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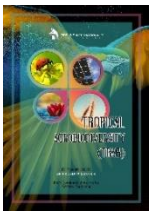

RESEARCH ARTICLE

ROLE OF *APIS LABORIOSA* BEES FOR THE HIMALAYAN BIODIVERSITY CONSERVATION AND THEIR POTENTIAL CONSERVATION EFFORTS

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ABSTRACT

Among the five species of bees present in the Himalayas of Nepal, *Apis laboriosa* is the native species that makes open nesting in a single comb in the cliffs. It is seen in large numbers there. It is believed to have contributed to the preservation of the biodiversity in the Himalayan region of Nepal and is one of the most important pollinators in the area. This being said, there is a significant research gap and a dearth of studies and study on the specific bee species, which presents a wonderful opportunity for additional research and reviews on this species. The identification and taxonomy, habits and habitat, pollinator role of *Apis laboriosa* in the preservation of Himalayan diversity, global and Nepalese conservation strategies currently in place, and suggested conservation strategies for this species of bee are all covered in this paper.

KEYWORDS

Bees; Biodiversity; Conservation agriculture; Pollinators

1. INTRODUCTION

The Himalayan enormous honey bee is an extraordinary but largely unknown species of bee because of its nesting place on difficult cliff walls in the Himalayas (Musir, 2017). Frederick Smith identified numerous characteristics that he thought distinguished Apis laboriosa from lowland A. dorsata, leading him to name the first specimen. The specimen was gathered by Smith in the rugged hills of western Yunnan. This taxon was disregarded until began reevaluating the taxonomy of honey bees (Maa, 1953). Here is how it is distributed: India (Assam; Sikkim); China (Western Yunnan). Not to mention, probably, in North Burma. The first detailed descriptions of the morphology, biology, and geography of Apis laboriosa offered strong evidence for the species' identity as a distinct entity, different from lowland giant honey bees (Prescott, 1990). There was also a range map that showed 22 locations along the main rivers that pour into the Himalayas in Nepal. They highlighted how "scarce" the reports were outside of Nepal, including just four locations in Arunachal Pradesh and one in "Tibet". The fact that Apis laboriosa and A. dorsata samples were collected from the same site (Denling Forest, Kameng Div., Arunachal Pradesh, 229 mas.l.) is noteworthy since it suggests that these two species coexist in some areas of Asia.

More than 20 years have passed since the most recent *Apis laboriosa* range map was released. There were glaring gaps even with all the locale data that was available at the time (e.g., in Bhutan, northeastern India, northern Myanmar, Laos, and Vietnam). Since then, more fieldwork, new publications, and naturalists sharing their images and videos on iNaturalist and other websites have contributed to a sharp rise in the number of verified reports. With four native species—*Apis cerana*, *Apis florea*, *Apis dorsata*, and *Apis laboriosa*—and one foreign species—the European bee, *Apis melliferea*—introduced for honey production, the Himalayas of Nepal are home to a great diversity of honey bees. Known as the Himalayan hive honey bee, *Apis cerana* can be managed to produce honey or left in hives. It is a wild species. Honey from *Apis dorsata*, *Apis laboriosa*, and *Apis florea* is harvested in the wild instead of being housed in hives. While *Apis dorsata* is known as the jungle or forest bee, *Apis laboriosa*, also known as the Himalayan cliff honey bee, makes its nests on cliff sides.

Since native honey bees are natural pollinators of a wide range of native plants and contribute significantly to insect biodiversity in the Himalayan region, Nepal's native honey bees are essential to the preservation of biodiversity in mountainous regions. Simultaneously, they effectively counteract soil deterioration by improving the cycle of replenishment, resulting in increased pollination, seed production, plant growth, and ultimately, a return of biomass to the soil. Despite this fact, little information regarding their population status, their contribution to maintaining biodiversity, or emerging threats to their existence. The objectives of this review paper are to review the role of *Apis laboriosa* bees for the Himalayan biodiversity conservation in Nepal and the potential conservation efforts done by Nepal for *Apis laboriosa*

2. METHODOLOGY AND DISCUSSION

Various online journals, articles, book and book sections, article in a periodical, conference proceedings, report, website, electronic source, case studies, government as well as non-governmental sites were assessed for preparing this review paper.

2.1 Taxonomy and Identification of *Apis laboriosa*

Classification of the taxonomic status and biology of *Apis laboriosa* Smith is one of big interest because this bee is apparently the largest of the Apis, the only non-tropical member of the genus Apis, and virtually unknown to all but local residents in aspects of its ecology and natural history. To differentiate it from *Apis dorsata*, as resolved by some researchers showed considerable differences in size, vestiture and coloration (Shakagami et al., 1980; Banjade et al., 2023). Although these differences were stable and reliable as diagnostic features, the only morphological characters that was divergent between the two groups, I.e. *Apis laboriosa* and *Apis dorsata* was

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the shape of the spiracular plate on the eighth hemitergite which solves the taxonomic problem but the evolutionary or biological distinction between the species remain obscure.

A morphometric study of a "super dorsata" bee from elevations between 1500 and 4000 meters in Nepal was published by Sakagami et al. in 1980. The study used more than 70 carefully chosen characteristics. Cockerell originally gave this bee the name "MegApis laboriosa" in 1906. The following arguments support the proposal to identify this taxon as a fifth Apis species: 1. Important quantitative differences supposed to be exceeding those found within one of the Apis species 2. Presumably sympatric occurrence 3. Ecological divergence

Compared to *Apis dorsata*, *Apis laboriosa* has a fully dark abdomen and long, golden thoracic hairs. *Apis dorsata* has dark thoracic hairs and several orange or yellow anterior abdominal segments. The Rocky Mountains are home to *Apis laboriosa's* open single-comb nesting sites, which are higher than those of *Apis dorsata* and do not overlap. The birds build their nests on overhanging cliffs.

Table 1: comparative morphological characters between workers of *Apis laboriosa* (new bees) and *Apis dorsata* (Ahmad et al., 2003)

Characters	New bees	A dorsata	P
Proboscis length (mm)	6.956 ± 0.023	6.560 ± 0.030	P < 0.05
Forewing length (mm)	14.139 ± 0.035	12.933 ± 0.055	P < 0.05
Cubital indexes	8.489 ± 0.324	5.278 ± 0.182	P < 0.05
Length of sternite 3 (mm)	3.985 ± 0.013	3.689 ± 0.016	P < 0.05

2.2 Geographical distribution of *Apis laboriosa*

By virtue of the efforts of who mapped and located 345 localities—Bhutan, China, India, Laos, Myanmar, Nepal, and Vietnam—among the 349 locations of *Apis laboriosa* foragers or nests (Ratto et al., 2018). Over a span of more than 2,500 kilometers, the species is spread almost continuously along the Pan-Himalaya region, starting in Uttarakhand, India, and moving eastward through Nepal, Sikkim, and northern West Bengal (Darjeeling), Bhutan, northeastern India, Yunnan and southern Tibet in China, as well as the northern regions of Myanmar, Laos, and Vietnam.

2.3 Elevational distribution of Apis laboriosa

About 77.2% of the recordings were between 1000 and 3000 masl, and nearly all of the records (94%) fell within the altitudinal range of 500-3500 masl (Muir, 2017). Additionally, they corroborated observations made in Arunachal Pradesh at lower elevations as opposed to locations farther west in Bhutan, Nepal, and Uttarakha`=3nd, India. In "Denling Forest," in western Arunachal Pradesh, India, 229 meters above sea level was believed to be the lowest elevation ever measured.

2.4 Sympatric occurrence of *Apis laboriosa* with *A. dorsata*

During their fieldwork, a group researcher discovered five locations spread across three districts in northeastern India's Arunachal Pradesh where *A. laboriosa* and its sister species *A. dorsata* foraged together (Ahmad et al., 2003).

2.5 Habit and habitat

The world's largest honeybee, *Apis laboriosa*, is found in Nepal's northern Himalayan areas, which are ecologically sensitive, at elevations ranging from 850 meters to 3500 meters. The cliff honeybees are the common name for it. They have bands of white on the abdominal segments and are completely black in appearance. *Apis laboriosa* builds a single, 0.8-meter-wide, one-meter-long comb that is hanging from precipitous cliffs (Banjade et al., 2023). One corner of the comb is used to store honey. This species' seasonal migratory, which occurs in the winter when it migrates to warm temperate regions up to 850 m, is crucial to its survival in the extremely harsh environments of the Himalayan regions. There, they spend around seven months (October-April).

A variety of flowers are in bloom at this time of year. Similar to this, during the summer, colonies of *Apis laboriosa* begin to migrate to sub-alpine regions between 2500 and 3500 m at the base of the Himalaya, where they spend five months (May to September) while the ambient temperature progressively rises beyond 25 ºC (Banjade et al., 2023). At least twice a year, the migratory *Apis laboriosa* makes open-air nests (Banjade et al., 2023). The rate at which bee species are going extinct globally is frighteningly fast increasing. Every year, about 0.2-0.3% of all bee species go extinct. Within the next 30 years, certain species found in tropical forests may go extinct (Banjade et al., 2023). It is predicted that during the next fifty years, 50,000 species will be in danger of going extinct and that approximately 60,000 species will go extinct in the near future. In Nepal, habitat loss is a result of the destruction of natural forests, which offer energy, lumber, feed, ecological balance, and other benefits.

As a result, pollinators and biodiversity are at risk. Sustainable agriculture is in danger because of the demand from a growing population to meet their needs, which is a result of expanding farmland and the loss of pollinator habitat. The Himalayan locals' damaging honey-hunting practices are causing the colonies of *Apis laboriosa* to diminish in size. It is predicted that during the next fifty years, 50,000 species will be in danger of going extinct and that approximately 60,000 species will go extinct in the near future. In Nepal, habitat loss is a result of the destruction of natural forests, which offer energy, lumber, feed, ecological balance, and other benefits. As a result, pollinators and biodiversity are at risk. Sustainable agriculture is in danger because of the demand from a growing population to meet their needs, which is a result of expanding farmland and the loss of pollinator habitat. The Himalayan locals' damaging honey-hunting practices are causing the colonies of *Apis laboriosa* to diminish in size. Domesticated native species are being fully replaced by the foreign *Apis mellifera*, which carries noticeably higher pollen burdens.

2.6 Himalayan bee flora in Nepal

One of the most important factors for the survival of the bees in the adverse environmental condition of the Himalayas is due to the availability diverse bee flora which blooms almost year -round. As reported by researcher, in every 10 kilometers upland, diverse vegetation is available (Caughlayer and Sinclau, 1994).

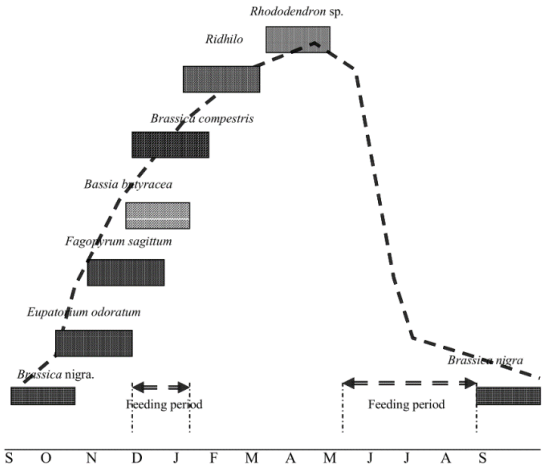

Figure 1: Main bee flora and flowering time of Himalayan bee flora in Nepal

2.7 Global significance of pollinators

Because it permits plant reproduction and the production of food for people and animals (fruits and seeds), pollination is a crucial ecological service. These processes rely heavily on the symbiotic relationship between pollinated and pollinator species. Among many other agricultural products, pollination is essential to the development of fruits, vegetables, nuts, cotton, and oilseed crops. Pollinators support the survival of many plant species, including those that supply food security to countless rural households, and they also help to preserve biodiversity. Animal pollinators are essential to almost 75% of the world's primary crops and 80% of all blooming plant species (Woyke et al., 2012). Around 80% of the roughly one hundred animal-pollinated crops that provide the majority of the world's food supply are pollinated by wild bee species and other wildlife, with farmed bees contributing only 15% of the pollination process (Neupane, 2006). Pollination by animals is the process by which species, particularly agricultural crops, become diverse.

Therefore, pollinators are necessary for biodiversity, a diverse range of diets, and the preservation of natural resources. A variety of bees pollinate over 73% of the world's cultivated crops, including cashews, squash, mangoes, cocoa, cranberries, and blueberries; flies pollinate 19%, bats pollinate 6.5%, wasps pollinate 5%, beetles pollinate 5%, birds pollinate 4%, and moths and butterflies fertilize 4% (Kitnya et al., 2020). Plant

diversity directly influences pollinator diversity, and vice versa. Agricultural biodiversity is also threatened by the decrease in pollinator diversity and pollinator population levels. It is impossible to take pollination for granted because it is an ecological function and a necessary stage in plant reproduction. Many ecosystem services, such as carbon sequestration, preventing soil erosion, nitrogen fixation, maintaining water tables, absorption of greenhouse gases, and providing food and habitat for the majority of other terrestrial and aquatic life forms, are produced and directly provided by plants in a terrestrial ecosystem.

Due to lower agricultural yields, the loss of insect pollinators has a bigger potential impact on the production of food for humans. For self-incompatible and cross-pollinated crops, honeybees are the most effective pollinators because they sustain pollinator abundance throughout the flowering season, ensuring pollination services. Honeybee pollination improves fruit quality, lowers fruit drop, and boosts fruit set in several fruit varieties, including strawberry, peach, apple, plum, citrus, and kiwi. Citrus fruits' increased fruit juice and sugar content has also been mentioned in a number of reports.

2.8 National policies on conservation of pollinators

It is well known that honey bees are the primary pollinators in Nepal among other insects. Even scientists, politicians, and impoverished farmers cannot fully comprehend the role they play in pollinating flowering plants and preserving biodiversity (Banjade et al., 2023). Beekeeping is well-known for producing honey and providing pollination services to crops; however, in Nepal, research and development efforts have not focused much on the pollination services. Not only have policymakers downplayed the significance of beekeeping as a pollination tool, but government officials and agricultural scientists have completely disregarded it.

One of the seven agricultural products selected for the Nepal Trade Integration Strategy is beekeeping, and obtaining organic certification is one of the options. The 2009 Nepal Trade Policy places a strong emphasis on laboratory accreditation, quality control, diversifying the honey industry, enhancing packaging, and offering credit, financing, and marketing incentives. However, it makes no mention of protecting natural pollinators. The Agriculture Development Strategy acknowledges honey as a specialty commodity, but it makes no reference of any particular tactics. ADS only concentrates on strategies that boost commercialization, productivity, and competitiveness.

Likewise, development plans spanning three to five years concentrate on commercializing agriculture, offering agro-credit and insurance, enhancing quality control, testing, and certification facilities, and improving infrastructure. However, they do not address bee species conservation. Among various priority sectors identified by the Agriculture Perspective Plan (APP), beekeeping was included under Priority Output – Livestock. The APP has duly recognized the importance of beekeeping in reducing poverty and enabling women to participate in the productive labor force but fails to address the pollinators and its conservation strategies.

2.9 Conservation and utilization of pollinators

Nepal's indigenous honeybees play a significant role in maintaining biodiversity in mountainous regions as they are the natural pollinators for a wide variety of indigenous plants and also represent an integral part of insect diversity in the very region (Nabhan and Buchmann, 1997). Simultaneously, they provide an unsung hero to the fight against soil degradation by improving the cycle of replenishment: more plants, more pollination, more seeds, and more biomass returned to the soil (Banjade et al., 2023). They possess a value for local farmers as pollinators of cultivated plants and in terms of products like honey and wax, which have traditionally made a significant contribution to the livelihoods of remote mountain communities.

In the high Himalayas, pollination and other eco-services are mainly provided by Apis laboriosa, which has evolved to work under conditions of low oxygen and low temperature. It is the only bee that forages at higher altitudes and it forages intensively. A reduction in the number of Apis laboriosa could have a marked effect on the maintenance of local flora as well as on the pollination of cultivated plants, and it could nullify much of the efforts made by the Nepali government in these regions for poverty alleviation, as most of the inhabitants still depend on forest and agriculture, which in turn depend on pollination (Cornell, 2011). In addition to assisting in the conservation of honey bee biodiversity, maintaining the management of indigenous honey bee subspecies in their native habitats will also enable agricultural pollination and beekeeping activities to adapt to climate change (Thapa, 2001).

Since their arrival in the area during the Middle Ages, the Himalayan honey hunters have developed a deep bond with the bees. New generations of traditional honey hunters are made possible by increased tourism in the Himalayas, which also helps to preserve the *Apis laboriosa* species (Roubika, 1985). Human activity is endangering the endemic flora and fauna in the Kaski region of Nepal, as it is in many other parts of the world, but the Gurung culture and the indigenous species, which are integral to their customs, are in jeopardy. According to Joshi et al.'s research report from 2004, many honey hunters were compelled to give up their hobby due to the significant fall in *Apis laboriosa* populations in the late 1980s and early 1990s. However, the Annapurna Conservation Area worked very hard to improve the project's biodiversity and forest covering. A global mobilization of efforts to address pollination management and conservation has occurred in response to the impending pollination issue.

The ICIMOD program on 'indigenous honeybees of the Himalayas' started in 1991 to fill in gaps of knowledge about indigenous bees originally with the support of USAID, and since 1993 with the support of Austrian Ministry of Foreign Affairs through Austro projekt. The program is using a holistic approach to promote apiculture development and support the conservation of indigenous bees. The project has initiated to assess details on habitats, indigenous practices of honey hunting, changes that threatens their existence, and ways of including them in development plans.

2.10 Importance of wild bees for pollination and biodiversity conservation in Nepal

Pollination benefits plants 40–140 times more than honey and other bee products, and honey bees contribute 60–68 parts to this process (Thapa, 2001). The honey bee is responsible for pollinating a variety of crops, including hercogamy, sexually incompatible blooms, pin or thrum flowers, dioecious plants, and protogyny of protandry. More than three times as much money is spent on crops enhanced by honeybee pollination than is made from the honey the bees make. In terms of food, it can never compete with plants and animals, but through pollination, it can boost crop output and ultimately contribute to food security (Banjade et al., 2023). Thus, from the perspective of food security and biodiversity protection, honeybees are vital to humans. As a result of honeybees' greater interest in nectar, whereas native bees' primary focus is on gathering pollen, native bees are actually two to three times more effective pollinators than other honeybees (Bastakoti et al.,2024).

Different bee flora, such as eucalyptus, Shorea robusta, Bombax ceiba, Melia azedarach, Litchi chinensis, and other fruit trees, were planted to conserve the wild bee species in a project carried out by the Global Environment Facility, Small Grants Program in the Bara district, in cooperation with Sahajnath collaborative forest. Through media coverage, a march, street theater, floor talks, leaflets, workshops, and an interactive program on wild bee conservation, the project raised awareness of the issue ("Brief Introduction to Honeybees and Community Led Wild Honeybee Management in Bara," n.d.). It was said to have reduced fuel gathering from forests by 30% and raised locals' awareness of the need to conserve wild honeybees. The paper also recommends combining organic farming with beekeeping to guarantee the preservation of wild bee populations and honeybees.

2.11 Recommended strategies to conserve *Apis laboriosa*

In order to protect native bee species like Apis cerena, Apis dorsata, and Apis laboriosa, among others, several Asian airports have implemented quarantine policies to prevent the introduction of invasive bee species like Aps mellifera. Imports of queens and packages from nations where A. tumida is now endemic have been prohibited by South Korea and Japan. The effects of hunting on the viability of a species are contingent upon various factors such as population size and growth rate, the percentage of colonies that survive a typical harvest, the percentage of colonies that are harvested, migration rates from nearby regions, colony longevity, reproductive rate, and so forth (Banjade et al., 2023). Since, very little to almost no information is available about *Apis laboriosa* on the above-mentioned parameters, so it is very difficult to assess the effects of hunting on the population of the Himalayan bees. The critical parameters of hunted honey bee populations which are as follows:

i. "H" harvested rate: the percentages of harvested colonies

ii. "N" population size: the size of the entire population

iii. "r" growth rate: the variation in the number of colonies in a given season, assuming no harvesting

iv. "S" survival rate: the percentage of colonies that make it through harvest in order to procreate

The objective is to harvest colonies while maintaining H significantly less than r. For the giant bees we need someone to study a nesting site for a complete reproductive season, counting the number of established colonies at the beginning of the season, the number of migrants that join the nesting site, the number of daughter colonies, and the survival of all of these.

Apis dorsata and *Apis laboriosa* harvesting is frequently a damaging procedure. On the other side, bee hunters frequently support the preservation of forests and are conservationists. There are initiatives underway in Vietnam, Cambodia, and a few other regions of Indonesia to promote the non-destructive collection of honey from A. dorsata nests. This means that instead of burning or smoking the bees at night, harvesting can be done during the day by using bee smokers and protective clothes to keep hunters safe from stings. The absence of funds to buy smokers and bee veils puts the efforts towards sustainable honey collecting in jeopardy, as the hunting materials are made from materials collected from the forests.

Next strategy is to encourage bee keepers to keep native bees. If 1000 beekeepers kept 1 beehive of indigenous bees then they are less likely to get extinct. But the native species of bee should provide benefits to the beekeeper as compared to other exotic bees like Apis mellifera in terms of disease susceptibility, hardiness, honey collection and other behaviors. But in all aspects, Apis mellifera is profitable to any forms of native bees and the resource poor farmers should not take burden of conserving the native bees because it's the responsibility of all to conserve the native bees. Only farmers with surplus income should be encouraged to keep the native bees to conserve them (Dahal et al., 2024).

The underdeveloped nations lack awareness of the local pollinators and how important they are to enhance agricultural yields and biodiversity when it comes to developing land management policies that benefit the pollinators (Khanal et al., 2024; Muir, 2017). The lack of knowledge in many areas about beekeeping and managing native bees creates an opportunity for the introduction of foreign bees, whose conventional management techniques are well-known to all. Combining a land use strategy with pollinator restoration planning can be accomplished with the help of a landscape approach to pollinator protection. In locations without substantial natural areas, modest strands of traditional agriculture could assist conserve pollinators and continue pollination services (Prescott, 1990). Additionally, the ability to maintain natural vegetation, corridors between agricultural fields, and diversified production systems could also help. Natural or semi-natural environments that are governed by customary rules and are overseen by indigenous groups are significant biodiversity refuges and hotspots for pollinator conservation (Ratto et al., 2018; Robinson, 2012; Thapa, 2001). They also provide vital ecosystem services, such as pollination.

In Madagascar, community-managed forests have enhanced crop pollination in nearby farming areas. Improving pollinator conditions may require habitat enhancement, such as the installation of artificial nests. A variety of woods in varying successional stages can be found in areas with variable farming techniques; these forests' pollinator fauna should be investigated so that appropriate management strategies for improved pollinator fauna can be informed by such studies (UNEP, 1993; Yadav et al., 2024). In areas where native pollinators are in danger of going extinct, the provision of direct and indirect financial incentives guarantees a greater diversity of pollinators. A particular financial provision for pollinator conservation was included in the US Farm Bill, demonstrating the potential benefits of preserving non-cropped land in the agricultural landscape for the conservation of pollinators.

There is an urgent need to establish and standardize standards for the trade of managed pollinators in order to avoid the relocation of species or their genetic material from their natural range into non-native environments, as evidenced by the lack of coordination in the transportation of controlled pollinators, whether native or imported. In order to shield wild pollinators from competition, controlled pollinator placement in or near protected areas needs to be thoroughly thought out and understood. The FAO's recommended best management practices for apiaries contribute to disease prevention and transmission, as well as meeting the needs of both managed and wild pollinators. Since there is a serious paucity of long-term data on pollinators—particularly wild or native pollinators—standardized taxonomic training and capacity building are necessary to solve this data shortage. Pollinator conservation may benefit from funding fundamental scientific studies to expand our understanding of pollinators' taxonomy; nevertheless, taxonomy is only significant for invertebrate pollinators (Khanal et al., 2024). Effective conservation action is hampered by a lack of taxonomic expertise, according to reviews of regional conservation needs for native bees. A dearth of specialists exists to identify species, even those with descriptions, and many places harbor a large number of undiscovered species. Evaluation of the relative effects of pollinator-friendly versus unfriendly practices (or landscapes) on the entire spectrum of benefits supplied by pollinators is necessary, in addition to information regarding the efficacy of practices at supporting pollinators.

3. Conclusion

One of Nepal's five native honeybee species is the cliff honeybee (*Apis laboriosa*). Deforestation had severely reduced the population, and honey hunters killed all adult bees and destroyed the brood in order to gather honey. Although this honeybee species is abundant in the Himalayan regions of Nepal, it is not as well-studied and researched as other honeybee species. To preserve this native honeybee species, a number of biodiversity conservation initiatives are required. These initiatives include protecting the Himalayan bee flora, controlling and regulating exotic bee species, encouraging farmers to raise native bee species, and providing financial incentives from the government to farmers who contribute to the preservation of this native bee species. Reforestation, sustainable honey collection, predator control, and lessening competition with other plants for bee flora

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