PART II
Honeybee Resources

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Species and Genetic Diversity in Himalayan Honeybee

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Introduction

Honeybees are social insects with which man has established a harmonious coexistence and can be considered as an example of gene-culture coevolution. These insects are of great economic importance because they not only produce honey and beeswax but also act as primary pollinating agents of many agricultural and horticultural crops. It is due to bee pollination that crop yield increases, quality of seed and fruit improves, and heterosis can be exploited. Beekeeping can play a vital role in sustainable mountain development as it increases economy without changing environmental balance. As a cottage industry it is a source of income of the rural people. Beekeeping is one of the important components of Integrated Rural Development Programmes. The Hindu Kush-Himalayan region has a thriving beekeeping industry. Great strides in modernizing beekeeping with the exotic and native honeybee species are being made. From the beekeeping point of view, temperate (high hills and interior valleys), sub-temperate (mid-hills) and sub-tropical (low-lying hills) zones are ideally suited.

Species Diversity

Out of the four species of the genus *Apis* found in the Hindu Kush-Himalaya, *Apis cerana* F., *Apis dorsata* F. and *Apis florea* F.

are sympatric and exotic species *Apis mellifera* L., the European bee is allopatric in distribution. Sakagami *et al.* (1980) reported *Apis laboriosa* from the Himalaya as another new distinct honeybee species even larger than *Apis dorsata*. However, these findings of the Japanese researchers need further confirmation. A brief account of the biological and economic characteristics of these species of honeybee in relation to beekeeping is given here.

APIS DORSATA F. (ROCK BEE)

This species of honeybee is found all over the Himalaya up to the height of even 2000 metres above mean sea level. This species is migratory in nature. The colonies arrive in the temperate mountain region in the spring season, (March–April) and descends to the plains in June, before the monsoon. During migration of the colonies, swarms are known to make a short halt *en route*. They build a single-comb nest fixed to a branch in an open cave under a roof or rock. The size of a single open air comb of *Apis dorsata*, depending on the season and stage of development of a colony, measures 1.5 to 2.0 m from side to side and 0.6 to 1.2 m from top to bottom. In the upper portion of the comb is stored honey and pollen, and this is generally 10 to 25 cm thick. Below this storage area is the brood nest. A single colony has 60,000 to 100,000 worker bees. Sometime 50 to 100 colonies aggregate on a single tree. According to an estimate made in 1950, 75 per cent of all harvested honey and 81 per cent beeswax is harvested from the colonies of this species in India. However, with the large-scale introduction of *Apis mellifera* and with the expansion of modern beekeeping with *Apis cerana*, the percentage has changed considerably and it is difficult to make an exact estimate. According to different authors, honey yield per colony may vary from 5 to 50 kg. However, the average honey yield per colony is about 5 to 10 kg. This species of honeybee is also an important pollinator of different agricultural and horticultural crops.

APIS FLOREA F. (LITTLE BEE)

Like *Apis dorsata*, this small bee also builds a single comb which is often suspended from branches of bushes, hedges, trees, caves of building, house chimney, empty caves, piles of dried sticks, etc. The comb measures about 35 cm in length and 18 cm in height and about 2 cm in thickness. Honey is stored in the upper part of the comb which is about 5 to 7 cm thick. The species usually inhabits the plains and hilly areas and is generally found up to the height of 1500 m above mean sea level. This species can exist with the other three species of honeybee including exotic *Apis mellifera*. These bees migrate frequently and colony seldom remains at one place for more than five months at a stretch. The bees choose a shady nesting place during the hot summer and in autumn they make short migration to an unshaded place. The annual honey yield from a colony varies from 1 to 3 kg. It is believed that the honey produced by *Apis florea* has special medicinal value and mystical properties. *Apis florea* honey has a higher dextrin content and less tendency to granulate as compared to the honey from other *Apis* species. These bees are valuable pollinators of many agricultural crops including sarson, toria, sunflower and alfalfa.

Seelay (1985) has given very interesting biological and foraging statistics regarding *Apis florea* and *Apis dorsata*. According to him, *Apis dorsata* worker bees are five times heavier, the colony size is 30 times more massive, and the foraging area 100 times larger than that of *Apis florea*. The maximum flight range of *Apis dorsata* is 10 km and it is 10 times more than *Apis florea* (1 km). During flight, the *Apis dorsata* worker bee consumes three times more energy as compared to *Apis florea* but the former species can carry a given mass of pollen/nectar across a given distance with 30 per cent less energy.

APIS MELLIFERA L. (EUROPEAN HIVE BEE)

The European honeybee, *Apis mellifera*, is the most important of all the species as a honey and beeswax producer. This species of honeybee is superior to others due to the maintenance of a prolific queen, less swarming tendency, gentle temperament, good honey gathering qualities, and guard against enemies except wasps and mites. Several attempts have been made, since the beginning of this century, to introduce this exotic species of honeybee into some countries of this region. However, the Italian strain of this species (*Apis mellifera ligustica*) was successfully introduced and established in northern India for the first time at the beekeeping research station at Nagrota Bagwan (Himachal Pradesh) during the early sixties by a group of scientists from Punjab Agricultural University, Ludhiana headed by Dr. A.S. Atwal. Subsequently the experiment was extended to the plain areas of Himachal Pradesh and Punjab. Through extensive research and experiments for the past 20 years, it has been possible to acclimatize these bees. However, large-scale import and multiplication of exotic *Apis mellifera* for higher honey production into several parts of Asia (including this region) is still a controversial subject among leading bee scientists. Doubts are being expressed that this species may not adapt well in its new environment due to different climatic conditions, flora, mating competition with *Apis cerana* and hazards of predators and disease. Koeniger (1976) made the following observations regarding the introduction of *Apis mellifera* into Asia during the International Conference on Apiculture in Tropical Climates:

> In the past, many attempts have been made to import *Apis mellifera* to Asia, but most of these experiments were failures. The northern *mellifera* bees are not adapted to the various enemies of honeybees. In Pakistan for example, the hornet (*Vespa orientalis*) destroys the colonies, in Sri Lanka it was observed that all *mellifera* bees were caught by bee eaters (Merops). In other parts of Asia, it has been reported that *Apis cerana* robbed *mellifera* colonies. At other places, where the *mellifera* colonies were protected against predators, it was observed that all virgin queens failed to mate during their mating flights and we can guess that the *mellifera* drones were prevented from copulating with the queens by the competition from drones of the other honeybee species. Nevertheless, at some places in northern India, *Apis mellifera* seems to survive. In consequence of this situation, some might consider it useful to import a tropical race of *Apis mellifera* but I want to stress that this would be a very hazardous and risky project. In the light of the sequence of events in South America, it seems possible that a tropical *Apis mellifera* could irreversibly damage the fauna of Asia, and indeed the consequence of such a step cannot be calculated.

However, so far, this exotic species is doing well in the plains and the sub-mountainous region of northern India, and parts of Pakistan except at heights beyond 1500 m above mean sea level, where the native *Apis cerana* is well adapted. Thus both species seem to be complimentary to each other as far as beekeeping in the plains and hilly regions of this subcontinent is concerned.

APIS CERANA F. (ASIAN HIVE BEE)

The closest relative of *Apis mellifera* L. is *Apis cerana*. This species is native to southern and eastern Asia. Generally speaking, it is a bee with a gentle temperament, industrious, with cleanliness qualities, and can be handled easily. However, this species has not become very popular with the beekeepers because of its frequent swarming, absconding and robbing habits; production of a large number of laying worker bees and the helplessness against the predators. Honey yield obtained from *Apis cerana* is about three times less than that of *Apis mellifera*. In spite of these limitations, the species is similar to *Apis mellifera* as far as nesting and dancing behaviour and in building of parallel combs are concerned. This native species of honeybee has many valuable characters of economic importance which have not been explored so far.

Genetic Diversity of *Apis cerana*

Before discussing the different geographic races and ecotypes of *Apis cerana*, it is important to make a distinction between these two concepts based on the earlier studies on *Apis mellifera*. As a result of a continuous process of natural selection through centuries, different geographic races of a particular species of honeybee have evolved. Such geographic or natural races are different from other domestic animals because the latter were evolved through planned breeding by man. In the case of honeybees, such geographic races have been evolved under the influence of natural abiotic and biotic factors existing in the environment. Such geographic races of *Apis mellifera* existing in tropical Africa, north Africa and near east and west Mediterranean region have been identified through computer-based biometric analyses (Ruttner 1985, 1986). These results reveal that even each geographic race of honeybee species has further locally adapted populations called ecotypes which differ from each other in several biological and economic characters. Such ecotypes adapted to specific environment have also evolved through the process of natural selection. The biological and economic differences existing in different geographic races and ecotypes of honeybees provide an excellent opportunity for their genetic improvement by selection and breeding. These differences have been extensively exploited by man in *Apis mellifera* with remarkable success.

For example, by the crossbreeding of *Apis mellifera* races, it is possible to increase honey production by 200 per cent (Fresnaye and Lavie 1976) and to develop low and high preference lines for the better pollination of agricultural crops (Nye and Mackensen 1970). However, very little is known about *Apis cerana* except the arbitrary hilly and plain varieties of this species (Kapil 1956; Narayanan *et al.* 1960, 1961a and b, Kshirsagar 1976). These earlier biometric investigations were based on a few morphological characters and geographical samples and also lacked proper statistical analysis of data. However, in the recent past, attempts have been made to identify different races of *Apis cerana* by using computer-assisted standard statistical methods. These results are reviewed as follows:

Ruttner (1985, 1986, 1987) has distinguished four different races of *Apis cerana: Apis cerana cerana, Apis cerana himalaya, Apis cerana indica* and *Apis cerana japonica*. His study was based on 34 morphological characters studied in 68 samples of *Apis cerana* collected from different parts of Asia (Fig. 3.1). Statistical methods included principal component analysis, discriminant analysis or cluster analysis. Research group in Himachal Pradesh University, Shimla, has also carried out biometric studies on *Apis cerana* worker bees found in northeast, northwest and south India representing different physiographic conditions. From each locality, 60 field bees (workers) were collected in the summer from four to five wild colonies located in forests. In all, 55 morphological characters related to the tongue, antenna, forewing, hindwing, hindleg, tergites and sternites were studied. These characters were selected on the basis of previous work of Alpatov (1929) and Ruttner *et al.* (1978). Statistical analysis were carried out by using computer-based univariate and multivariate discriminant analyses in collaboration with Professor Howell V. Daly at the University of California, U.S.A. The results of these analysis as well as those of Ruttner (1985, 1986, 1987) are given as follows:

a) Apis cerana cerana

This sub-species/race is distributed over north China, northwest India, northern Pakistan and Afghanistan. In northwest India, Mattu and Verma 1983, 1984a and b, Verma and Mattu, 1982; Verma *et al.*, 1984 made detailed biometric studies on worker bees of *Apis cerana* from 12 localities of Himachal Pradesh (Himachal region) and eight localities of Jammu and Kashmir (Kashmir region) representing different altitudes.

Univariate analysis of data computed for 55 morphological characters of *Apis cerana cerana* showed significant differences in 28 characters in the Himachal region and 18 characters in the Kashmir region. In bees of Himachal, 40 characters showed a significant positive correlation with altitude, whereas, in Kashmir, 22 characters were positively correlated with altitude. Worker bees from the mountainous zone were significantly bigger in size and darker in colour than those of the sub-mountainous zone. Bees of the Kashmir region were significantly larger in 39 morphometric characters as compared to the Himachal region. This sub-species is also larger in body size as compared to bees of northeast and south India.

Verma, *et al.* (1987) also made discriminant analysis of *Apis cerana cerana* found in Kashmir and Himachal regions by computing their centroids based on the mean values. In this analysis, 97.04 per cent of the bees were correctly classified according to geographic regions. These results also supported our earlier univariate analysis results (Mattu and Verma 1983, 1984a and b) that bees from the Kashmir and Himachal regions of northwest India can be clustered biometrically into two separate sub-groups. Thus *Apis cerana cerana* in north-

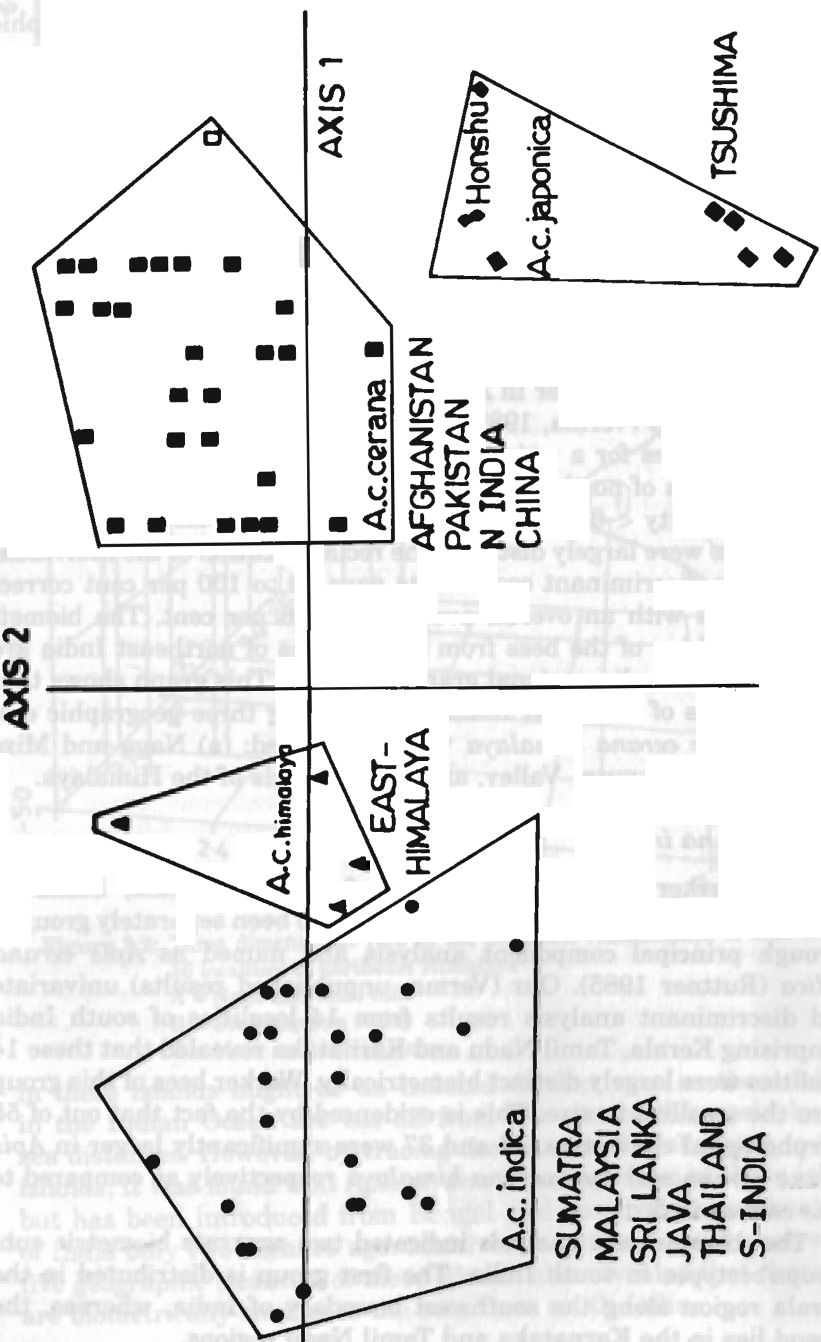

Figure 3.1: Principal component analysis (34 characters) with 68 *A. cerana* samples of 20 worker bees each (after Ruttner 1986)

west India may further comprise two separate ecotypes or geographic populations.

b) Apis cerana himalaya

Ruttner (1985) reported that bees from the eastern Himalaya form a separate cluster from the bees of the western Himalaya. These bees are possibly a separate race which he named as *Apis cerana himalaya* (Ruttner, personal communication). Biometric results on *Apis cerana* from northeast India (comprising Nagaland, Manipur, Mizoram, Assam, Meghalaya, Arunachal Pradesh and Sikkim) support these observations of Ruttner (1985) because out of 55 morphological characters, more than 45 were larger in *Apis cerana cerana* as compared to *Apis cerana himalaya* (Verma, 1987).

The F values for a univariate analysis for each of 55 characters for 16 localities of northeast India were all highly significant (significance probability < 0.0000). The discriminant analysis indicated that 16 localities were largely distinct. The reclassification of the individual bees by the discriminant coefficients gave 80 to 100 per cent correct classification with an overall average of 91.6 per cent. The biometric relationships of the bees from 16 localities of northeast India are shown in a three-dimensional graph (Fig. 3.2). This graph shows that from the bees of northeast India, the following three geographic ecotypes of *Apis cerana himalaya* were recognized: (a) Naga and Mizo Hills, (b) Brahmaputra Valley, and (c) Main axis of the Himalaya.

c) Apis cerana indica

The worker bees of *Apis cerana* from south India, Sumatra, Malaysia, Sri Lanka, Java and Thailand have been separately grouped through principal component analysis and named as *Apis cerana indica* (Ruttner 1985). Our (Verma, unpublished results) univariate and discriminant analysis results from 14 localities of south India comprising Kerala, Tamil Nadu and Karnataka revealed that these 14 localities were largely distinct biometrically. Worker bees of this group were the smallest in size. This is evidenced by the fact that out of 55 morphological characters, 44 and 37 were significantly larger in *Apis cerana cerana* and *Apis cerana himalaya* respectively as compared to *Apis cerana indica*.

The discriminant analysis indicated two separate biometric subgroups/ecotypes in south India. The first group is distributed in the Kerala region along the southwest boundary of India, whereas, the second lies in the Karnataka and Tamil Nadu regions.

We also made biometric studies on *Apis cerana* samples collected from five localities of the Andaman Islands with the idea that bees

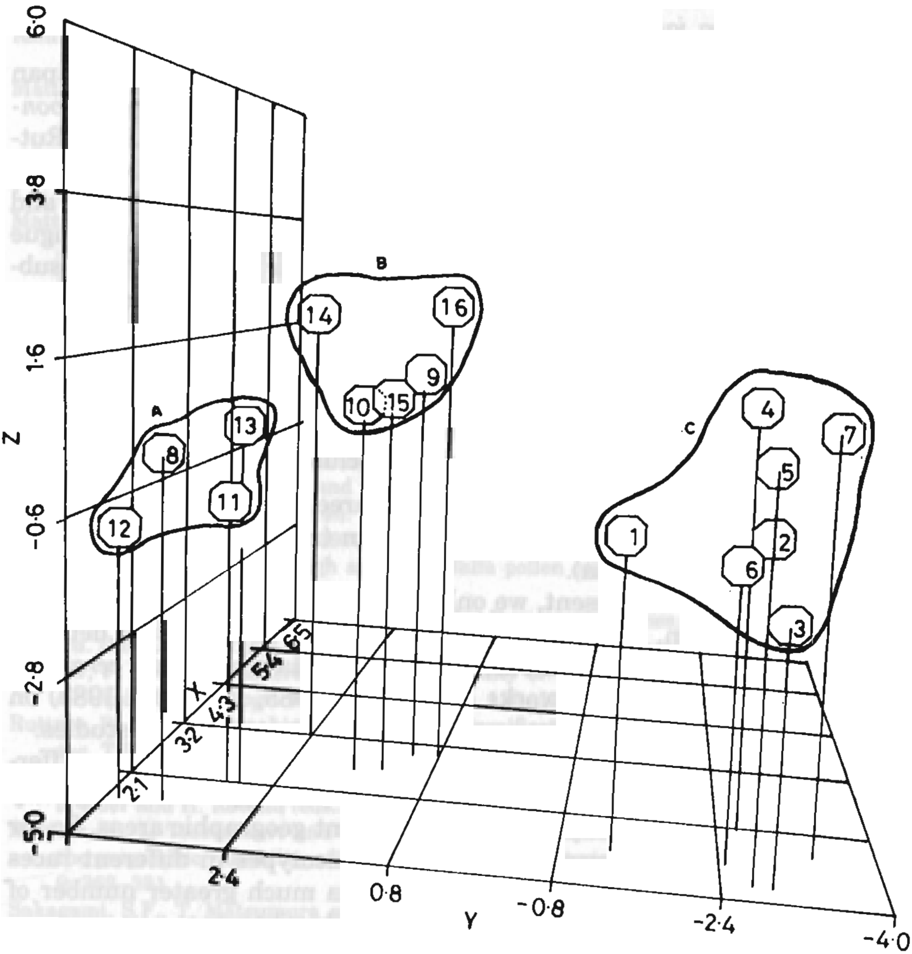

Figure 3.2: Three dimensional view of the biometric relationships of bees from 16 localities of northeast Himalaya
A = Naga and Mizo hills
B = Brahmaputra valley
C = Main axis of Himalaya

in these islands might be an isolated distinct race as these islands in the Indian Ocean are cut off from the rest of the world by long sea distances. However, by tracing the history of beekeeping in these islands, it was found that *Apis cerana* is not a native of these islands but has been introduced from Bengal and possibly from other parts of India only two decades ago. Multivariate discriminant analysis for five geographic localities of these islands also revealed that these bees are biometrically similar to the bees from south India.

d) Apis cerana japonica

This sub-species is well adapted to the temperate climate of Japan except Hokkaido island in the north. However, *Apis cerana japonica* is gradually being replaced by *Apis mellifera* (Okada, 1986). Ruttner (1985) reported that this sub-species can further be divided into two separate ecotypes or sub-groups i.e. Honshu (Tokyo region) and Tsushima bees. These two ecotypes differ from each other in tongue length, forewing length, hair length and colour patterns. This sub-species also has higher cubital index and slender abdomen as compared to other races of *Apis cerana*.

Conclusions

From the above results, the following conclusions can be drawn:

1) Morphometric comparison of the three *Apis cerana* races found in India revealed significant differences in (northwest India > northeast India> south India).

2) Although at present, we only know four races of *Apis cerana* in the Asian region, there may be more addition to this list if detailed investigations are made in other regions of Asia where *Apis cerana* is found. Above-mentioned works of Ruttner (1985, 1986 and 1987) on the biometry of *Apis cerana* provide excellent base for such studies.

3) Each race of *Apis cerana* can be further divided into different ecotypes or geographic populations. These ecotypes are biologically meaningful because they occupy the adjacent geographic areas. So far we have identified seven such sub-groups/ecotypes in different races of *Apis cerana* in India but there may be a much greater number of ecotypes representing the different geographical regions.

4) Present results also suggest that any taxonomic decision or construction of evolutionary relationship among the races of *Apis cerana* should be based on the total distribution of the species in the geographic region wherever, it is found. For such investigation, a regional project aided by some international agency is proposed.

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4

Impact of Human Activities on the Himalayan Honeybee, *Apis laboriosa*

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Although it has been exploited by humans for perhaps thousands of years, the Himalayan honeybee, *Apis laboriosa*, has only very recently come under scientific scrutiny. Our limited knowledge of this bee is mainly due to the fact that *laboriosa* is found only in remote valleys of the mountainous regions of Bhutan, China, India, and Nepal, where it nests beneath rock overhangs on vertical cliff faces (Sakagami *et al.* 1980). The more that is learned, the more it becomes apparent that human activities are having an increasingly deleterious effect on populations of this bee. Anecdotal evidence suggests that within the last 50 years the number of colonies of *laboriosa* has greatly declined throughout much of Nepal (see Valli and Summers 1988) and possibly in other countries as well.

Given the worldwide importance of honeybees as pollinators, and the probability that *laboriosa* is of similar importance, a decline in numbers of colonies may, in turn, have an adverse impact on the quality of human life in those areas where it is found. Therefore, it is of some interest to understand how human activities interact with the ecology of *laboriosa* and to examine the implications of those interactions. Because most of what is known about *laboriosa* stems from studies conducted in Nepal (Underwood 1986, 1990a, 1990b), much of the following discussion will be directly applicable there, but, because of cultural or geographic differences, may have slightly less relevance in other parts of its range.

Habitat and Seasonal Cycle

In order to understand the impact of human activities on *laboriosa*, it is important to know the habitat and seasonal cycle of colonies of this bee. *Apis laboriosa* nests on cliffs at altitudes ranging from 1200 to 3500 metres or more, but an individual colony does not remain in one place the year round (Underwood 1990a). From about early February until late November or early December, colonies are found at heights of at least 10 metres above the ground and are typically aggregated, with as many as 76 colonies or more at a single cliff site. The high altitude sites, above about 2500 metres, are occupied only during the short summer season, from May or June until late September or early October. The best available information indicates that reproduction, the multiplication of colonies via swarming, takes place only during spring and is concentrated during the months of April and May. Thus colonies probably do not reproduce at the high altitude sites occupied during summer. Certain cliff sites are favoured and are returned to year after year. At lower altitudes (1200–2000 metres), if colonies are undisturbed, they may remain on a given cliff from early spring until late fall and a few may even stay through the winter if conditions are unusually favourable. Most colonies exhibit a very different wintering strategy, however.

In late November or early December, colonies abandon their combs at the cliff sites and move to protected locations beneath rocks or fallen logs or at the base of overhanging trees (Underwood 1990b). Winter clustering sites differ from cliff sites in two important ways: they are always near the ground, often less than a metre high, and they are small and dispersed, meaning that only one colony occupies a single wintering site. If undisturbed, a winter swarm will remain clustered, without building a comb, for as long as six to eight weeks. At this time of the year, temperatures may drop below freezing and bees in the cluster must rely on the food stored in their honey stomachs or what little forage they can find on those days when it is warm enough to fly. For a full month from about mid-December until mid-January there is little or no forage available even if the weather is favourable for flight. In late January or early February, the swarms move back to the cliffs and immediately begin to build a comb, thus starting the yearly cycle again.

Impact of Environmental Degradation

In Nepal, the lower range of altitudes at which the Himalayan honeybee is found is precisely that at which some of the greatest alterations to the environment due to human activities have occurred. Until about 30 or 40 years ago, the population density of humans at altitudes below 1000 metres was quite low due to the threat of malaria. Also, because of the shortening growing season with increasing altitude, there were few permanent settlements higher than 2500 metres. With the vast majority of the population concentrated in the middle hills, much of the forest in this area disappeared as land was cleared for agriculture. What forest remained was under increasing pressure from the cutting of firewood, lopping of trees for fodder, and the direct grazing of buffalo, cattle, goats, and sheep on the forest floor. Such is still the case today, for although efforts at reforestation have begun, they have not yet turned the tide and although many people have relocated to lower altitudes and to the Terai, the middle hills are, from an ecological point of view, still dangerously overpopulated.

The destruction of forest habitat has undoubtedly had a great deal to do with the reported decline in numbers of *laboriosa* colonies. In fact, it can be argued that habitat destruction has probably had a greater impact on *laboriosa* than has the direct destruction of colonies during the honey harvest. When forests containing many different types of flowering trees and other plants are replaced by agricultural land, it usually means a reduction in the amount of forage available to bees. Many of the staple crops grown in the hills are of little or no value to honeybees. Such crops include rice, wheat, barley, potatoes, radishes, and various green vegetables. Although corn may provide some pollen, it produces no nectar and is of questionable value to bees. Furthermore, increasing amounts of insecticides are being used and bees collecting pollen from corn have been killed because of sprays used to control harmful insects (personal observations).

One of the few widely grown crops that is of value to honeybees is mustard or rape, *Brassica campestris*, grown for oil seed. Since this crop is grown on only a limited amount of land in the hills and is in flower for a relatively brief part of the year (late winter or early spring depending on the altitude), it cannot make up for the myriad variety of honey plants that might have been available if the land had not been cleared for agriculture. Because of the loss of forage plants due to the conversion of forests to fields, colonies in spring would not be able to build their populations as rapidly and this might force them to forego swarming or cause them to cast small swarms that would have a reduced probability of survival. In either case, the result would be an eventual decline in colony numbers.

Another aspect of the problem of habitat destruction became evident during a recent study of the behaviour of winter swarm clusters of *laboriosa* (Underwood 1990b). As has been mentioned, the sites occupied by colonies in winter are very different from the cliff sites where colonies nest during the rest of the year. The cliff sites seem to be chosen to thwart predators such as bears or martens that would be interested primarily in the brood and honey. Colonies on cliffs are very visible, but the bees are active and able to mount effective counterattacks that probably ward off even flying predators such as large hornets and birds. Also, the practice of nesting on the same cliff with other colonies probably gives a measure of additional security.

Given the advantages of nesting high above the ground in close proximity to other colonies, why do bees seek winter quarters that are near the ground and separated from the clustering sites of other swarms? Since colonies in winter have no stored honey or brood to protect, there is little danger from predators interested in these commodities. This might explain why winter clusters are seemingly unconcerned with being near the ground, but is not in itself an explanation of why bees leave the cliffs.

One of the key factors leading to the effort to conceal winter clusters in low, dispersed locations seems to be bird predation. Although apparently not a serious problem at other times of the year, predation by birds can have devastating effects in winter. Because of the cold temperatures, the bees are unable to defend themselves effectively. Ashy drongos (*Dicrurus leucophaeus*), little bronzed drongos (*D. aeneus*), and chestnut-bellied rock thrushes (*Monticola rufiventris*) have all been observed preying on winter clusters of *laboriosa* (Underwood 1990b). If colonies remained on the cliffs in winter, they would be completely exposed and visible to birds from a long distance. Winter swarms are probably dispersed because an aggregation of such colonies would be more difficult to conceal and a colony unable to defend itself could expect to derive no benefit from other nearby swarms that would be in a similar predicament. Repeated attacks by birds cause swarms to abscond; presumably they seek another, better hidden, clustering site.

The practice of grazing livestock in the forest may affect the survival of winter clusters in two ways. First, a swarm unlucky enough to choose a site near a major forest trail may be intentionally molested by those whose charge it is to look after the animals. Such a swarm may be stoned in an effort to cause it to abscond or it might be destroyed outright by burning. It is feared that cattle or buffaloes might be stung and, in trying to escape, could blunder off a precipice or otherwise injure themselves. A second consequence of the grazing of livestock is that the animals destroy, by eating or trampling, low vegetation that helps to conceal winter swarms. If a swarm is made more visible, its chances of being detected by birds are increased. Absconding because of attacks by humans or other predators is an energetically expensive undertaking for winter swarms. It is possible that several such moves might so deplete a swarm's food reserves that it would be unable to survive the winter even if it did not succumb directly to the attacks themselves.

Impact of Human Predation

One of the major threats to *laboriosa* colonies nesting on cliffs is predation by humans. Because colonies reuse the same cliff sites every year, these locations are well known to people and there is in many parts of *laboriosa*'s range a long history of honey-hunting (Valli and Summers 1988). A typical honey harvest starts with the smoking of the bees to drive them out from their combs and make them less aggressive. Often a smokey fire is built at the base of a cliff and the smoke rises to the colonies above. Then a rope ladder is tied to a tree and lowered from the top of the cliff so that the honey hunter who descends it will be within reach of some of the colonies. Each colony of bees builds a single comb and usually this entire comb is destroyed; the brood portion (the lower part of the comb) is taken first and then the upper, honey portion is harvested.

Between the time the cliff is smoked and the time when the comb is cut, the bees usually are able to imbibe enough of the stored honey to allow them to survive for at least several days. This is enough time for the colony to move to a new cliff (once their comb has been destroyed bees rarely remain at the same site) and begin the task of building a new nest. In some instances, the topography of the cliff is such that the honey hunter cannot reach all of the colonies nesting there and not all are harvested. If the whole cliff has been smoked and all of the bees disturbed, however, even those colonies that did not have their comb destroyed will abscond (personal observations).

The destruction brought by the honey harvest is one of the most obvious consequences of human interaction with the Himalayan honeybee and it is tempting to lay much of the blame for the decline in colony numbers on this practice. In fact, there are probably few colonies directly destroyed during the harvest. These would involve colonies whose queens were accidently killed or perhaps colonies that had recently swarmed and had not yet had a new queen emerge. Such colonies would be unable to rear new queens since their brood would have been destroyed and they would be doomed.

At the lower altitudes, the timing of the honey harvest often coincides with the time of reproductive swarming by *laboriosa*. If a colony is harvested before it has swarmed, it is unlikely that it will be able to muster the resources for another attempt at reproduction until the next year. Even if a colony were successful in reproducing before the harvest, its population would be depleted by the act of swarming and the destruction of brood comb by the honey hunters. If that colony then absconded to a cliff at a higher altitude, it might again fall prey to another honey harvest and be further weakened to the point where it might not survive. Thus, the effect would be one of no net reproduction. A lowering of the reproductive rate would have the effect of reducing colony numbers since those colonies that died (for whatever reason) would not be replaced as quickly.

If there were no environmental degradation (*i.e.*, no loss of forage for bees) and the decline in *laboriosa* populations could be attributed to the practice of honey hunting alone, one would expect that the production of honey per colony among those that remained would rise since fewer bees would be competing for the same resources. This has apparently not been the case as the amount of honey harvested per colony is also said to have declined (Valli and Summers 1988). The recent discovery of the brood disease European Foulbrood in colonies of *A. laboriosa* in western Nepal may be an indication that environmental deterioration has reached a critical stage. European Foulbrood occurs in colonies of the Western honey bee, *Apis mellifera*, but is considered a "stress disease". That is, it only manifests itself in colonies that have been weakened by some kind of stress, such as poor foraging conditions. It is also possible that the foulbrood was recently introduced in Nepal through the importation of colonies of *A. mellifera* (such an importation is rumoured to have occurred, but there is no way to confirm it). In either case, this disease, which may be severe enough to kill some colonies, can be blamed, directly or indirectly, on the actions of humans.

Conclusions

There can be little doubt that human activities have had an adverse impact on many aspects of the environment in the Himalaya. The decline in population of the Himalayan honeybee is just one example of that impact, but, as is so often the case in questions of ecology, this decline may have ramifications that affect the quality of human life as well. The importance of *Apis laboriosa* as a pollinator has never been studied, but it is safe to say that a decline in colony numbers cannot but have negative consequences for agriculture, especially at high altitudes in the Himalaya.

It has been stated that many of the traditional agricultural crops are of little value to honeybees and the bees, in turn, are not needed to pollinate those crops. This situation is changing, however, especially in those areas where efforts have been made to promote the growing of fruits as a cash crop. Throughout the Himalayan region, temperate fruits, especially apples, grow best at altitudes of about 2000 to 3000 metres. Apples require insect pollination and, worldwide, honeybees are the pollinators of choice. There is reason to believe that, at least for some varieties, *Apis laboriosa* may be a superior pollinator to either of the two species of honeybees (*A. mellifera* and *A. cerana*) commonly kept in hives. Of these two, only *cerana* is native to the Himalaya and it is rarely found at altitudes as high as 3000 metres.

At the present time, there is no reason to believe that *Apis laboriosa* is in any danger of extinction because of the negative consequences of human activities. However, nothing has yet been done to stem the decline of colony numbers and the activities discussed above are unlikely to stop in the near future. Although the grazing of livestock in forested areas is a destructive process, preventing such grazing, even if of long-term benefit, would pose a great hardship to people in the near term and would be an unpopular policy difficult to enforce. Reforestation efforts are essential in order to repair ecological damage already done, but these are unlikely to be of much benefit to honeybees. When tree plantings are made, they typically involve blocks of one or a few species chosen for their fast growth and utility for fuel or fodder and with little regard for other useful qualities.

Perhaps one of the first steps in the salvation of *laboriosa* will occur as a result of the very decline in the number of colonies and of production per colony already noted. As the value of the honey harvest declines, the practice of honey hunting will become less attractive and there is some hope that with reduced hunting pressure, *laboriosa* populations will rebound. Recently, a direct effort toward conservation has been made in Bhutan, where harvests of cliff bee nests have been banned. Although apparently initiated because of religious considerations rather than any concern for a decline in the bee population, the ban may provide indirect agricultural benefits.

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5

Honeybee Resources in North West Frontier Province of Pakistan

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Honeybees are kept mainly for honey production in Pakistan for the last two hundred years whereas in the United States of America, honeybee pollination contributes US$18 billion annually to agriculture in addition to the direct income from honey production and pollination service charges to the beekeeper. Now the awareness of the multiple benefits of bees pollination is being created through the government TV/radio and seminars/workshops and training courses throughout the country to convince the farmers, particularly the progressive fruit and oil seed growers, to increase their crop productivity through the renting of honeybee colonies on subsidy for pollination purposes.

North West Frontier Province of Pakistan is very suitable for beekeeping on account of its different ecological zones of tremendously rich flora on 8.33 million hectares, out of which two million hectares, i.e. about one-fourth is cultivated. There are about 20,000 honeybee colonies. This province has a potential of producing 35 tons of honey per annum. Whereas at present only about two tons of honey is produced in a year as shown in Table 5.1. Major sources of honey are loquat, sunflower, sarson (winter crops); citrus, sheesham, eucalyptus, willows, stone and pome fruits (spring crops); bekar, acacia, shaftal, berseem and lucerne, corn and sorghums (summer crops); ber, sunflower and shein (autumn crops) both in the mountain areas as well as the plains. Apiary migration (migratory beekeeping) is vigorously followed in accordance of the floral charts.

There are four species of honeybee in North West Frontier Province of Pakistan. These are widely spread in the province.

1) *Apis dorsata*
2) *Apis florea*
3) *Apis cerana*
4) *Apis mellifera*

The first two species of honeybee cannot be domesticated and build their nests in the open air on tall trees and shrubs respectively. Whereas the rest of the species i.e., *Apis cerana* and *Apis mellifera*, are domesticated and kept in modern movable-frame hives for honey production as well as for pollination. *Apis cerana* is a native species and is being kept in the northern hill and mountain areas of Pakistan such as Dir, Chitral, Swat and Kashmir in earthen pitchers, hollowed logs fixed in the walls of the room of the house for the last 200 years. It was found in natural nests in crevices and cracks of the hills and mountains and dead hollowed trunks of the old trees much before the dawn of civilization in the above-mentioned hilly tracts.

Eighty-five per cent of the local bee colonies were destroyed during 1981–82 due to the acarine disease caused by *Acarapis woodi* which was possibly introduced by the Afghan refugee beekeepers who brought bee colonies along with their other belongings from their homeland, Afghanistan, in 1980.

1) Apis dorsata

This species is locally called Domna or giant honeybees. They build nests in the open air on strong branches of mostly tall trees, in shady places during summer and in sunny places or at least facing toward the sun in winter. Even on a single large tree many nests are found. This species passes summer and autumn in the forest reserves in Changa Manga, Punjab and Haripur on Ber (*Zizyphus* spp.), early bloom of sarson and loquat blossom in the Punjab and Haripur respectively and then in late winter migrate to the North West Frontier Province to continue foraging on mustard, citruses, stone and pome fruits, bekar, *Acacia*, berseem up to mid-June. They have a very long flight and migrate long distances throughout the country and help tremendously in crop pollination.

Their nests are always tapering at one end to form a honey chamber. The other end consists of the brood. The size of the nest is variable, depending on the location, flora and blossom duration. Usually its length ranges from three to seven feet and the width varies from two to three feet. Obviously the nest is divided into two chambers/apartments in a 3:1 ratio for brood and honey respectively. The tapered end contains honey which is white in colour and the brown chamber consists of eggs, larvae and pupae. At the base line, i.e., attachment line, the honey chamber base is about 10 cm wider as compared to the brood chamber base of 4 cm.

This species is a high honey producer and good pollinator, but hard to handle on account of its aggressive temperament. There is a need for immediate research for improvement of honey collection technology and to demarcate separate suitable location for them in order to avoid food competition with other species of honeybees.

Honey hunters collect a lot of honey from this species at a nominal rate of leasing forest reserve from the forest department. A large number of *Apis dorsata* nests are usually seen on trees from February to June in North West Frontier Province.

2) Apis florea

Apis florea is also commonly called small/little bee because its size is the smallest among the other species of honeybees. This species also builds its nests in shrubs, trailers (grapes), bushes around bangalows, gardens, lawns in the open air in a protected places. This species forms a single comb on a twig or branch of the host plants. The comb size is very variable; producing about 1 to 2 kg of honey at one time.

Several experiments were conducted for its domestication in hive type shelters or confinements but none of them was found feasible and economical. We developed a method which involved collecting stray wild nests along with the twigs which are then tied to a branch of a fruit tree in a row, in the months of December/January facing the sun. In the winter months, these nests are sheltered with gunny bag and plastic sheets placed on top. In the months of April, May and June the shelter is removed and only thick shade is ensured to avoid the heat of the direct sun. This method ensures clean and easy harvest of honey: one from mustard/citrus and another from fruits, *Acacia* and berseem, in March and May respectively. This honey is very costly particularly if sold as comb honey.

3) Apis cerana

This is a native species of the region and is found abundantly in the northern areas of North West Frontier Province. It is kept in earthen pitchers/logs by mountain communities and also in modern movable-frame hives, in the plains. This species is smaller in size than the European bees. *Apis cerana* is very prone to swarming and wax moth. It requires frequent cleaning and prevention from the attack of wax moth. It has some posture good traits, such as the ability to escape predators (hornets), and good clustering to avoid cold temperature in winter. These bees fly swiftly and in a zigzag manner. They are well suited to the mountain areas. They forage extensively and intensively. Geographic ecotypes have evolved through natural selection over a long period of time exhibiting a variable vast genetic pattern or traits. This species works for longer durations, starting from early dawn and carrying to late evening. This species does not produce propolis. In the Himalaya, there are certain "bee dens" and some specific valleys in the mountains which are known for the honey hunting during the honey flow season, such as Champtali valley around the 'Shangla hills and Darora in Bunir hills'. These "bee dens" are locally called as "Mucho Qamar" or "Mucho Qamaroona" in Pushto. Such bee dens are also found in Barawal and Termangal districts of Dir and Kohistan. In late spring or early summer, the mountain people go to these dens for honey hunting and for the collection of wild bee swarms of *Apis cerana*. These dens are full of *Apis cerana* where they build their nests usually in cracks/crevices or in trunks of dead and hollowed old trees. The mountain local people fix their own pitchers, or mostly logs, in these bee dens for harvesting honey from their own logs in September or October. This is one source of income for the mountain community, to sell honey and beeswax in the local markets. The mountain men do not use bee swarm collection baskets but they still use old trousers (*shilwars*) fitted with a string for closing it after collection of the swarm.

4) Apis mellifera

The European bees were imported from Italy, West Germany, Russia, the United Kingdom (U.K.) and Australia during the past 20 years into Pakistan. Due to the lack of bee specialists at the quarantine posts and the non-existence of bee disease laboratories in the country, many bee diseases were inadvertently introduced into the country. This situation was much worsened when the Afghan refugees brought honey bee colonies along with their belongings, into Pakistan during 1980–81. The Afghan refugee beekeepers kept migrating/shifting their apiaries from one place to another throughout Pakistan without any specific search for seasonal bee flora. This resulted in the outbreak of an epidemic causing heavy destruction, of about 85 per cent colonies of *Apis cerana* and 55 per cent colonies of *Apis mellifera*, in 1982.

Apis mellifera is good for migratory beekeeping and produces more honey and other hive products such as propolis and royal jelly. A migratory beekeeper is able to harvest five times more honey in accordance to the honey extraction calendar as given in Table 5.1, with an average yield of 23 kg honey per colony.

TABLE 5.1

Honey extraction calendar

No. of times of honey harvest	Period of honey extraction	Nectar source	Average honey yield per colony
First	4th week of January to end of February	Loquat (*Eriobotrya* sp.), Mustard (*Brassica.* spp.)	10–15 kg
2nd	4th week of April	Bhaikar/Baza (*Adhatoda vasica*) *Citrus* spp. *Eucalyptus* sp. Stone and pome fruits	15–20 kg
3rd	3rd week of May	Phulai (*Acacia modesta*). Guava (*Psidium guajava*) *Eucalyptus* sp. Bottle brush (*Callistemon* sp.) Shisham (*Dalbergia sisoo.*) Keekar (*Acacia* sp.)	20–25 kg
4th	3rd week of June	Shaftal (*Trifolium resupinatum*) Berseem (*Trifolium alexandrianum*) Alfalfa (*Medicago sativa*)	25–40 kg
5th	2nd week of September to the end of October	a) Ber (*Zizyphus zuzuba*) Cotton (*Gossypium* spp.) Dates (*Phoenix* sp.) Bananas & summer vegetables b) Shain (*Plectranthus rugosus*)	a) in plains 15–20 kg b) in hilly areas 30–42 kg
		Range:	19–42 kg
		Mean:	23 kg per colony per season

Thus a commercial migratory beekeeper can obtain about 23 kg round the year per strong colony in the North West Frontier Province of Pakistan including the Himalayan region.

Honey Extraction Practices

There are mainly two methods of honey extraction in NWFP. One is the indigenous/crude method and the other is the centrifugal machine method.

(1) Honey Extraction by Squeeze

A crude method of honey extraction is where the honeybees are kept in an earthen pitcher or hollowed log, mostly in mountain areas of this province. The pitchers or hollowed logs are immitations of the natural nests found in the cracks and crevices of the mountains, hill dens and hollowed walls/trunks of old dead trees. The honey hunters of the hill communities felt the need to keep the bees in their natural environments. Therefore, keeping the natural nests as models, the old/primitive honey farmer prepared the logs and pitchers or pipe of not less than 30 cm diameter, from mud. A narrow hole is made in the anterior end of the pitcher or log and a lid of about 15 cm diameter is made at the posterior end. These logs/pitchers do not have frames or separate honey super/chamber. These are fixed in walls of rooms with the anterior end (entrance for the bees) facing the sun, and the posterior end inside the room, for easy removal of honey comb. At the end of the honey flow season the bees are smoked out from the posterior end after removing the lid and then the beekeeper either removes the entire comb or two parallel combs on either side. The combs are crushed and squeezed in a tin or iron mesh to obtain honey. This is not a good method of honey extraction because the brood gets destroyed and in most cases, the bees abscond. The honey also, is not of good quality as it carries a lot of pollen grain and brood contents.

About 15 years ago, the squeezed comb-wax was not utilized for any purpose and was thrown away. But, thanks to our extensive training courses, now it is sold to the wax dealer in Mangwara, District in Swat valley. The wax dealer melts it in large pans to remove the impurities and converts it into wax blocks, each of 21 × 30 cm. These are then marketed for foundation sheets, candles and cosmetics at the rate about Rs 60 to 80 per kg.

The local beekeepers sell the honey in tins to the honey dealers at Mangwara city, each tin of honey weighs about 25 kg. The honey is then bottled after filtration, in 1 kg or half kg bottles, for retail sale at the rate about Rs 50 to 60 per kg.

2) Honey Extraction by Machine

In the plains both the species, *Apis cerana* and *Apis mellifera*, are kept in modern bee hives. After honey flow season the well capped honey frames are taken out of the supers. These are uncapped either by knife or fork. These uncapped frames are then put into a honey extractor, which works on the centrifugal driven principle. There are two types of honey extractors; one machine is manual and the other is power-driven. The former is usually kept by small/hobbyist beekeepers and the latter by commercial beekeepers. Honey extracted by this method is fine and clear, and it is stored in tins or barrels for wholesale or is bottled from the outlet of the extractor for direct home/family consumption and retail sale in Jomma Bazar and the Flea markets.

3) Honey Hunting

This is also a crude/rough method of obtaining honey from the wild bee colonies of *Apis dorsata* in the forest. This honey is thus called forest honey. This honey is generally "robbed" by honey hunters. They use a rope and a long telescopic pipe fitted with a sharp blade a sickle type of knife, for either removing the entire comb or for cutting only the honey portion. Honey is squeezed out using a fine thin cloth or mesh. Forest reserve such as Changa Manga are given on lease to the honey hunters by the forest department. They produce an approximate yield 4 tons of honey annually.