

ORIGINAL RESEARCH ARTICLE



Which mountain cliffs do *Apis laboriosa* honey bees select as nesting sites and why?

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Summary

Apis laboriosa and *Apis dorsata* are closely related migratory open-air nesting bees which nest at mountain cliffs. It is not known why they select certain cliffs over others. We examined 16 nesting cliffs, at which 258 *A. laboriosa* colonies nested. The studies were conducted in Nepal in 1998 and 1999 and in Bhutan in 2008. Most cliffs are of a grey to black colour, but all *A. laboriosa* bees selected as nesting sites light-coloured unweathered cliffs. The light cliffs appear as a result of water erosion, and the unweathered cleared surface assures strong fixation of the combs to the rock. This way the nest will not tear away from the cliff overhangs. Near some nests, a white area is present on the vertical wall of the cliff. This is the surface cleared by bees, which previously nested here. It is possible to spot actual or potential nesting cliffs of these bees from far away.

¿Qué acantilados selecciona la abeja *A. laboriosa* como lugar de anidación y por qué?

Resumen

A. laboriosa y *A. dorsata* son abejas migratorias estrechamente relacionadas con nidos al aire libre que anidan en los acantilados de las montañas. Se desconoce cómo y por qué seleccionan determinados acantilados. Examinamos 16 acantilados de anidación en los que 258 colmenas de *A. laboriosa* habían anidado. Los estudios se llevaron a cabo en Nepal en 1998 y 1999 y en Bután en 2008. Muchos de los acantilados son negros o grises. Sin embargo, todas las abejas de *A. laboriosa*, seleccionaron sitios de anidación con colores claros en acantilados protegidos de la intemperie. Los acantilados de colores claros son resultados de la erosión del agua. Las superficies despejadas protegidas de la intemperie aseguran una fuerte fijación de los panales a la roca. De esta forma el nido no se separa de los salientes del acantilado. Cerca de algunos nidos, un área blanca está presente en la pared vertical del acantilado. Esta superficie fue limpiada por las abejas que previamente establecieron sus nidos allí. Es posible observar lugares de anidación actuales o potenciales para estas abejas desde lejos.

Keywords: nesting cliffs, migratory honey bees, *Apis laboriosa*, *Apis dorsata*, Bhutan, Nepal, India

Introduction

Open-air nesting honey bees *Apis laboriosa* and *Apis dorsata* provide approximately 70 – 80% of the honey in India and Nepal. They construct just one large comb. *A. laboriosa* build nests in the mountains under overhangs jutting out from vertical rock exposures called cliffs. *A. dorsata* build nests in similar sites as well as on ceilings of buildings and under large branches of trees. The bees migrate at least twice a

year. Little is known about the biology of these bees. Which cliffs are selected by the bees as nesting sites? Is it possible to predict which cliffs are potential nesting sites for the bees? These are questions that need to be answered.

Underwood (1986 and 1990) monitored 20 mountain nesting sites of 247 *A. laboriosa* colonies in the Himalayas, Nepal. International programs like ICIMOD (International Center for Integrated Mountain Development) Kathmandu, also monitored the nesting cliffs of *A. laboriosa*

in Nepal. Ahmad *et al.* (2003) monitored 26 cliffs on which 303 colonies nested and Joshi *et al.* (2004) monitored 148 nesting cliffs with 479 bee nests. The Keystone Foundation monitored nesting cliffs of *A. dorsata* in India (Keystone Team, 2001; Darwin Initiative, 2007; Klett, 2008 and Sharma, 2008). Tshering (2008) monitored 29 nesting cliffs with 285 *A. laboriosa* colonies in Bhutan. Thus, detailed surveys of several hundred nesting cliffs of *A. laboriosa* and *A. dorsata* have been conducted. Such characteristics like the location, direction toward the sun, altitude, cliff aspect, distance from water, distance from the ground, number of nests per cliff and surrounding vegetation were described. Those authors reported that similarly looking cliffs were observed that had no indication of bee nests.

Until now, it remains unknown why the bees choose certain cliffs and not others as their nesting sites. The nesting cliffs and honey hunting were described by Strickland (1982). Coloured cliffs were pictured in an album (Valli and Summers, 1988), on many colour photos on the internet (Turner website A and B), in many videos concerning the Himalayas (Ayabaya, 1994; David, 2009; Gurung, 2008 and Masalawala - website) and India (Keystone, 2006 and Turner, 2010) and many more. It is surprising that no one has looked systematically at traits of certain cliffs that favour their use as nesting sites.

We examined the main distinct differences between rock cliffs occupied by bee colonies, and those that were not occupied. We also tried to explain why the bees selected their particular site for nesting and why they did not choose other sites. This enabled us to better predict which cliffs bees will select as their nesting sites.

Materials and methods

The studies were conducted in Nepal in 1998 and 1999 and in Bhutan in 2008. Altogether, we examined 16 nesting site cliffs of *A. laboriosa* bees. We examined in detail the nesting sites of 258 bee colonies, of which 229 were active and 29 were abandoned combs. In Nepal, we collected some data whilst investigating the biology of *A. laboriosa* (Woyke *et al.*, 2001b, 2003). We visited four nesting sites. One nesting cliff was in the Kaski district on the Annapurna slope in Kyumi at the Modi Khola riverside near Landruk (28° 22' N, 83° 50' E. alt. 1250 m). This was the Landruk site of Underwood (1986), (alt. 1250 m) and the Kroja Bhir Landruk of Ahmad *et al.* (2003), (alt. 1565 m) and Joshi *et al.* (2004). The observations were conducted here in winter, for six days, from 27 November to 2 December 1999.

Three nesting cliffs were situated in the Sindhupalchok district at the Bhote Koshi riverside along the Arniko Hwy from Kathmandu to Kodari at the Nepal - Tibet border. The first nesting cliff was located in Chale (27° 52' 58 N, 85° 54' 51 E, alt. 1178 m). This is the Listi Mai cliff of Ahmad *et al.* (2003). The second Kodari nesting site was further north near the Kodari river fall in the cliff on the right

tributary river of the Bhote Koshi river (27° 56' 02 N, 85° 56' 11 E, alt. 1475 m). The third cliff was in Tatopani, on the Tibetan riverside near the bridge to China (27° 56' 51 N, 85° 57' 06 E, alt. 1520 m). We examined those nesting cliffs in spring on 28 March 1988 and in the winter on 5 - 6 December 1999.

The investigations in Bhutan were conducted from 22 to 25 September 2008. We examined here 12 nesting sites. Three of them (Nos. 1 - 3) were near the Samdrupjongkhar road from Thimphu, the capital of Bhutan to Jakar, the capital of the Bumthang district. The first nesting cliff was about a 45 min drive from Thimphu. It was near the 109 stupas at the Dochula pass (27° 29' 72 N, 89° 45' 00 E, alt. 3108 m). Four sites (Nos. 2 - 5) were near Jakar (27° 33' 65 N, 90° 44' 20 E, alt. 2620 m), and 7 sites (Nos. 6 - 12) were 16 km east of Jakar in the remote Tang valley (27° 33' 29 N, 90° 48' 16 E, alt. 2800 m) along the Tang Chug riverside.

We investigated the characteristics of the nesting cliffs and examined in details the nesting sites of individual colonies. We counted the number of active bee colonies and of abandoned combs. With the aid of 12 X 50 binoculars, we examined the nesting sites of individual bee colonies from a distance of 5 to 28 m. The geographical locations of the cliffs and the altitude were taken from the map of Google Earth, or the Bhutan Everest internet programs.

Results

The characteristics of the *A. laboriosa* nesting sites were better defined in Bhutan than in Nepal. In the photos, the cliffs are shown at first and then the nesting sites of individual colonies. The nesting sites we examined are numbered according to the sequence in which we examined them. The descriptions are presented in order to make it easier to understand the characters of the sites selected by individual colonies, and the origins of the traces left on the rocks by colonies, which had already migrated away.

Bhutan

Environment

The environmental conditions around *A. laboriosa* nesting sites were well conserved along the way from Thimphu, to Jakar. The soil nearby was of a reddish-brown colour. Farmers had cultivated the land on the plains and hills. In the mountains, herbs, bushes and trees were growing. Deeper, the soil was typically laterite and of red colour. The soil covered whitish rocks that, based on examination by the Geological Institute in Warsaw, consisted of, white quartz. During the rainy season, accumulated water spills over vertical slopes. As a result, soil erosion occurs and exposes the vertical strips of whitish rock underneath. We saw these exposed whitish rock strips from the sides of the road from Thimphu to Jakar (Fig. 1). Red trails of the soil mixed with rain water were visible at the whitish surface of the rocks.

When weathered, cliffs in this area become grey or black in colour. When the surface is scratched, or removed, for example, during road work, the original, underlying whitish rock appears.

Nesting cliffs

A. laboriosa colonies nested beneath overhangs on the steep cliff walls of the mountains. Although the colour of most of the cliffs was grey to black, *A. laboriosa* bees selected vertical strips of light whitish colour for their nesting sites (Figs. 2 - 8). Those light cliff strips presented a kind of shallow vertical niche sunk between the dark rocks. The walls of the light cliffs consisted of unweathered rocks. Longitudinal trails of the red soil were visible on the surface of the whitish rocks. This was similar to the light strips on the steep, sloping sides of the road (Fig. 1).

Characteristics of particular nesting sites

In nesting site No. 6 at the light-coloured cliff near the entrance to the Tang valley, several overhangs or smaller niches were present (Fig. 4). Five active *A. laboriosa* bee colonies nested here beneath three overhangs. The ceilings of those overhangs were white with traces and remnants of previous combs (Figs. 9, 10, 11). Three active nests and one abandoned comb were situated underneath one overhang (Fig. 10). One nest each was present under two other overhangs (Fig. 11). There were also several other unoccupied overhangs or niches with white ceilings on which traces or remnants of previous combs were visible (Fig. 12). Neither nests nor remnants of combs were, however, found beneath overhangs which were similar looking but, which had grey or reddish ceiling (Fig. 13). Under the overhang with three nests and one empty comb, there was a lot of melted wax present on the rock (Fig. 14). Some streams of dripped, melted wax were also present underneath the other overhangs or niches. The white quartz reflected the heat of sun, which had melted the abandoned combs.

Five colonies were at nesting cliff No. 9 (Fig. 7). Of the three colonies nesting nearby, two were hanging beneath larger overhangs with deep niches below. The third colony, however, nested beneath a small overhang with a shallow niche underneath (Fig. 15). Fig. 16 shows that the bees of the third colony hung not only beneath the overhang but they also covered a large area of the vertical wall above the nest.

Six colonies and one abandoned comb were present on the nesting site No. 8 (Fig. 6). All were hanging from overhangs with white ceilings (Fig. 17). The abandoned comb was built perpendicular to the surface of the rock. When the colony grew, the bees could not extend the length of the comb, because the niche was shallow. Thus, the bees extended the comb over the upper vertical wall. Because the upper part of the comb was white, it can be concluded that the comb cells were filled with honey. After the colony emigrated, the empty cells were partly melted by the sun. As it may be imagined, the bees

cleared the weathered surface on the vertical wall before they attached the new part of the comb there.

At nesting site 7 (Fig. 5), we found five active colonies and one empty comb. Because the niches beneath the overhangs were shallow, the bees also covered the vertical wall above the nests (Fig. 18). Fig. 19 shows a large white cone shaped area on the vertical wall over the nest. Evidently, the previous colony built the comb perpendicular to the surface of the wall, similar to that presented at Fig. 17. A large part of the comb was built above the roof of the shallow niche. The bees cleared off the weathered dark-grey surface of the rock leaving a large white cone shaped area on the vertical wall over the nest (Fig. 19). Near the other colony, several cleared areas are visible (Fig. 20).

Three colonies nested at the light-coloured cliff, No. 12 (Fig. 8). One nest was hanging in a small niche (Fig. 21). Large, white, cleared, cone shaped areas are present above the nest. They indicate that at least four previous colonies had constructed the large upper part of their combs over the vertical wall above the attached roof. One of the previous colonies cleared the base for the comb over slightly weathered grey rock, but the other colonies cleared their bases over reddish rock surface.

Two colonies nested in another niche (Fig. 22). One small colony hung from the white ceiling. The white cone shaped areas indicated that at least two previous colonies had extended the upper parts of their combs over the vertical reddish wall above the niche. The second colony was hanging in a very peculiar way because there was no upper ceiling to fasten the comb to. The bees attached the comb to the lateral edge of the niche. As a result, a long slim nest appeared (Fig. 22). A colony nesting on a large white surface cleared on the vertical wall by previous colonies was present in site No. 1 (Fig. 23). Nesting site No. 3 was on a light rock surrounded by trees (Fig. 3). There was one larger cliff with a partly white ceiling (Fig. 24). One nest was hanging from that white ceiling. There were white areas around indicating that previous colonies had extended their combs over the weathered rock, leaving cleared parts of white rock. The ceiling area outside the white traces of the previous combs was, however, grey, suggesting that the first colony settled on the ceiling, which was a little weathered.

Nesting site No. 5 was under the Rabten zam bridge over the Chumey river near Jakar (Fig. 25). Two colonies nested here, one large and one small. We measured the large nest, and it was 1.20 m high and 1.80 m long. The other nest was a much smaller 40 x 30 cm. The bees covered only the central part of the small comb, and this was probably a queenless colony with laying worker bees. The bottom ceiling of the bridge was light grey, but the place where the large colony nested was white (Fig. 25). There were no physical remnants of previous combs, but the outlines of comb cells from a previous comb were visible. Evidently, at least one colony had nested here previously. That previous colony had cleared the weathered ceiling of the bridge leaving the white area and had constructed their comb



Fig 1. Light strips over road slopes, Bhutan.



Fig 2. Nesting cliff No. 2, Bhutan.



Fig 3. Nesting cliff No. 3.



Fig 4. Nesting cliff No. 6.



Fig 5. Light erosion strips, cliff No. 7.

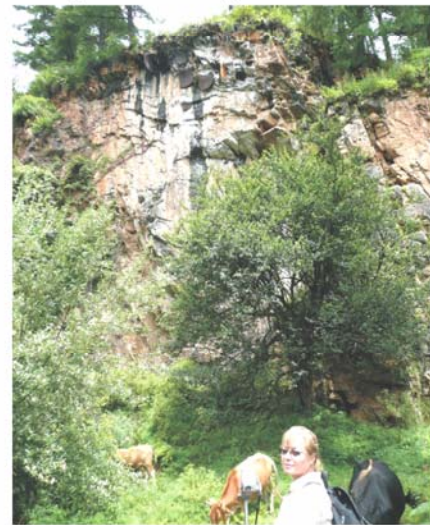


Fig 6. Nesting cliff No. 8.



Fig 7. Nesting cliff No. 9.



Fig 8. Nesting cliff No. 11 & 12.



Fig 9. Nests on light cliff.



Fig 10. Comb with remain of queen cell.



Fig 11. Comb beneath white ceiling.



Fig 12. Remnants of combs on white ceilings.

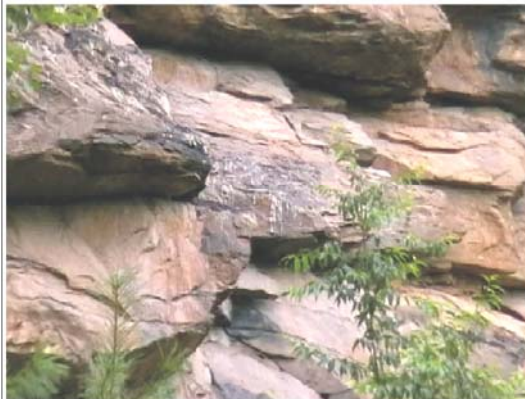


Fig 13. No nests on dark overhangs.



Fig 14. Melted wax beneath nests.



Fig 15. Deep and shallow niches.



Fig 16. Bees above the ceiling.



Fig 17. Parallel and perpendicular combs.



Fig 18. Bees on combs above ceiling



Fig 19 White surface cleared by previous colony.



Fig 20. White surfaces cleared by several colonies.



Fig 21. Several large white cone shaped areas above the nest.



Fig 22. Slim long nest.



Fig 23. Nest on cleared white vertical wall.



Fig 24. Colony hanging under the white ceiling.



Fig 25. Colony under a bridge.



Fig. 26. Traffic on bridge with colony.



Fig 27. Annapurna nesting cliff.

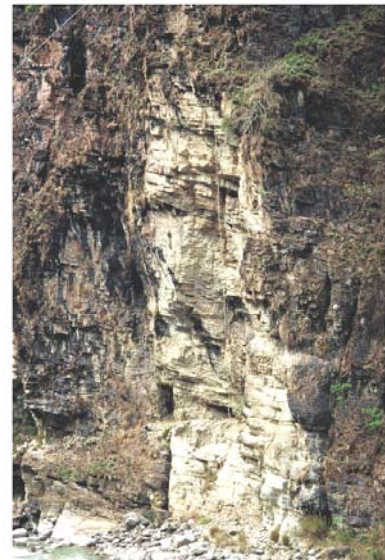


Fig 28. Challe nesting cliff.



Fig 29. Kodari nesting cliff.



Fig 30. Tatopani nesting cliff.



Fig 31. Three nests under light ceilings at Annapurna.



Fig 32. Nest under shallow niche.



Fig 33. Nest built perpendicular or parallel to the wall.



Fig 34. Nests under large white ceiling in Chale.



Fig 35. Nests in deep niches at Chale nesting site in December.



Fig 36. Terrain depression over the Kodari nesting site.



Fig 37. Nests at the light part of the Tatopani cliff.



Fig 38. *A. dorsata* nesting site in Nilgiris hills, India.

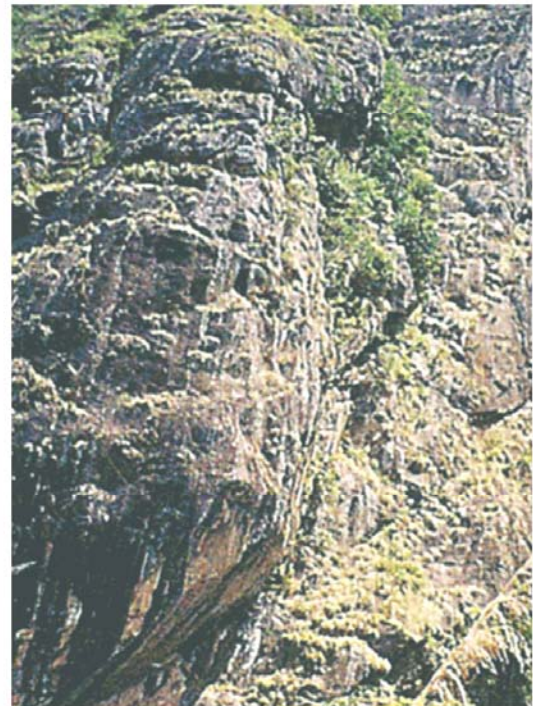


Fig 39. Light erosion strips at *A. dorsata* nesting cliff in Nilgiris hills, India.

near the edge of the bridge. When the colony grew up, some bees also covered the nearest part of the vertical edge of the bridge and cleared the underground. After that colony migrated, a white area also remained on the vertical edge of the bridge (Fig. 25).

The present colony did not construct its comb over the leftover traces of the comb of the previous colony, but nearby. A larger portion of the comb of the present colony adhered to the white area, but the left side of the nest was hanging from the grey part of the ceiling. After the colony migrates, the expected cleared white area should be visible there. Heavy vehicle traffic occurred on this bridge. Within seven hours, we counted 96 cars, including some heavy trucks (Fig. 26) and nine motorcycles. This is the first description of *A. laboriosa* nesting under a man-made structure.

Similar looking cliffs or niches were present in other mountain rocks, and the surface of those cliffs was a weathered grey to black colour, but we did not find any *A. laboriosa* nests on such cliffs.

Nepal

In Nepal, we examined four nesting cliffs. One was on the mountain side of Mt. Annapurna (Fig. 27) and three others on the Bhote Koshi riverside along the road to Tibet (Figs. 28 - 30). Of the four nesting sites examined by us in Nepal, three were similar to those in Bhutan. The whitish nesting cliffs were located between steep vertical weathered dark rocks (Figs. 28, 30), but the nesting cliff near Kodari was situated between a vegetation-covered mountain side (Fig. 29). All four nesting cliffs were not whitish like in Bhutan but pale yellow. The unweathered rocks were similar to sandstone. Fewer reddish laterite traces were present on the light unweathered rocks of the cliffs. The overhangs or niches occupied by the colonies had whitish ceilings (Figs. 31 - 35).

At the Annapurna nesting cliff (Fig. 27, alt. 1250 m), 16 active *A. laboriosa* colonies nested from 27 November to 2 December 1999. Outlines of traces, and remnants of previous combs were visible on the whitish ceilings (Figs. 31 - 33). Bees of nests built in shallow niches covered also the roof wall above the nest (Fig. 32). Some nests were built perpendicular and the other parallel to the wall (Fig. 33).

We had the opportunity to examine the three other nesting cliffs in Nepal twice. On the lowest situated Chale nesting cliff (Fig. 28, alt. 1178 m), the colonies nested under large overhangs (Fig. 34) or in deep niches (Fig. 35). Only 43 active colonies nested beneath the ceilings in the spring, (28 March) 1998, but as many as 14 recently abandoned (fresh) combs were present there. Evidently, the colonies started to swarm and abandon the combs in March. Previously some $43 + 14 = 57$ colonies nested here. The next year in the winter, (5 and 6 December) 1999, 53 active colonies nested here (Fig. 35) and only four recently (fresh) abandoned combs were found. In total, $53 + 4 = 57$ colonies nested here earlier this year. Thus, in both years, the same number of swarms selected this cliff as their nesting site.

The Kodari nesting cliff (alt. 1475 m), between the vegetation, was also light-coloured. On Fig. 36, a depression is visible in the terrain above the cliff, and this is the way rain water flowed down over the cliff. On 28 March 1998, four active colonies and one abandoned comb were present here. The next year, 5 - 6 December 1999, six active colonies and two abandoned combs were found here (Fig. 36). Thus, in the first year $4 + 1 = 5$ swarms, and the next year, $6 + 2 = 8$ swarms selected this cliff as their nesting site.

Fig. 37 shows that at the highest located Totapani nesting cliff (alt. 1520 m), the colonies nested on the left light coloured part of the cliff, but not on the right dark weathered part. The first year, 28 March 1998, 14 active colonies nested here. The next year, 5 - 6 December 1999, 10 active colonies and three abandoned combs were found here. Thus, the first year 14, and the second year $10 + 3 = 13$ swarms selected this cliff as their nesting site.

Discussion

We found that all 258 *A. laboriosa* colonies in Nepal and Bhutan nested on unweathered light cleared cliffs. We examined also hundreds of dark weathered cliffs and did not find any active nest, abandoned comb or remnants of combs. The colonies nested under cleared light ceilings of the overhangs or niches. In Nepal $57 + 5 + 14 = 76$ swarms selected three cliffs as their nesting sites in 1998. The next year 1999, $57 + 8 + 12 = 77$ swarms selected the same cliffs as nesting sites. Thus, both years, almost the same number of swarms selected the three cliffs as their nesting sites. Woyke *et al.* (2012) suggest that the next season, only the maternal colonies return to the site, but not the reproductive swarms.

Similar looking nesting cliffs are visible in other papers (Strickland, 1982; Underwood, 1986 and 1990; Valli and Summers, 1988; Ahmad *et al.*, 2003 and Joshi *et al.*, 2004), and on colour photos on the internet (Turneret, web ref), in the videos (Ayabaya, 1994; David, 2009; Gurung, 2008; Masalawala, web ref), and in a film (Turneret, 2010). Even the black and white photos of Strickland (1982) show bees nested on the light-coloured surfaces of a cliff. Thus we have concluded that from all of the possible places in the whole Himalaya mountain range, *A. laboriosa* bees select the light-coloured cliffs as their nesting site.

We found only one nesting site of *A. dorsata* with one colony, in the lower Chitwan district in Nepal, and were not able to study nest traits for this species. The light-coloured cliffs described by us as nesting sites of *A. laboriosa* are, however, very similar to the nesting cliffs of *A. dorsata* in India presented in several papers (Keystone Team, 2001; Darwin Initiative, 2007; Klett, 2008; Sharma, 2008), on the colour photos on the internet (Turneret, web ref), in the videos (Keystone, 2006; Turneret, 2010) and many others. The nesting site of *A. dorsata* in India (Fig. 38) is very similar to the many *A. laboriosa*

nesting sites which we found in the Himalayas (Fig. 9). The black cliffs with several light nesting strips of *A. dorsata* in India (Fig. 39) are very similar to the black cliffs with light nesting strips of *A. laboriosa* in Nepal (Fig. 5). We have thus concluded that both *A. dorsata* and *A. laboriosa* bees select similar un-weathered light-coloured cliffs as nesting sites.

The characteristics of the nesting sites described by the above authors, such as direction toward the sun, altitude, cliff aspect, distance from water, distance from the ground and others, varied and it happened that the same character was opposite in different nesting sites (e.g. direction East-West, low-high, near water or away). The cleared rock surface described by us was, however, similar and present in all nesting sites. The description of the cleared rock ceilings, to which the bees of all colonies fixed the combs, we consider to be the main finding of this present paper.

It happened that the raw un-weathered rocks of the cliffs were light, - white in Bhutan and pale-yellow in Nepal. We also observed many *A. dorsata* nests under differently coloured ceilings of home overhangs, roofs, water-tanks, branches of trees and others, but the ceilings near the nests were cleared un-weathered. We thus conclude that not the colour but the cleared ceiling is the primary character determining the selection of the nest site.

The question is, why do the bees select cleared un-weathered cliffs for nesting sites and not weathered ones? Unfortunately it was not possible to prove the answer experimentally, so therefore we present a logical suggestion (hypothesis) supported by some arguments. A nest filled with brood and honey and covered by the bees is heavy. It is certain that a comb fixed to a solid, cleared un-weathered ceiling can bear a heavier load, than comb fixed to a weathered surface. A heavy bee nest fixed to a weathered ceiling, would drop down before the colony reached full development and before it swarmed. During evolution, such colonies were eliminated and only those which fixed the comb to solid, cleared un-weathered ceilings survived. This suggestion is supported by the phenomenon described by Woyke *et al.* (2001a). Immigrating swarms of *A. dorsata* never construct their new combs on the remnants of the previous year's combs. Those remnants had not been protected for a long time. They are damaged by wax moths feeding on them and are weakened by unfavourable environmental conditions. Such weakened remnants cannot support a heavy nest. Therefore the bees fix their combs to solid cleared ceiling base. In the present studies, we also found many unoccupied remnants of *A. laboriosa* combs, but the combs of the active nests were fixed to the cleared surface nearby. This supports the suggestion presented above.

The next question is, how do the un-weathered light cliffs appear and how are they maintained within the weathered black ones? This is the effect of erosion by water. The stream of water flowing down periodically wears away any weathered particles from the surface and keeps the rock cleared. The effect of this phenomenon is visible along the road from Timphu – Jakar (Fig. 1).

There is still the question of why a white area appears on the vertical wall near the nesting sites of some colonies (Figs. 15 - 23). The colonies do not construct combs taller than 1.2 m. Tall combs filled with honey and brood are heavy and could tear off from the attached base. This is why growing colonies extend their combs lengthways, but some colonies also construct their combs perpendicular to the cliff wall. When the overhang is shallow, there is no place to extend the comb lengthways. Therefore, the growing colony extends the construction of the comb above the horizontal overhang, on the vertical wall of the cliff. Before the bees fix the extended part of the comb, they clear the weathered surface of the rock wall above the nesting site. After the colonies migrate and after the combs are destroyed, a white area remains on the vertical cliff wall.

In summary therefore, the migratory *A. laboriosa* and *A. dorsata* select nesting sites on un-weathered cliff overhangs or niches with cleared ceilings to which the bees fix the combs. The walls of the cliffs are cleared by water erosion. We suggest that the bees select such cliffs as nesting sites because the cleared ceilings assure a solid base for fixing the combs. When the raw un-weathered rock is of light colour, then the nesting cliff of those bees is visible from far away.

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