Summary

Sikkim is widely acknowledged as India's most significant biodiversity Hot Spot. During the past few decades, there has been a visible symptom of landscape degradation and depletion of forest quality at some locations in Sikkim. Tourism impact, unregulated resources extraction, hunting and poaching, profitable and non-profitable forest products collection became the primary threats to biodiversity in the state. Yuksam-Dzongri trekking trail is an attractive destination for both tourists and naturalists. The natural resources of the area faced tremendous pressure resulting from the rise in population, tourist number and the number of trainees of Himalayan Mountaineering Institute. Studies on such disturbances and their consequent responses by both plant and animals are ever-ignored issues in this area. Even the checklists for flora and fauna were not available and records not maintained properly.

A multi-disciplinary group of experts and research team was involved in monitoring and applied research during Sikkim Biodiversity and Ecotourism Project tenure. Various research thrusts in the project were (i) dynamics of tourism growth and assessment of landscape change, (ii) socio-economic development, tourism growth and environmental degradation, (iii) holistic study of sacred Khecheopalri lake ecosystem, (iv) impact of grazing on plant diversity and productivity in an

alpine pasture, and (v) impact of habitat disturbances on bird and butterfly communities along the trail.

The present study was undertaken to address the fifth issue i.e. impact of habitat disturbances on bird and butterfly communities along the trail. An extensive research work was carried out during the period 1996 to 1999 with two broad hypotheses as (i) intensive firewood and fodder extraction will modify tree species composition, age structure and woody biomass productivity of warm-temperate (lower forest) and cool temperate-subalpine (upper forest) forests and (ii) such changes effect bird and butterfly communities at different forest conditions in terms of species composition, abundance and richness. An attempt was made to examine (a) forest cover types and user groups, (b) species preference for fuelwood, fodder and timber, their quality and consumption, (c) tree species diversity, population structure and regeneration, (d) woody biomass, productivity and extraction in closed (stands with less human disturbances and >40% canopy cover) and open (stands with more human disturbances and <40% canopy cover) canopy. The impact was determined in birds and butterfly by evaluating (e) diversity, species composition, seasonal variation and (f) relationships with the habitats various statistical tests.

Yuksam-Dzongri trekking corridor (26 km long) encompasses elevation from 1780 m to 4000 m. The area extends from 27°19′13″ to 27°29′4″ north latitude and 88°9′18″ to 88°15′ east longitude. The trail passes through Sachen, Bakhim and

Tshoka in the southwestern part of Khangchendzonga Biosphere Reserve in Sikkim, India. Temperate conditions prevailed at Yuksam, sub-alpine at Tshoka and alpine at Dzongri. Summer temperatures at these places were mild ranging from 20°C to 24°C at Yuksam, 15°C to 16°C at Tshoka and 11°C to 13°C at Dzongri. Yuksam is a trailhead for this corridor and leads to the Base Camp, Dzongri, Thangsing and Gocha La in West Sikkim. Yuksam has 11 settlements with 274 households comprising of 1573 people. One settlement with nine households is inside the reserve at Tshoka (3000 m) on the trail. Majority of the ethnic people of Yuksam are Subbas, followed by Bhutias, Lepchas, Nepalis and Tibetan Refugees mainly at Tshoka.

Salient findings of the research

1. Land use cover at the warm temperate broadleaf forest covered an area of 1666 ha and cool temperate-sub-alpine forest 1265 ha. The trekking corridor comprised of 986 ha closed canopy forest and 2009 ha open canopy forest.

2. Records on incidental animal sighting by villagers revealed 19 species including three endangered species viz., snow leopard, musk deer and red panda. Commonly sighted animals are Himalayan barking deer, Himalayan black bear, ghoral, clouded leopard and leopard cat.

3. In Yuksam, out of 11 settlements five use the Yuksam-Dzongri corridor forest for firewood, fodder and grazing.

Remaining six settlements are more dependent on other surrounding forests. Tshoka, a settlement inside the biosphere reserve area was totally dependent on trail forest. Apart from these settlements, Himalayan Mountaineering Institute (HMI), travel agencies and their support staff and trans-humans (yak and sheep herders) also depend on corridor forest either for firewood or for fodder.

4. The total demand of fodder was found 1209 Mg yr^{-1} for the entire livestock present in the study area. During 1996-98, a net increase of 63% fodder demand was estimated. Fodder demand for cattle was the highest (41%) followed by sheep (21%) and goat (14%). The demand for dzo, yak, pig and horses were, 13%, 8%, 1% and 2% respectively.

5. Collections of firewood from forests were mainly made during the winter season. Frequency of collection was recorded highest during the month of January and minimum in September. The data from the field revealed that frequency of chopping trees for firewood was the highest for medium sized trees followed by small and large trees.

6. The total demand for the firewood for community as well as other tourism purposes was estimated to be 2433 Mg $year^{-1}$. About 55% of the total demand was met from the trail forests both for community and tourism purposes.

Domestic cooking is the major consumer of fuelwood followed by water heating and other purposes. Consumption ranged from 2264 Mg $year^{-1}$ by community and lowest of 1.02 Mg $year^{-1}$ by pack animal operators. Amount of the firewood consumption among the family was the highest in winter (29±10.1 $kg^{-1}day^{-1}family^{-1}$) and lowest in summer (18±6.9 $kg^{-1}day^{-1}family^{-1}$). The mean daily consumption of the wood was found 25.5 $kg^{-1}day^{-1}family^{-1}$ for an average household size of 6.28 individuals with per capita of 3.45 kg at lower elevation and 4.17 kg at higher elevation. Hotels and lodges consumed about 40-50 kg of firewood daily and Himalayan Mountaineering Institute (HMI) course groups used about 240-520 kg per day per group depending on the size of groups.

7. Out of total 273 households, 80% of the households used firewood followed by 14% kerosene, 3% LPG and 4% electricity at Yuksam and 100% firewood at Tshoka. Large number of trees with <10 cm DBH were used as timber for house construction and renovation just in a time interval of 3-5 years. Use of medium sized trees (20-40 cm DBH) and large trees (40-70 cm DBH) were comparatively low and in greater time intervals of 5-7 years and 15-25 years, respectively. Number of lopped branches and chopped trees were high in the open forest condition and low in the closed canopy forest. Other indicators of disturbance like depth of humus, depth of dry leaf litter and depth of clayey

soil were higher in the closed canopy forest showing less interference. Trampling impression and dung numbers were higher in open forest condition where animals were usually stalled overnight.

8. With reference to community preference of firewood species, *Rhododendron* spp. and *Quercus* spp. matched with high wood quality suggesting that their preference of firewood species was compatible with energy/chemical properties of woody species.

9. Firewood collections were mainly made during the winter (November to March) season. Tourism enterprises (travel agencies and the support staff) related collection of the firewood occurred mainly in two-peak tourist seasons during March to May and August to December. Frequency of chopped trees showed a low pressure on 10-20 cm diameter at breast height (DBH) class, medium pressure on 50-60 cm and high pressure on 20-50 cm class trees at the lower forest.

10. Out of 56 tree species recorded from the sampled plots of the lower forest, 52% species were widely used as firewood, 37% fodder and 32% timber. In the upper forest, out of 32 species encountered 53% were used as firewood, 31% fodder and 31% timber.

11. In the lower forest, tree species diversity was found greater in the open canopy forest (H′=5.5) than in the closed

canopy forest (H′=2.04), whereas at the upper forest, it was higher in the closed canopy forest (H′=2.8) compared to that of open canopy forest (H′=2.5).

12. Out of 56 woody tree species, only twenty species were found regenerating at the lower forest accounting 43% of the total at the closed and only 47% at the open canopy forests. At the upper forest out of 32 species, 19 species were found regenerating and accounted 56% of the total species at the closed canopy and 58% at the open canopy forest.

13. The open canopy condition of the lower forest showed markedly reduced IVI values and basal area of the species of high firewood preference compared to the closed canopy forest. At the upper forest also, the IVI and basal area values of used species were similar.

14. Densities of trees reduced from 435 trees ha^{-1} in the closed canopy condition to 206 trees ha^{-1} in the open canopy at the lower forest. Likewise, at upper forest, it reduced from 319 trees ha^{-1} in the closed canopy forest to 222 trees ha^{-1} in the open canopy forest.

15. The basal area of the trees reduced from 59 m^2ha^{-1} in the closed canopy forest to 23 m^2ha^{-1} in the open canopy forest at the lower forest and from 50 m^2ha^{-1} in the closed canopy forest to 40 m^2ha^{-1} in the open canopy forest at the upper forest.

16. The standing woody biomass were 704 Mg ha^{-1} and 399 Mg ha^{-1} in the closed canopy and open canopy forest respectively at the lower forest, and 382 Mg ha^{-1} and 306 Mg ha^{-1} in the closed and open canopy forests at the upper forest. Standing woody biomass of *Quercus lamellosa* shared 37-40% and net primary productivity (NPP) of the stands 18-28% in both the closed canopy and open canopy conditions of the lower forest.

17. Annual extraction of nearly 50% of the net primary productivity (NPP) was recorded from both the closed canopy and open canopy conditions at the lower forest whereas at upper forest, about 46% of NPP removal was recorded from the open canopy forest and 21% from the closed canopy forest. Extraction of *Q. lamellosa* was the highest in the close canopy and open canopy forests followed by *B. sikkimensis, A. laevigatum* and *Quercus* sp.

18. Sikkim Biodiversity and Ecotourism Project conducted various capacity-building training and conservation awareness programs and promoted eco-friendly tourism in the study area during 1996-1999. Development and compliance of code of conduct for conservation by travel agencies and by visitors as well as by the community was an initial step towards reduction of firewood collection from the corridor. Provision of kerosene and liquified petroleum gas (LPG) from policy level decision made

convincing impacts by the reduction of fuelwood use both by travel agents and communities.

19. An increase of LPG use from 1% to 3% among the community and from 8% to 14% among the tourism related stakeholders was recorded during the period from 1996 to 1998. Similarly, stove and kerosene use increased from 5% to 14% among the communities and from 14% to 18% among the tourism-related stakeholders. There was a substantial reduction of firewood use from 93% in 1996 to 80% in 1998 among the communities and from 73% in 1996 to 49% in 1998 among the tourism enterprises.

20. Over the two year period, 7149 bird (individuals) representing 143 species were detected. Of these 143 recorded species, 40% (57) were common among the four stands. About 22% species differed significantly between the two-forest types (lower and upper forest) and only about 15% species significantly differed between the habitat conditions (closed canopy and open canopy forest). Out of 143 species, 10% were restricted to the closed canopy condition in contrast to 16% in open canopy conditions of the lower forest. In the upper forest, only 3% of the total species were observed as exclusively present in the closed canopy and 6% at the open canopy forests.

21. Bird species richness (BSR) and diversity (BSD), and tree species richness (TSR) and diversity (TSD) showed strong

negative and linear trend with increasing elevation. The relationships for bird species and its diversity had stronger trend with increasing elevation than tree species and its diversity.

22. Both the BSR and BSD showed positive and linear relationship with the TSR and TSD. But the relationships were not consistent at different habitat conditions, seasons and forest areas. Both the canopy conditions and the forests showed strong seasonal variation in bird species diversity.

23. Five principal components (PCs) from Principal Component Analysis (PCA) were extracted to represent vegetation parameters which together accounted 83.1% of the total variance. The PC1 represented habitat with closed canopy, higher woody biomass and high basal area. The PC2 represented habitat with higher number of lopped branches and chopped trees with lower litter and humus depths, and higher trampling suggesting high disturbances. The PC3 represented diverse stand with higher herb as well as shrub richness and complex vertical stratification.

24. BSR and BSD were significantly and positively correlated with PC3, which represented the tiered heterogeneity with diverse habitat. Bird density showed significant positive relationships with PC2 and PC3, which suggested that the

disturbed areas and habitat with vertical heterogeneity have higher bird density.

25. Species composition (number of species/guild) showed significant difference between the two forest types, seasons and guilds. This suggests that there was a variation in species composition at the two forests types, seasons and among the feeding guilds.

26. Among the migratory groups, incidental species significantly differed between the habitat conditions and seasons. Resident species composition was significantly influenced by season. There was a significant variation in summer visitors between the seasons as well as at different habitat conditions. Summer visitors showed weak but significant difference between the two forests, habitat conditions and seasons. Among the feeding guilds, insectivores significantly differed between the two forests as well as between seasons. Apart from insectivores, forest types, plots and seasons also significantly influenced the omnivores. Among the migratory groups, only winter visitors were found to have significant relation with PC2. Insectivores were positively related with PC1, omnivores with PC2 and PC3. Nectarivores were positively related with PC2 and carnivores were positively correlated with PC3.

27. A total number of 49 butterfly species were observed and recorded within an altitudinal range of 1700 to 3700 m amsl. The most common species were moore's bushbrown, plain tiger, common tiger and common crow. Lesser-sighted species were common bluebottle, yellow sailor, hill gegebel and spectacle swardtail.

28. Butterfly species diversity, its richness and the evenness were all significantly differed between the forest types (Mann Whitney test U=2489.5, P<0.000, U=2070.5, P<0.009, U=2175.5, P<0.001) respectively. On the other hand, the difference in butterfly species between the open and closed canopy conditions was significant (U=1799.5, P<0.21).

29. Mean number of species of butterflies differed significantly between the forest types and habitat condition (ANOVA: $F_{1,106}$= 7.4, P<0.007 and $F_{1,106}$= 5.9, P<0.01) respectively. Significant interaction between the forest types and seasons ($F_{1,106}$= 9.2, P<0.003) indicates that the forest types and seasons influenced the variation in number of species among the forests with the change of the season.

30. Both butterfly species diversity (Y=9.58-1.2lnx, R^2=0.59, P<0.001) and its richness (Y=9.08-1.1lnx, R^2=0.30, P<0.01) were significantly and negatively correlated with the rise in elevation.

31. The regression drawn on the diversity indices showed significant relationship between the tree species diversity

and butterfly species diversity ($Y=-0.42+0.46x$, $R^2=0.53$, $P<0.001$) but the relationship among the species richness of these two groups were not significant ($Y=0.64+0.12x$, $R^2=0.12$, $P<0.15$).

32. Pearson product moment correlation on 3PCs extracted from the vegetation data showed significant correlation of butterfly diversity only with PC3. The correlation with the other components was insignificant.

33. The overall trend in diversity indices in butterflies, birds and the trees were remarkably similar across the elevation and habitat types. All the three groups (trees, birds and butterflies) were generally higher at the open canopy forest and showed a strong correlation among the groups.

Conclusion

Forest based resources are the integral part of livelihood for the people of Yuksam and Tshoka. Population growth and rapid increase in tourism sector have caused threat to the forest resources and biodiversity of the area. Substantial closed canopy areas have been opened as a result of firewood, fodder and timber extraction. Tourism related pressure on the forest has been more distinctly visible at Tshoka, the first camping site on the trail. Removal of selective canopy species for firewood and timber has changed the forest structure. Regeneration of canopy species has been relatively lowered at the open canopy conditions where the human pressures are maximum.

Bird diversity reflect tree diversity and feeding guilds appeared as predictor for habitat quality. Maintenance of habitat heterogeneity is important for conservation of biological diversity in the area. Therefore, maintenance of vegetation rich habitats with structural complexity is recommended for conservation of bird. Analysis on community structure of butterfly and their association/relationship with the habitat revealed that they are more sensitive to the human disturbances. There is strong correlation among the tree, bird and butterfly diversity indices. This finding has asserted indicator properties of birds and butterflies in biodiversity assessment.

If managers wish to regulate pattern of harvest on natural resources based on disturbance regime, then strategies to compensate for these initial differences must be developed first for conservation. Management of this trekking corridor forests should be oriented in such a way that only the canopy species regeneration is encouraged. Compliance to the code of conduct for conservation by tourists, enterprises and communities especially on the use of alternative to firewood would enhance the forest condition making the destination more attractive and valuable in terms of biodiversity.