Flameback *Dinopium shorii.*

% of variation.

First ordination plot sought to group sampling sites on the basis of their woodpecker communities **(Fig. 18)**; in particular, component 1 was represented by Greater Yellownape and component 2 the Lesser Yellownape. In this space, two prominent clusters of sites were obtained: i) Karvapani, Jhajra, and Chowki and ii) Kalusidh, Thano, Kansrao, and Timli. Examining the geographical location of these sites, it became clear that spatial proximity had also contributed to much of their similarity in woodpecker composition (**Fig. 3**). It is also interesting to note that Kalusidh, Kansrao and Timli in the second cluster had very low borer infestation rates.

In the second ordination plot, woodpecker species were grouped based on their habitat selection as inferred from their distribution across sites. In the analysis, the first component explained 51.8% of variation in the relative abundance of woodpeckers, while the second component contributed to 23.7% of variation, with component 1 represented by Karvapani, and component 2 by Chowki. As evident from the plot **(Fig. 19)**, Himalayan and Greater Flamebacks shared similar habitat requirements. Similarly, Greater Yellownape, Rufous Woodpecker, and Streak-throated Woodpecker showed greater similarity in their habitat occupancy.

It is, therefore, clear that habitat selection of woodpeckers in Doon valley is not heavily influenced by rate of sal-borer infestation, though both the yellownapes do seem to show marked proclivity to borer-infested forest patches.

Amongst the 11 resident species in TMDSF at least six showed preference to sal dominant patches in TMDSF **(Table 2)**.

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Fig. 10. Fulvous-breasted Woooodpecker *Dendrocopos macei.*

Conclusion

Out of 13 species of woodpeckers sampled in tropical moist deciduous sal forests of Dehradun valley, the abundant species were, Grey-headed Woodpecker, Fulvous-breasted Woodpecker, Grey-capped Pygmy Woodpecker, Greater Flameback, Lesser

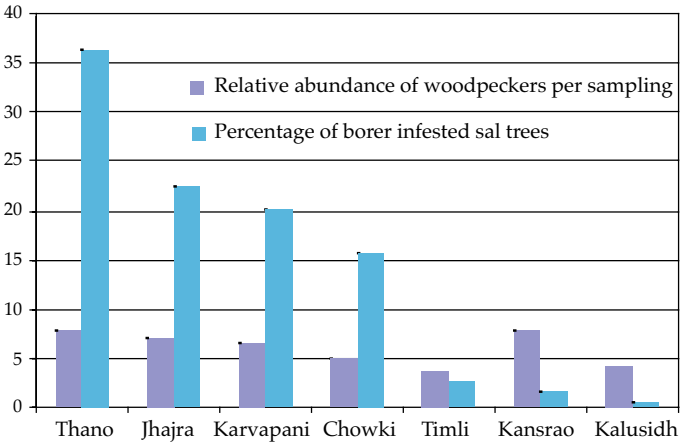

Fig. 12. Relative abundance of woodpecker in different sal forest sites in Dehradun valley under varying level of sal borer infestation.

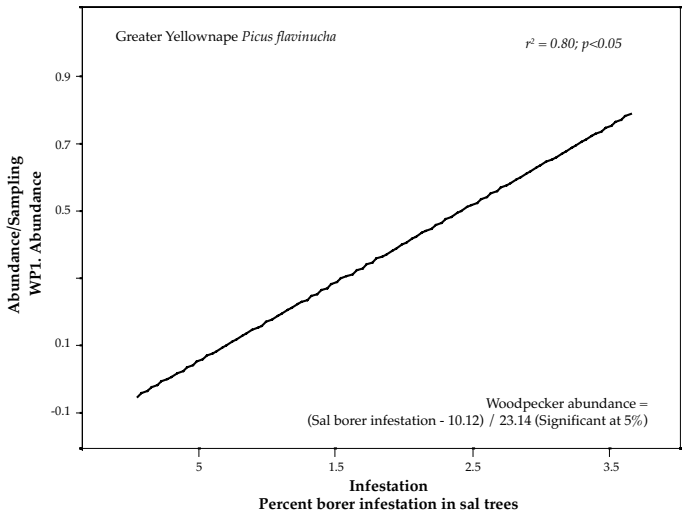

Fig.13. Relationship between sal borer infestation and abundance of Greater Yellow nape, *Picus flavinucha* in Dehradun Valley (2004–2007)

Yellownape, Black-rumped Flameback, and Himalayan Flameback, respectively. While, five species were uncommon, namely, Greater Yellownape, Brown-fronted Woodpecker, Speckled Piculet (**Fig. 20**), Rufous Woodpecker, and Streak-throated Woodpecker, respectively. The remaining two species are vagrant records. The Yellow-crowned Woodpecker was rare in TMDSF of Dehradun valley, as it prefers 'dry deciduous' vegetation lying south of the valley. On the other hand, Brown-fronted Woodpecker (**Fig. 21**) occurs mainly in the higher hills (above 1,400m), but was also observed once in TMDSF of the valley as it descended down during extreme winter conditions in sal forests.

Highest seasonal abundance of woodpeckers was recorded during winter (December-February) in sal forests. Species diversity of woodpeckers was greater in sites with high borer infestation (> 20% borer infested trees) as compared to stands with low infestation (< 3% infestation) indicating that borer infested sites attract greater diversity of woodpeckers. Thus, woodpeckers in general play a significant role in predating on the borer thereby minimizing the borer infestation. This is in consistency with other studies outside sal forests (Beeson 1941; Dennis 1967; Stoddard 1969; Jackson 1988, 2002).

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Fig. 14. Lesser Yellownape *Picus chlorolophus* female.

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Fig. 15. Grey-capped Pygmy Woodpecker *Dendrocopos canicapillus*.

At species level only two species, Greater Yellownape and Lesser Yellownape showed significant increase in borer infested stands, suggesting that these species could be important predators of the sal heartwood borer. Amongst resident species of woodpeckers, abundance of Greater Yellownape, Lesser Yellownape, Grey-headed Woodpecker, Himalayan Flameback (**Fig. 11**); Fulvous-breasted Woodpecker were more in pure sal stands as compared to mixed forest stands. On the other hand abundance of Streak-throated Woodpecker, Rufous Woodpecker (**Fig. 17**), Grey-capped Pygmy Woodpecker, Greater (**Fig. 22**) and Black-rumped Flameback (**Fig. 7**) had more abundance in mixed

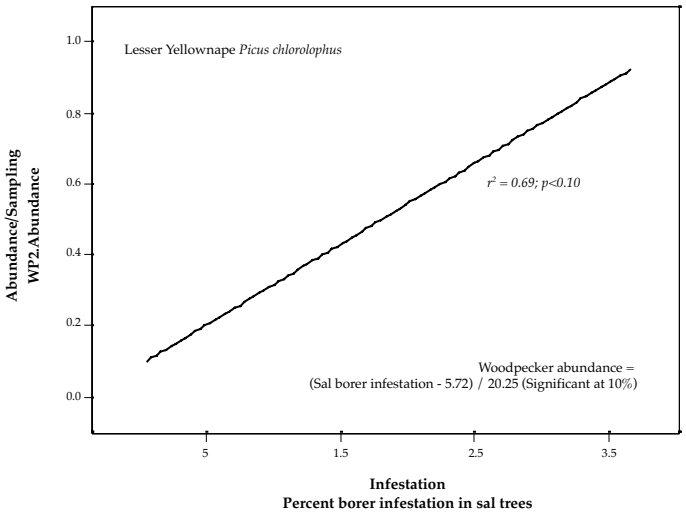

Fig. 16. Relationship between sal borer infestation and abundance of Lesser Yellownape *Picus chlorolophus* in Dehradun Valley (2004–2007)

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Fig. 17. Rufous Wooodpecker *Micropternus brachyurus.*

forest than in pure sal stands. Species preferring sal dominated stands should thus play a major role in checking the borer infestation as compared to the other species.

It was also determined that proximity of sites with each other played a significant role in determining species composition of sal forest in Dehradun valley than other factors i.e. borer

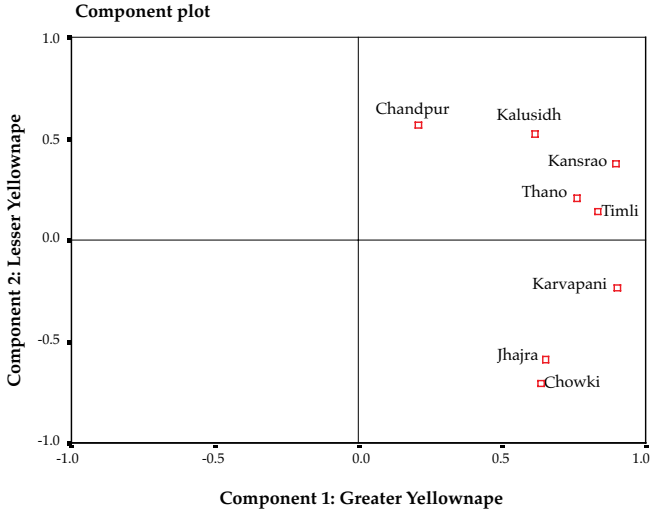

Fig 18: Ordination of woodpecker sites in species space in Dehradun valley based on two most important components.

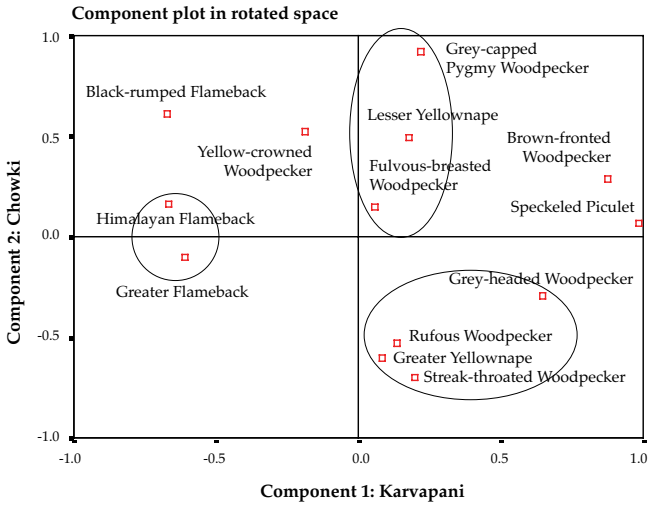

Fig. 19. Ordination of species in sites space in Dehradun valley based on two most important components.

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Fig. 20. Speckled Piculet *Picumnus innominatus.*

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Fig. 22. Greater Flameback *Chrysocolaptes lucidus.*

infestation.

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Fig. 21. Brown-fronted Woodpecker *Dendrocopos auriceps.*

References

Ali, S., & Ripley, S. D., 1987. *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka.* 2nd ed. Delhi: Oxford University Press.

Beeson, C. F. C., 1941. *The ecology and control of the forest insects of India and neighboring countries*. Dehradun: Vasant Press.

Bhandari, R. S., & Rawat, J. K., 2001. Sal Heartwood borer, *Hoplocerambyx spinicornis* Newman (Coleoptera: Cerambycidae) and its management. *Indian Forester* 127 (12): 1387–1393.

Brooks, F. E., 1923. Oak sapling borer, *Goes tesselatus* Halde-man. *J. Agri. Res*. 26: 313–318.

Dennis, J. V., 1967. The Ivory-bill flies still. *Audubon* 69 (6): 38–44.

Fayt, P. 2003. *Population ecology of the Three-toed Woodpecker under varying food supplies.* PhD. University of Joensuu.

Forest Survey of India. 1995. *The state of forest report*. Dehradun: Forest Survey of India.

Grimmett, R., Inskipp, C., & Inskipp, T., 1998. *Birds of the Indian subcontinent*. New Delhi: Oxford University Press.

Jackson, J. A., 1988. The southeastern pine forest ecosystem and its birds: past, present, and future. Pp. 119–159. *In: Bird Conservation 3* (Ed.: Jackson, J. E.). Madison: University of Wisconsin Press.

Jackson, J. A., 2002. Ivory-billed Woodpecker (*Campephilus principalis*). Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/711.

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Fig. 23. Mixed sal forest patch at Karvapani.

Fig. 24. Pure sal forest patch at Timli, Dehradun.

Kaiser, H. F., 1960. The application of electronic computers to factor analysis. *Educational & Psychological Measurement* 20: 141–151.

Kanjilal, U., 1969. *Forest flora of Chakarata, Dehradun and Saharanpur forest divisions, Uttar Pradesh.* Delhi: Manager of Publications.

Kazmierczak, K., 2000. *A field guide to the birds of India, Sri Lanka, Pakistan, Nepal, Bhutan, Bangladesh and the Maldives.* 1st ed. London: Pica Press / Christopher Helm.

Linsley, E. G., 1961. *The Cerambycidae of North America*. Part I. Introduction. University of California Publications in Entomology, Volume18. University of California Press, Berkeley, CA.

Magurran, A. E., 1988 *Ecological diversity and its measurement.* Princeton, New Jersey: Princeton University Press.

Murphy, E. C., & Lehnhausen, W. A., 1998. Density and foraging ecology of woopeckers following a stand-replacement fire. *J. Wildlife Management.* 62 (4): 1359–1372.

Odum, E. P., 1997. *Ecology: a bridge between science and society*. Sunderland, Massachusetts: Sinauer Associated Inc.

Osmaston, B. B., 1935. *Birds of Dehradun and Adjacent hills*. Indian Military Academy. Supplement.

Rasmussen, P. C., & Anderton J. C., 2005. *Birds of South Asia: the Ripley guide*. Washington, D. C. & Barcelona: Smithsonian Institution & Lynx Edicions.

Roonwal, M. L., 1977. Field ecology of sal heartwood borer, *Hoplocerambyx spinicornis* (Cerambycidae), in sub-Himalayan forest. Part–2. Seasonal life history, sex variation, sex ratios, wood fibers, and operculum of pupal chamber. *J. Indian Acad. Wood Sci.* 8 (1): 27–40.

Shannon, C. E., 1948. A mathematical theory of communication. *Bell System Technical Journal* 27: 379–423, 623–656.

http://cm.bell-labs.cpm/cm/ms/what/shannonday/paper.html

Shannon, C. E., & Wiener, W., 1963. *The mathematical theory of communities*. Urbana: University of Illinois Press.

Singh, P., & Mishra, R. M., 1986. A threatened epidemic of sal heartwood borer nipped in the bud. Pp. 907–909. *Proceedings 2nd Forestry Conference*: F.R.I. Dehradun.

Singh, A. P., 2000. Birds of lower Garhwal Himalayas: Dehradun valley and neighbouring hills. *Forktail*. 16: 101–123.

Singh, A. P., 2002. New and significant bird records from Dehradun valley, Lower Garhwal Himalayas, India. *Forktail* 18: 151–153.

Solomon, J. D., 1968. Cerambycid borer in mulberry. *J. Econ. Entomol*. 61: 1023–1025.

Solomon, J. D., 1972. Biology and habits of the living beechborer in red oaks. *J. Econ. Entomol*. 65: 1307–1310.

Solomon, J. D., 1974. Biology and damage of the hickory borer, *Goes pulcher*, in hickory and pecan. *Ann. Entomol. Soc. America* 67: 257–260.

Stoddard, H. L., 1969. *Memoirs of a naturalist*. Norman: University of Oklahoma Press.

Stebbing, E. P., 1899. *Injurious insects of Indian forests*. Calcutta: Supt. Govt. Printing Press.