

Article

Investigating Co-occurrence among Look-alike Species: The Case of Three Bears in Northeast India

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Abstract: At the most basic level, the assessment of a species' status involves knowing where it occurs. Determining the presence of rare species is difficult, and can be further confounded by the presence of a more common look-alike species. We investigated one of the few places in the world where three species of bears have been reported to co-occur at a fine scale: Balpakram National Park, Meghalaya, India. Asiatic black bears (*Ursus thibetanus*) are fairly common, and we sought to determine whether sun bears (*Helarctos malayanus*) and/or sloth bears (*Melursus ursinus*) also resided there. The local Garo language has words for three types of bears, and some local people reported the continued presence of a small type of bear, possibly the sun bear, but the probable extirpation of sloth bears. Because these bears look somewhat alike, local people and government forest officers could not provide convincing accounts of the presence of more than one species. We measured claw marks on climbed trees, a method used to differentiate sun bears from Asiatic black bears where both are known to occur; however, this method turned out to be unreliable for detecting sun bears where their presence was unknown because sun bear-sized marks are not distinguishable from juvenile black bears. We recommend targeted camera trapping near recent purported sightings of the other two bear species.

Keywords: local ecological knowledge; sign survey; rare species; detecting species presence; species misidentification; species coexistence; *Ursus thibetanus*; *Helarctos malayanus*; *Melursus ursinus*



Citation: Garshelis, D.L.; Dharaiya, N.; Sharp, T.R.; Pigeon, K.E. Investigating Co-occurrence among Look-alike Species: The Case of Three Bears in Northeast India. *Diversity* **2022**, *14*, 717. <https://doi.org/10.3390/d14090717>

Academic Editor: Jon Paul Rodríguez

Received: 23 July 2022

Accepted: 15 August 2022

Published: 29 August 2022

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1. Introduction

Bears (Ursidae) are a small family, with only eight species, which range across four continents and the Arctic. Europe and South America are each inhabited by a single extant bear species, whereas multiple species exist in North America and Asia, and in some of places there is wide overlap of two species. However, there is just one place in this global distribution where historically three bear species may have overlapped on a broad scale. Northeast India (hereafter NE India) marks the eastern extremity of the range of sloth bears (*Melursus ursinus*), the western extremity of the range of sun bears (*Helarctos malayanus*), and is near the center of the range of Asiatic black bears (*Ursus thibetanus*; hereafter black bear) (Figure 1). This region thus represents a unique area in terms of bear ecology and conservation.

NE India may possess a distinctive suite of resources that can sustain all three species. In comparison, there are no historical or even fossil records of sun bears in peninsular India, or of sloth bears crossing into present-day Myanmar. The conditions outside of NE India must be different enough to limit the geographic range of these two bears. Several recent studies of bear ecology were conducted in NE India [1–4], but none investigated the limiting ecological factors or even ecological differences among species. Steinmetz et al. [5]

identified gradients in fruit and insect abundance as being factors related to the range limits of these three bears.

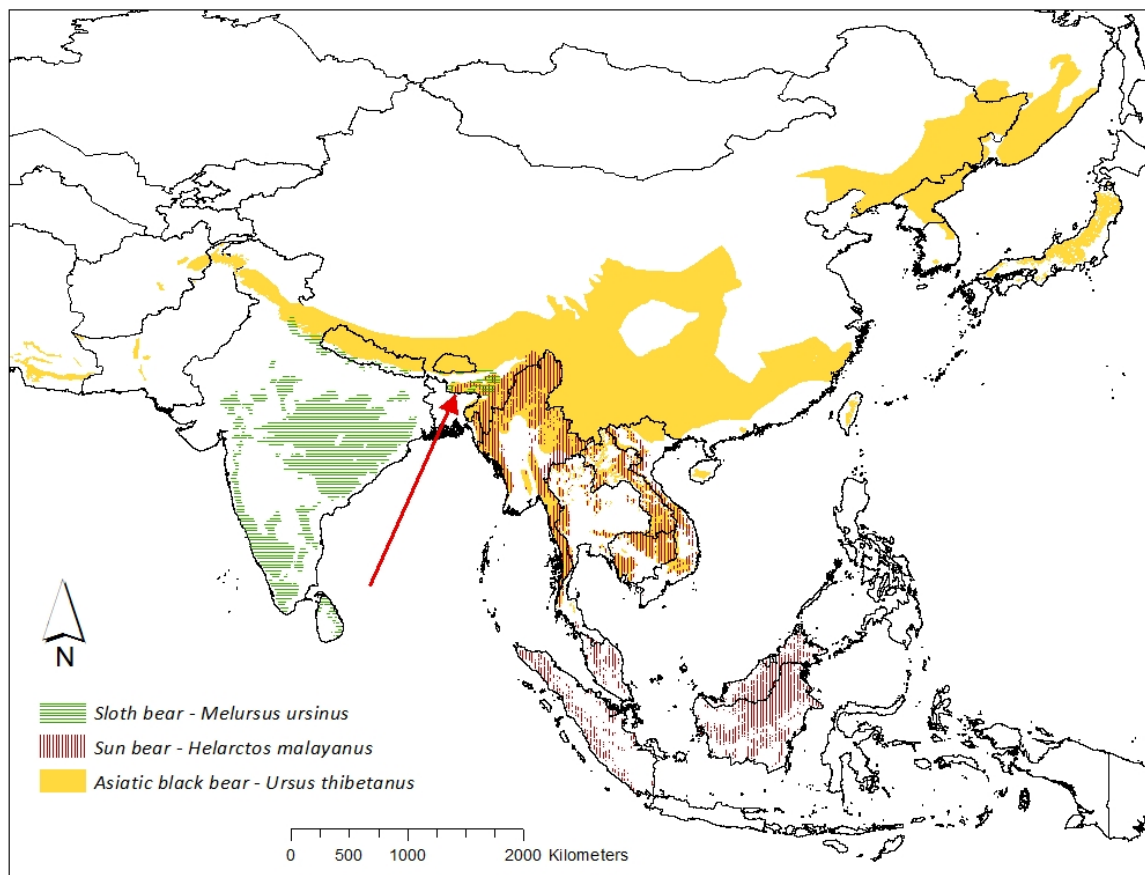


Figure 1. Range map of the three species of Asian bears that converge in Northeast India (red arrow). Depicted here is the maximum present range, combining categories for extant and possibly extant range from the IUCN (International Union for Conservation of Nature) Red List.

Ecological studies have been conducted in Southeast Asia, where sun bears and black bears overlap broadly (Figure 1), and on a fine scale [6–8]. These studies have found remarkably similar fruits in the diet and use of habitat for these two species; however, competition among the species appeared limited by some niche separation. Specifically, sun bears relied more on insects and black bears dominated in fruit-rich montane forests [9,10]. Even at baited camera traps, the two species had similar activity patterns and showed no avoidance of each other, despite black bears being significantly larger [11].

In NE India, records of where bears of each species formerly existed are rather vague, in part due to species misidentifications, and in part due to fragmentary records that are difficult to verify [12,13]. In fact, it is unknown whether all three species actually coexisted on a fine scale anywhere in the region. Sethy et al. [14] attempted to ascertain which protected areas across NE India are now occupied by each of the three species, based on sign surveys and a questionnaire survey of villagers, but they recognized significant uncertainties about identifications of the different bear species from sign or sightings; thus, most sites were classified as unknown presence for sloth bears and sun bears, whereas black bears, considered far more common across the region, were regarded as present in virtually every area. They concluded that the data were not reliable enough to distinguish presence of the rarer two species. Given that bears have long been hunted by people, attack people, and often depredate their crops and livestock, it is rather surprising how little we actually know of their occurrence, and specifically co-occurrence, in this distinctive landscape.

We set out with the purpose of locating a spot in NE India where these three bear species still coexist. That aim fits within a larger goal of understanding the factors limiting bear distribution. Some of these factors may be ecological, and others anthropogenic. It is also possible that the coexistence of these three species, or even two of these species, requires some threshold of resources; if that balance is disrupted, inter-species competition may allow only one species to persist [5]. Hence, there may be downstream conservation implications in finding and examining a place where a species at the edge of its geographic range coexists with another, or conversely, investigating a place where that situation occurred in the recent past but was disrupted by human activities.

In the process of conducting our assessment, it became clear that black bears occurred across much of the region, whereas the other two species were rarer, and only known from a few select spots. Likewise in Bangladesh, just to the southwest of NE India, black bears remain fairly widespread, whereas sloth bears disappeared within the past two decades and sun bears may be hanging on only in a small cross-border population [15,16]. To the north, sun bears also disappeared from southern (Yunnan) China [17], and sloth bears may only be an occasional visitor to southern Bhutan [18], whereas black bears range widely across China and Bhutan. Choudhury [12,13] reviewed the present status of all three of these bear species across NE India and concluded that the sloth bears and sun bears had lost a significant portion of their ranges since the early 1900s.

Hence, to find a point of overlap required a method where we could detect two rare species in the presence of a more common species. All of these species have unique characteristics, yet they are often misidentified from sign, sightings, and even camera trap photos [19,20]. This paper is devoted largely to the methods we used, the problems encountered, and recommendations for the future based on our experiences. Whereas this investigation was specifically about bears, some of the issues that we encountered have wider applicability to assessments of presence of other look-alike species, especially when one is common and others rare.

2. Study Area

2.1. Choice of Study Site

There are three states in NE India, Assam, Meghalaya, and Nagaland, where all three species are reported to potentially occur in the same vicinity [21]. However, the distribution of each species in each state is nebulous at best, often based on unconfirmed reports. A new checklist of the mammals in NE India that includes all three bear species was based on the same repeated sources, none of which have been recently verified [22].

We attempted to gain information on the occurrence of black bears, sloth bears, and sun bears from forest department staff, to identify potential areas where two or all three species might still co-occur. In 2017, we conducted workshops in Assam, Meghalaya, and Nagaland. Surprisingly, among the 80 experienced forest field staff and officers to whom we talked, no one knew how to differentiate the three bear species by sight or sign, and very few were even aware that multiple bear species occurred in the area. However, the best available sources of information [12,13,21,23] led us to focus on Meghalaya as a place that could have all three species. Checklists of the mammals in this state listed all three bear species, although the information again referred to old sources, with no recent verification [24,25]. The Chief Wildlife Warden of Meghalaya [26] directed us to Balpakram National Park as being a safe place to work and where local staff were willing to assist. This park, in the Garo Hills, also represents the most western historical range limit reported for sun bears, but with no recent documented occurrence; thus, there was a certain appeal in finding out whether this species still exists there.

2.2. Study Area Description

Meghalaya was formed as a state in 1972, by carving out the Jaintia Hills, Khasi Hills, and Garo Hills districts of Assam. The state is bound by Assam to the north and east, and Bangladesh to the south and west. It is the wettest state in India, with a distinct summer

monsoon (June–September) followed by a dry winter (November–February) [27]. The state is heavily forested (76%; [28]), with high floral biodiversity and endemism [29,30]. Of the seven states in NE India, Meghalaya has the lowest percentage of state-owned forest (12%) [28], with most forest being community-owned [31]. Some community forests include sacred groves that were preserved for religious and cultural beliefs [32,33]. The three different hill ranges in Meghalaya are home to three tribal ethnic groups, each with their own language. Most of the people rely on traditional agriculture, and practice *jhum* or shifting cultivation as well as terraced cultivation [34]. The hunting of wildlife is prevalent among the tribal people in NE India, both for food and socio-cultural reasons, and this includes bears [35,36].

Balpakram National Park (BNP) is located in the Garo Hills region of southwestern Meghalaya (25°20′–25°30′ N; 90°45′–91°0′ E; Figure 2). The elevations range from <200 m to 1049 m at Chitlang peak. The 220-km² park was acquired in pieces, previously being owned by clans of local people. It was established in 1987 and the expansion is continuing, although with some pending legal controversies about acquisitions [37]. Adjoining the park are Rewak and Baghmara Reserve Forests, Siju Wildlife Sanctuary, community forests, and *jhum* agriculture.

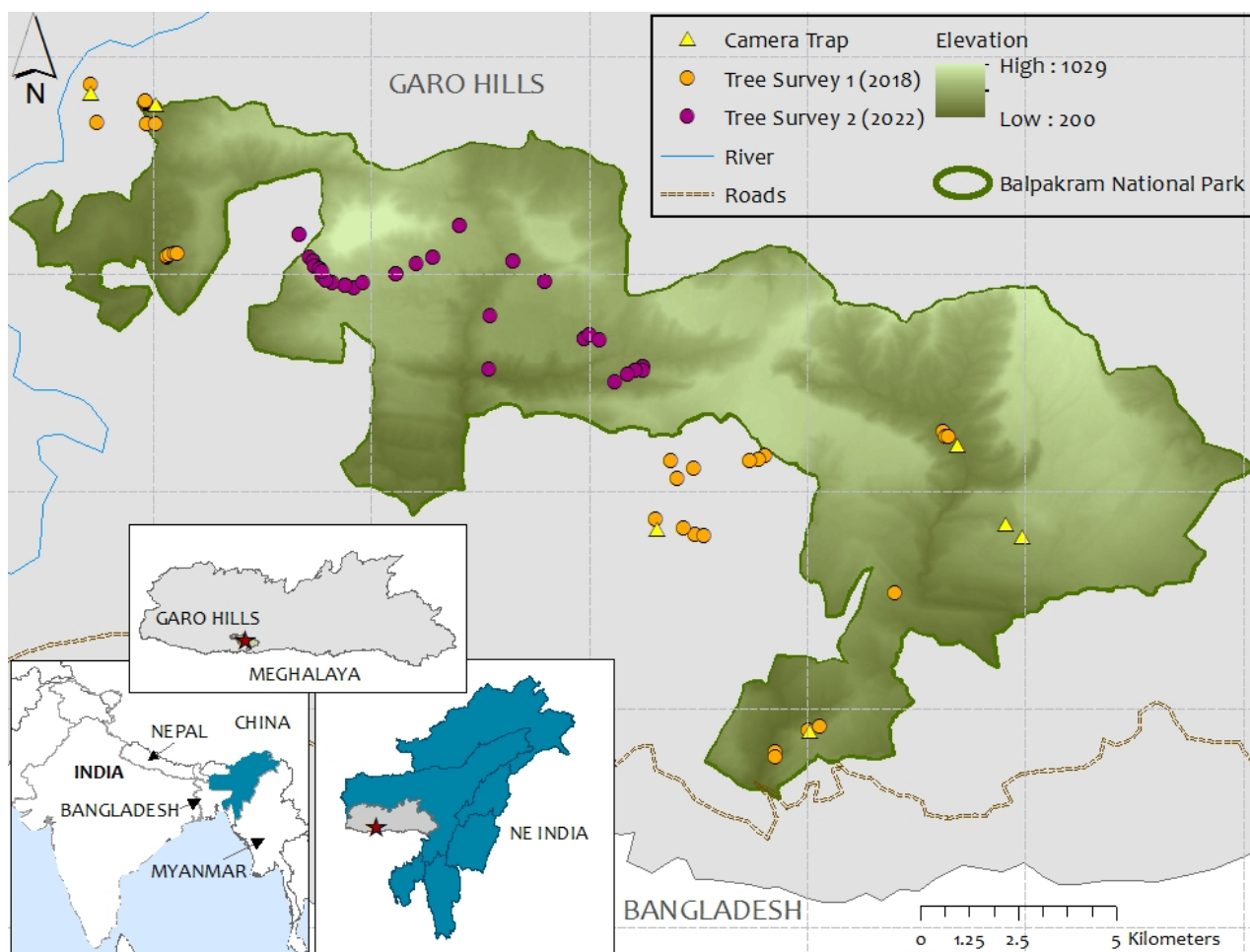


Figure 2. Sites where bear claw-marked trees were found and camera traps set (no bears photographed) in and around Balpakram National Park (star), Meghalaya, India, 2018–2019, and 2022.

Known as the land of eternal wind, Balpakram is sacred to the local Garo people and thought to be inhabited by spirits. Due to poor road access and local tribal customs and mythology, the forests have been relatively undisturbed. Forest types include tropical moist evergreen, tropical semi-evergreen, shola, grassland savanna, tropical moist deciduous,

bamboo, and secondary forest resulting from shifting cultivation [37]. These forests contain a high density and diversity of trees [38].

The harvesting of timber, bamboo, firewood, and non-timber forest products is prohibited inside the park, as is grazing livestock and hunting wild animals. According to the local authorities, the extent of illegal hunting is low. The park and the surrounding forested landscape are home to a wide diversity of wildlife, including primates, such as the threatened stump-tailed macaque (*Macaca arctoides*) and endangered hoolock gibbon (*Hoolock hoolock*), a large population of Asian elephants (*Elephas maximus*), and at least 20 species of carnivores [39]. However, there is no recent evidence of tigers (*Panthera tigris*) [40]. The World Wildlife Fund has designated the entire eastern Himalayas, including BNP, as a Global 200 ecoregion because of its high biodiversity, and the Indian government has nominated the Garo Hills Conservation Area, including BNP, as a UNESCO World Heritage Site [39]. However, due to the poor road access and few facilities in the park, tourism is low. Access is especially limited during the monsoon season, when the area receives >4000 mm of rainfall.

3. Methods

We used a combination of three methods to attempt to ascertain which bear species were present: surveys of local ecological knowledge; sign surveys; and camera trapping. We conducted our first field season during November 2018 to March 2019. We conducted a second field season during March–April 2022, focused in a specific area (see below).

3.1. Surveys of Local Ecological Knowledge

We conducted interviews with local villagers and forest officers about their knowledge of bears in the area. We asked how often they saw bears, and under what circumstances. We asked how many bear species they believed were present in the area now and in the past, and how they differentiated these species. We did not prompt villagers or officers with photographs or other information, but sometimes asked them afterwards if they could point to the species they were referring to on photographs. We did not use a questionnaire format, but rather carried out an informal discussion, with follow-up questions prompted by their answers. We also asked about their use of the forest, bears and other animals damaging their crops, and to recall any cases of bears being hunted. The interviews required an on-site translation between the local Garo language, Hindi, and English.

3.2. Sign Surveys

We searched for bear sign along human and animal trails and by meandering through the forest. We did not conduct formal transects (with randomized starting points and direction, and fixed width) because our intent was not to quantify sign density but rather to find as much bear sign as possible and distinguish the sign to species. We also visited sites with bear sign that was previously discovered and reported to us by local forest staff.

For sloth bear sign, we searched for dug-out termite mounds or scats with termites [41]. We specifically asked people about the places where we might find termite mounds. In addition, knowing that sloth bears often occur in grasslands, we visited the largest grassland savanna in the park, looking for termite mounds.

For black bears and sun bears, we searched for claw marks on climbed trees (Figure 3). Sun bears are significantly smaller than black bears, and in a controlled captive and field study, it was discovered that the spacing of the toes on each individual set of claw marks, especially those on the hind feet, is generally closer together for sun bears than black bears; however, claw mark widths of young black bears are not distinguishable from sun bears [42].

We obtained measurements of hind foot marks that showed at least four of the five claws. We distinguished hind foot marks as being roughly perpendicular to the trunk, whereas front foot marks were somewhat diagonal, resulting from the bear grasping the trunk [42]. We created a permanent template by pressing a sheet of paper over the individual sets of hind foot marks and punching holes with a pencil point over the center of

each gouged mark (Figure 3). If the mark was elongated from the claw slipping downward, we punched the hole at the point where the claw stopped slipping and gripped the bark, normally at the bottom of the mark. On this template, we then measured the straight-line distance (width) across sets of four and five claw marks to the nearest millimeter. We measured five-claw width from toe one to five (Figure 3). We measured four-claw width from toe two to five or one to four, whichever was shorter; if only four marks were visible on the tree, we measured the width, even if we could not tell which toes they were from. We sought to measure all of the distinctive marks with four or five claws that were within our reach, and we specifically looked for marks of different sizes on the same tree. We used these measurements to separate which bear species likely left the marks on the trees, as per the key created by Steinmetz and Garshelis [42] (Tables S1–S3, Supplementary Materials). We also estimated the age of each mark [43], and thereby partitioned out the recent (<1 year-old) marks for a separate analysis.



Figure 3. Measurements of hind foot claw marks of bears (marks perpendicular to the tree trunk—left panel) were used to try to distinguish black bears from sun bears. We held a paper over the claw marks and created a permanent template by punching holes at the bottom of each mark (right). On this template we measured spacing of the narrowest span across four claws, and the span across all five claws (if all five claws were visible) (yellow arrows). We distinguished whether claw marks were recent (as shown here), based on the color and extent of regrowth of the bark.

During our 2018–2019 field season (hereafter survey 1), we learned of a widescale mammalian biodiversity survey of BNP and surrounding landscape that was conducted several years earlier (2012–2015) [44–46]. They employed systematic camera trapping and sign surveys. They also used claw mark measurements on trees in an attempt to differentiate black bears from sun bears, as per Steinmetz and Garshelis [42]. These investigators shared their raw data with us. Those data seemed to show a spatial aggregation of sun bear-sized claw marks in a central portion of the park. However, we learned that these investigators

measured the marks differently, making the bear species categorization uncertain. These results prompted us to conduct a follow-up sign survey targeting the area with a high proportion of sun bear-sized marks. In this follow-up survey (2022, hereafter survey 2), we used a precut paper gauge held up to the marks on the tree to quickly assess whether any were sun bear-sized. If only black bear-sized marks were found, one good set was recorded on a paper template. If a sun bear-sized mark was found, it was recorded, and we looked for and recorded all other marks that we could reach from ground level. We sought to determine whether the tree had only been climbed by a smaller bear (i.e., sun bear size) or by a small bear and a larger bear (i.e., black bear size), which could mean either a black bear mother and cub, or a sun bear and a black bear.

Tree identification was difficult because all of the fieldwork was conducted during the non-fruiting season. Typically, a member of the park staff would try to identify the common name of the tree in Garo, and we later attempted to find the corresponding scientific name (some translations provided in [39,47,48]).

3.3. Camera Trapping

We set 11 cameras (Spypoint Force 10, Victoriaville, QC, Canada) in areas close to where we found bear sign or along trails that we expected bears to use (Figure 2). We were not permitted to use lures. The cameras were operational for 10–98 days, from early December 2018 to early March 2019.

4. Results

4.1. Local Ecological Knowledge

We conducted 14 in-depth interviews with the elders in different villages and many more casual discussions with a host of park staff and villagers. Generally, we learned that whereas the park staff were not aware of more than one species of bear, a few villagers thought that there were two different species of bears in the area, and some claimed that there used to be three. The descriptions provided to us (without prompting) of the three species seemed to match those of the black bear (large, black, white crescent chest mark), the sun bear (small, short hair, arboreal, sleeps in a tree nest constructed of broken branches—note: tree nests are also common for black bears, and recognized as such within BNP [49]), and the sloth bear (long shaggy coat, termite-eater, aggressive, attacks people).

We learned that there are Garo words for three different kinds of bears. *Makbil wak*, translated as “pig bear”, is the black bear, which is the most common, according to everyone with whom we spoke. *Makbil merang* was mentioned to us only twice, and was said to mean “long-haired bear” or “bear with mane”. Sloth bears have long hair and a distinctive mane, so the Garo word matches these characteristics. *Makbil sarang* was translated to us in various ways, as meaning “bear that eats the first crop of fruit”, “danger bear”, or “bear with orange on chest”, and was considered to be a distinctly smaller bear. Sun bears are much smaller than black bears or sloth bears, but we are not aware of this species eating fruit earlier than black bears—in fact, sun bears are more insectivorous than black bears [9,10,50]. In addition, sun bears are generally unaggressive and thus less dangerous than black bears and far less dangerous than sloth bears. Sun bears often do have an orange chest marking, but we are cautious of this translation from Garo, since the translator had just attended our workshop where we taught park staff the characteristics of these three bears, and showed photos of sun bears with orange chest markings.

People reported seeing bears occasionally (but not commonly), especially raiding their farms and orchards, but we heard few complaints about them. The main cash crop was betel nut (fruit of the areca palm, *Areca catechu*), which bears do not eat. However, people also cultivated jackfruit (*Artocarpus heterophyllus*), which is readily eaten by bears in other states in NE India and elsewhere, where it is a source of reported conflicts with people [15,51–53]. Additionally, beyond BNP there were plantations of cashew (*Anacardium occidentale*), which could be attractive to bears. However, people seemed mainly unconcerned about depredations of these crops. From the descriptions of the few crop-raiding bears, all were likely to

be black bears. A study of habitat associations by the wildlife in the park suggested that black bears commonly occur in forests near villages, and visit *jhum* areas to feed [49].

We became aware of two bear attacks, both reported to be black bears. A man (approx. 40 years old) was attacked in the early morning of 12 November 2020 while walking down a trail towards his *jhum* field, about 500 m from his village. A bear approached on an adjoining trail, and the man ran. The bear pursued, grabbed him, they both fell and rolled. The man played dead, but the bear continued to maul him, scratching his chest. His wife, who was also walking to the field, rushed to help him, and threw a log towards the bear. It did not hit the bear, but nevertheless forced it to run off.

Ten days later, in a village about 150 m away from the first incident, a woman (approx. 60 years old) was working in her *jhum* field in the afternoon when she saw a bear approaching. The bear abruptly attacked and she fell unconscious. When she regained consciousness, the bear was gone. Although she had significant injuries, she was able to walk back to the village to seek help. She recalled afterwards that she had seen three cubs before the incident, and presumed that the bear that attacked her was their mother. We were told that bear attacks are not unusual, yet they are rarely reported.

We found nobody who believed that sloth bears (*makbil merang*) still existed in or around the park, although a few people indicated they had been present 30 or more years ago, and were notably more aggressive than black bears. One man from a village on the northern border of the park, near the Khasi Hills, mentioned that he used to see bears that fit the description of sloth bears in that area as recently as 10 years before (i.e., about 2008), but that he had not seen any since. We were not able to investigate this region, which possibly has the best sloth bear habitat.

A few people mentioned the possible existence of *makbil sarang* (presumably the sun bear). One particularly intriguing story we heard, from multiple sources, was that two sun bear cubs had been confiscated from a village near BNP in 2018, and brought to a nearby zoo. We checked on this, and found them to be black bears.

We heard of two people in different villages who had recently seen what they called *makbil sarang*. The villagers had related the sightings to a forest guard, who then told us. We were able to interview one of them in early April 2022, about a sighting 2 months prior. The man was on his way to go fishing, walking along a forest trail, when he spotted a bear in a tree. The bear quickly slid down, and then paused and stood on its hind feet in front of him. The man described the standing bear as only as high as his waist (~1 m), although he said it was not a cub. Both the man and bear ran away in opposite directions. The man indicated that he had previously seen one or more black bears (*makbil wak*), and thought that this bear was different.

4.2. Sign Surveys

The only definitive bear sign we found was claw-marked trees (Figures 2 and 3). We found no diggings or scats that we attributed to bears. In total, we measured 154 sets of claw marks showing at least four claws of which 119 were black bear size, 19 were sun bear size, and 16 were intermediate size.

The appropriate sample unit for the claw mark surveys is the tree, not the individual marks, because we measured a variable number of marks per tree (range one–six). This variation was due to some of the sets of marks not showing at least four claws, some being the front feet or at least not definitely the back feet (the claw mark key pertains only to the back feet), and some being too high on the tree to measure.

Of the 74 different claw-marked trees, 20 (27%) had two different-sized marks (combinations of black bear, sun bear, and indeterminate). Most striking is that all of the trees where more than one set of marks were measured contained either just black bear size marks, or black bears in combination with smaller marks. We found no claw-marked trees with exclusively sun bear-sized marks (Table 1).

Table 1. Bear claw (climbing) marks found and measured on trees in Balpakram National Park, 2018–2022, and fitting the size of sun bears or Asiatic black bears.

Survey No.	Claw Marks Measured	Trees with Marks	Avg. Measured Marks per Tree	% Trees with Sizes of Measured Claw Marks					
				SB Only	SB + ABB	Single ABB	>1 ABB	ABB + I	I Only
1	94	35	2.7	0%	31%	17%	40%	6%	6%
2	60	39	1.5	0%	13%	59%	21%	5%	3%
Combined	154	74	2.1	0%	22%	39%	30%	5%	4%

Survey 1: 2018–2019; survey 2: 2022 (see Figure 2). Claw marks measured = no. of bear claw marks measured and compared to species key [42]. SB = sun bear size mark; ABB = Asiatic black bear size mark; I = indeterminate size, between SB and ABB. Single = only 1 mark measured, but other marks likely occurred on the tree. SB + ABB or ABB + I = combination of different-sized marks.

Survey 1, which was primarily around the edges of the park in the reserve forests, recorded 13 of 35 (37%) trees with two different-sized marks (Table 1). Survey 2, which targeted an area in the park interior where other researchers reported finding sun bear-sized marks, recorded only 7 of 39 trees (18%) with two different-sized marks. We measured less marks per tree in survey 2 (Table 1) because we followed a different protocol, whereby we held a gauge to the various marks on the tree, and if we found no marks smaller than black bear size, we normally measured just a single set. The results did not change significantly when we partitioned out those marks distinguished as recent (<1 year); however, we only aged the marks in survey 1, where we found 18 trees with recent marks, of which 9 (50%) had two different-sized marks.

In one case, a local person brought us to a tree where a few months before he had seen two distinctly different-sized black bears (which he interpreted as either a male and female or a female and large offspring) feeding on a honeycomb. Our measurements of the marks keyed out as black bear and indeterminate. Interestingly, when we measured the width of the central three claw marks of the indeterminate sets, they keyed out to be sun bear size (as per [42]). Furthermore, we found some long sliding marks on this tree apparently caused by the bears hurrying down when they saw the person watching them. We also found another nearby fruiting tree with fresh claw marks matching the size of black bear and sun bear, and broken branches forming a platform (nest).

We were able to identify 49 of the 74 bear-climbed trees to genus or species (Table S4, Supplementary Materials). Identification was hindered because we were not permitted to collect leaf samples, we did not have a botanist on our team, and our local guide used Garo names for the trees, for which we could not always find a corresponding scientific name. Six of the climbed trees were figs (*Ficus* sp.) and 20 were either oaks (Fagaceae: *Castanopsis*) or laurels (Lauraceae: *Litsea*, *Cinnamomum*), all of which produce fruit that is commonly eaten by both black bears and sun bears in other areas [10,54]. In fact, 13 of the 15 genera of climbed trees that we identified were reported previously as food of black bears and sun bears (Table S4, Supplementary Materials).

4.3. Camera Trapping

We set camera-traps at 12 locations for a total of 577 trap nights, and captured 1990 images. We obtained no photos of bears, but 191 (10%) were of people. These involved 32 independent events, of which 9 (28%) parties included people with weapons (guns or local weapons).

5. Discussion

Recently, it was discovered that there is at least one place in the world where three species of bears exist together on a local scale. That place is northern Canada, along the southwestern edge of Hudson Bay, where camera traps have revealed the presence of polar bears (*U. maritimus*), American black bears (*U. americanus*), and grizzly (brown) bears (*U. arctos*) all at the same spot, although never together at the same time [55]. Whereas a few grizzly bears have historically occurred in this area, they have become far more common, apparently due to the increased expansion of immigrants southward along the Hudson Bay coastline during the past several decades, possibly related to climate change [56]. However,

there is currently no indication of the co-occurrence of resident breeding populations of the three species of bears in this area.

Conversely, our study sought to find a remnant place where resident populations of three species of bears co-occurred historically, and still do. We do not know if there ever was a place where the ranges of three extant bear species overlapped at the level of a forest patch, but if so, it would be NE India (Figure 1). Our study at one site there, in western Meghalaya, revealed that the co-existence of three bears is doubtful. Our study also revealed the difficulties of even detecting whether the site is occupied by two species of bears. Here, we critically examine the information obtained using the methods that we employed.

5.1. Local Ecological Knowledge

Black bears are undoubtedly the most prevalent, if not the only, bear in BNP. We heard this repeatedly in our many discussions with park staff and local people. Thus, it became apparent that we were looking for evidence of one or possibly two rare bear species in an area occupied by a much more common one. Given that most people did not know how many bear species lived in the region and were uncertain how to distinguish bear species by visual sightings or sign, we treated all second-hand evidence with some skepticism, but we attempted to pursue promising leads.

One of the strongest pieces of evidence for the existence of sun bears, which was instrumental in directing us to work in BNP, was the two orphaned cubs that had recently been found there. Our eventual discovery that these cubs were not sun bears underlines the issue of confusion between the species and demonstrates the importance of following up on all accounts of sun bears or sloth bears in the area.

We heard intriguing stories of past observations of both sun bears and sloth bears, suggesting that the three species may have overlapped here in the not-too-distant past (10–30 years ago). That overlap may have been on a macro-scale, but not within the same habitats, as we were told (by one person) that sloth bears were in a relatively close but different area. A few people suggested that sun bears might still occur, although we were told of just one recent, purported first-hand sighting. The description provided by that individual was a very small bear, which he identified as *makbil sarang*, although the bear he described was considerably smaller than a standing adult sun bear. If the standing bear was truly only waist high, as the person indicated, then it must have been a juvenile, in which case it could have been a black bear. Unfortunately, we could not determine from the translation of this interview why the person was so convinced that this bear was not a black bear.

In 2005, an investigator surveyed the local people in the South Garo Hills, including those living around BNP, asking what large mammals they had seen on community lands and what their perceptions were of population trends [57]. Black bears were among three species that most people thought were declining. The sample included 27 hunters, who would have been most familiar with the wildlife, none of whom had seen a sun bear in the previous 5 years.

5.2. Sign

The virtual absence of termite mounds meant that we could not reliably identify whether sloth bears were present based on sign (diggings or scats with termites). Moreover, without this key food source, we felt it was unlikely that sloth bears were present, although we recognize that there are places where sloth bears rely more on ants than on termites [58].

We had hoped to use claw marks to confirm the presence of sun bears, but an important constraint with differentiating black bears and sun bears from claw marks is that small black bears create sun bear-sized marks. Sometimes these small marks are identifiable as being from a cub or yearling, if the mother also climbed the tree.

Interpreting our data cautiously, we assumed that all cases where sun bear-sized marks occurred on the same tree and were about the same age as black bear-sized marks

represented a black bear mother and offspring. This interpretation, though, resulted in an unusually high percentage of mother–offspring incidents in the data: 22% overall; 50% for recent marks. Comparatively, only 9% of the bear claw marks were sun bear-size, in a protected area of China occupied only by black bears [42]. One explanation is that our data from along the edges of the park happened to be an area used heavily by females and cubs. Notably, at least one of the two bear attacks that we recorded along the edge of the park was by a female with cubs.

Another explanation for two different-sized marks on the same tree is that different individuals, possibly of two different species, climbed the same trees that had abundant fruit. Certainly, it is not unlikely that a fruiting tree could attract multiple bears at different times. Other studies have shown that black bears and sun bears eat the same fruits, use the same habitats, and can even be photographed at the same site a few days or even hours apart [9–11]. However, it would seem highly unusual that every tree climbed by a sun bear would also have been climbed by a black bear. If some trees are climbed by both species, there should also be some trees climbed only by black bears, which we found, and some trees climbed only by sun bears, which we did not find. This could make sense only if sun bears were much rarer than black bears. We note that the investigators of the mammalian biodiversity survey of BNP mentioned above, who measured claw marks somewhat differently, claimed to have found trees with only sun bear-sized marks [46]. It was their data that directed us to the area targeted in survey 2, where all of the trees that we found with sun bear-sized marks had accompanying black bear marks.

5.3. Habitat Considerations

We specifically searched for habitats that seemed suitable for sloth bears, namely sal (*Shorea robusta*) forest and grasslands [59]. In fact, one reason we chose this park as a study site is that it is one of very few places in NE India that has an extensive grassland [60]. However, we found no evidence of sloth bear diggings or termite scats, and although some people told us about places that had termite mounds, we searched there and found very few. We also investigated trees with honeycombs, looking for evidence of bear climbing, since sloth bears are also known to readily consume this food [61–63]. All of the climbed trees with honeycombs that we saw had marks indicative of black bears. We therefore concluded that it was unlikely, based on habitat (i.e., few termites), that sloth bears lived in this park.

Conversely, the habitat features in this park seem amenable to sun bears. Nearly all of the climbed trees that we recorded were fruit trees, known to be part of the sun bear diet in other places (Table S4, Supplementary Materials). Sun bears overlap with black bears throughout most of Southeast Asia at a patch-level scale, and many of their habitat requirements appear to be similar [5]. However, whereas black bear range extends much farther north and west (Figure 1), sun bears have apparently never crossed the Brahmaputra River. The reason for this is not entirely clear, but it seems probable that the alluvial grasslands along this river may have been a significant barrier, as it has been to a host of other Southeast Asian mammals whose distribution is restricted to the east side [64]. In addition to the alluvial corridor associated with the Brahmaputra River, there is a 200-km wide expanse of alluvial habitat within the Brahmaputra–Ganges River delta that separates the Garo Hills of Meghalaya from the Rajmahal Hills of Jharkhand [65]. This so-called Garo–Rajmahal gap imposes range limits not just for a variety of mammalian taxa, but also for birds, reptiles, and fish [66–68]. Thus, from the standpoint of zoogeography it seems reasonable that sun bears would have ranged westward to the Garo Hills (our study site), but no farther. Sloth bears would have crossed the gap because they readily use alluvial habitats, and black bears, which have the widest niche among these three bear species [59], could have bypassed the gap in the hills farther north.

5.4. Limitations of the Methods

Local people readily confirmed the presence of bears and provided some useful information about the context of their interactions with bears. They reported that human–bear conflicts were uncommon. However, after we left the field following survey 1, two people were attacked. The local people and park staff also reported that hunting bears was illegal and rarely occurred, yet our camera traps photographed people coming into the park with guns. Hence, the information we received was not entirely correct, either because people had limited information or because they did not openly share all of the information they had. Nevertheless, no person said that sun bears were common, and most knew nothing about this species.

The best evidence of sun bear presence that we uncovered was a single person who reported seeing one very recently. Whereas we have no reason to believe that this person intentionally tried to deceive us, we cannot discount the possibility that his prior local knowledge of the physical characteristics of a *makbil sarang* influenced what he thought he saw. We were told that a second person also independently saw one, possibly lending more credence to the story, but we were unable to talk to that person. The person we interviewed seemed quite convinced that he saw a different species than the more common black bear. However, we are aware of a number of reports of two species of bears in other places where we know with certainty that there is just one, or even three species where there cannot be more than two [69,70], due to people judging species by erroneous characteristics (e.g., size, coat color, behavior), or being confused by seeing pictures of bear species from other areas, or hearing about different bears from others in the community. There are still many places in the world where persistent stories of large primates not known to science have misled people who have seen bears walking bipedally [71,72].

In the early 1980s, two experienced wildlife scientists working in the Himalayas of Nepal learned of what local people considered to be a different kind of bear, not known to science. It purportedly lived in higher elevations than black bears, was smaller in size, more arboreal, and built more intricate tree nests. The local people had given this bear a distinct name (*rukhi balu*), and the researchers began calling it the Nepal tree bear. It was described in a book [73], and there are drawings, which look very much like juvenile black bears [74]. It is now known that only black bears reside in this area [75]. Our point is not that local people are necessarily wrong in differentiating different kinds of bears, but that they may categorize “types” that may not match actual species.

Some of our team had considerable experience in differentiating black bears and sun bear from sign (in Southeast Asia), so we started our study with optimism that measuring claw marks would work to distinguish these two species [42]. One lesson we learned in implementing the technique is that it is imperative to search the tree for different-sized marks, and not just record a single set of clear marks, assuming all marks are the same. This is not foolproof, as many marks do not have the necessary four or five toes needed for species identification. In survey 1, we also measured the widths of the central three claw marks, of which 47% were sun bear-sized, using the Steinmetz and Garshelis key [42], but this declined substantially using four-claw mark sets (17%), and even further with five-claw mark sets (5%). A second important lesson is to record the marks with a paper template, which is a more accurate measure that includes the curvature of the tree (since the bear’s paw must bend around the curve), and can serve as a permanent record that can be remeasured.

A final important caveat is that, even if we had found a few trees with only sun bear-sized marks, these could not be definitely categorized as sun bears because young black bears may climb trees as a refuge while their mother remains on the ground. Some might interpret this to mean that the species gauge developed by Steinmetz and Garshelis [42] is not useful, because small marks could be from either species. It is important to recognize that this key was developed for use in an area where both of the species were known to exist, and the purpose was to ascertain whether they used distinct habitats or types of fruits [9,10]. In that area, it was discovered that very few small marks occurred in montane habitat,

yielding the interpretation that in this habitat, sun bears were excluded by black bears. Our study was the first to try to employ the claw mark gauge to determine whether sun bears exist in an area known to be occupied by black bears. In this case, the interpretation of the marks must be done cautiously to avoid “discovering” sun bears in a place where they never existed or have been extirpated. This would be a serious conservation error. Hence, except in a case where sun bear-sized marks are common and often occur without accompanying larger marks, we suggest that investigators should be wary of using this sign as the sole evidence of the presence of this species.

We have come to believe through this study that the only definitive evidence of the presence of sun bears or sloth bears would be an alive or dead animal, a DNA sample (e.g., from fresh scat), or a clear photo. It is striking that there are no recent specimens and no photos of sun bears anywhere in Meghalaya. An important question is, what level of survey effort would be required to obtain a sun bear photo if this species was much rarer than black bears? Indeed, this is an important question for the detection of any rare species [76].

To investigate this question, it is instructive to look at camera trapping data from other nearby areas. At two study sites in Myanmar, one in the north and one in the west-central, black bears were much rarer than sun bears. Camera trapping revealed ratios of sun: black bear photos of 198:6 and 45:1, averaging 35:1 (Supplementary Materials in [77]). Likewise, a study in Laos obtained photos of sun bears at 104 camera-trap stations, but detected black bears at only 11 stations, giving a ratio of nearly 10:1 with similar detection probabilities for the two species [78]. Note that both studies had a lopsided ratio of photos strongly in favor of sun bears, demonstrating that this species is not harder to camera trap than black bears. In 2012–2015, a research team conducted an extensive camera trapping program across the BNP landscape to document the mammalian biodiversity. In nearly 4000 trap-nights of effort, they obtained only three black bear photos and no sun bear photos [46]. If black bears and sun bears have a roughly equal detection probability, and if (hypothetically) there were $10\times$ as many black bears as sun bears in BNP, then over 12,000 trap-nights would be needed to obtain a single sun bear photo. That would be $>3\times$ the effort expended by these investigators, which took 3 years. Likewise, in over 6000 trap-nights, three black bears but no sloth bears were photographed in Manas National Park, Assam [79], although both of these species were known to be present [80].

A sun bear photo might be obtained more quickly if cameras were put in the vicinity of purported sightings by villagers. We think that this strategy—targeted camera trapping immediately following the sighting reports—would be more efficient, and likely more convincing as to either the presence or absence of this species, because it would also help check on what villagers are calling *makbil sarang*. The detection of this species via camera trap would be significantly improved by using a lure, which could be done by a special permit.

5.5. Identifying Rare Look-alike Species

A number of recent studies have detected rare mammalian carnivores by camera trapping in Meghalaya or other areas in the region [44,45,81–83], including sun bears [84]. There is a difference, though, between detecting a species inadvertently during a biodiversity survey, and searching for a specific species that may or may not exist, or may never have occurred there historically. Searching for a rare species is especially difficult when there is another more common look-alike species present. This not only makes eye witness accounts less reliable, but also may cause errors in camera-trap identifications. Misidentification of camera trap images of black bears and sun bears is not uncommon [19]. Two recent published papers reporting photographic evidence of sun bears in China misidentified black bears [85,86]. Video footage confirmed at least one sun bear in China, although this occurred <1 km from the border with Myanmar, where a known population exists [17].

Historically, sun bears were reported from a number of places where we now know they did not exist. Strikingly, these erroneous reports were based on dead animals that

could be examined closely, and included Sri Lanka (called Ceylon at the time; [87]), the terai of Nepal [88,89], and Tibet [90,91]; in this last case, it was noted that, whereas the skull of the specimen matched that of a sun bear, the skin was similar to that of a black bear.

Knowledge of the presence of sun bears in India came relatively late compared to the other bear species. Jerdon's [92] comprehensive *Mammals of India* (first published 1867) listed four species of bears in India, including brown, Asiatic black, sloth, and the "red cat-bear" (red panda, not actually a bear, *Ailurus fulgens*), but did not include sun bears. Blyth's [93] 1863 inventory of specimens in the Asiatic Society's museum contained sun bears, but not from India. Sterndale's [94] 1884 comprehensive natural history of the mammals of India listed sun bears as stretching westward only to Burma (Myanmar). However, by 1888, Blanford [95] described their western range limit as Chittagong (now Bangladesh) and the Garo Hills (then part of Assam). This is the earliest record that we could find mentioning the presence of this species in the Garo Hills, where we worked. Blanford did not cite a source for his information, but a specimen from the Garo Hills (plus several other specimens from other unknown sites in Assam) was listed in Sclater's [96] 1891 updated catalogue of mammals in Indian museums, meaning that it had arrived since Blyth's inventory. Hinton and Lindsay [97] noted the collection of another sun bear specimen from the Garo Hills during 1919–1920. Finn [98], which was an update of Sterndale's work, repeated the Garo Hills as the western range limit of sun bears. In times when hunting bears for sport was legal in India, sun bears were reported to be far less common than black bears and sloth bears in NE India, and the occasional hunting of a sun bear warranted publication in the *Journal of the Bombay Natural History Society* [99]. As a consequence, the distribution of sun bears in NE India was always rather vague. Gee [100] reviewed a number of general places where sun bears had been reported in the early–mid 1900s, including Assam, and reiterated previous authors' mentions of their occurrence in the Garo Hills, but provided no new information.

It is within this context that we consider the most recent record of a sun bear in western Meghalaya, in what is now BNP. The person who reported this incident from the early 1980s (Anne Wright) was an accomplished Indian naturalist who had commonly seen black bears and sloth bears, and observed this one freshly killed individual to be different enough to warrant writing a letter to a local bear expert [12]. We had the occasion to talk to Mrs. Wright, through her daughter, and although she did not recall the incident, she felt that her knowledge of the other bear species supports her previous claim that it must have been a sun bear. An alternate explanation is that it was a black bear that had some characteristics of a sun bear. Unfortunately, there is no photographic corroboration, and we are unaware whether the specimen ended up in a museum. In the most recent case from the area, two cubs that were initially reported to be sun bears turned out to be black bears. However, the characteristics of the two species may be more easily confused in cubs.

Sloth bears are more widespread across India, and western Meghalaya appears well within their historical range [12], although there are no recent confirmed records from the state [101]. Nevertheless, it is important not to dismiss the possibility that the species still exists, but in very low numbers. Choudhury [102] reported a sloth bear that was killed in Assam in 2017, <10 km from the border of Meghalaya (<100 km from BNP), where no recent records of the species had existed, and far from any known population. This report was documented only because the bear had attacked and injured multiple people.

6. Conclusions and Conservation Implications

The assessment of species status is the first step in the "assess-plan-act" conservation cycle of the IUCN Species Survival Commission [103]. On the most basic level, assessment involves documenting presence. Across Asia, there remain many places where investigators are seeking to ascertain the presence of bears, using methods similar to ours [104,105].

Our aim was more complicated: we were trying to find a place where three bear species still co-occur within their historical range. We concluded that this was not the case in BNP, as there is no evidence of the presence of sloth bears, and we were explicitly told

by local people that this species no longer exists there. However, we could not ascertain for certain whether there is just one bear species (black bear), or two. We could not confirm the presence of sun bears, but the data we collected allow for the possibility that they could be present. Determining that a species is absent is far harder than determining its presence, because the latter requires just a single unequivocal documentation. The enigma represented by our study is how to proceed when the documentation is far less certain. We had one eye witness account by a local person; additionally, we measured claw marks that could have been sun bears, but a more parsimonious explanation (due to their co-occurrence with black bear marks on the same trees) is that they were juvenile black bears.

Where black bears and sun bears co-occur in Southeast Asia, their habitat use and food habits are very similar. Despite this, the relative abundance of these two species varies widely across the region of their co-occurrence. We assume that differences in the ratio of these two species are mainly habitat- and food-related, even if these factors are not well understood. We did not assess the food resources for bears in BNP, so we do not know whether a low density of fruiting trees could account for the scarcity or absence of sun bears.

The two species are also likely to compete at some level. However, it is not simply that black bears, being larger, always outcompete sun bears. In some areas, even at the northern edge of sun bear range, sun bears are more common than black bears (as mentioned above). In North America, American black bears can outcompete larger brown bears in some circumstances [106]. It may be that whichever bear species initially becomes more common is able to displace the other.

Human influences (e.g., disturbance, poaching, crops) also may favor one species over another. In Mizoram (southeast of Meghalaya), Sathy and Chauhan [52] reported the frequent depredation of crops by sun bears in a similar *jhum* agricultural system, so it is unclear why crop depredation is so low around BNP. It is possible that, despite the indications from park personnel and local people that there were few conflicts and negligible poaching, human-caused mortality was sufficient to depress the abundance of bears. Our camera trap observations of people with guns headed to the interior of the park suggest that hunting occurs more commonly than we were led to believe.

If sun bears do exist at a very low density, then an important conservation action to protect them would be to ensure protection against poaching. That action would be beneficial to a host of species. However, the point here is that a rare species that is very vulnerable to extirpation may provide the extra incentive to take action. In that way, knowing whether sun bears exist in this park is important. In fact, the occurrence of this species, at the most westward extent of its historical range, would also likely generate more conservation attention to this park in general.

Another reason for seeking to know whether sun bears exist in BNP is because such an understanding might help improve the conservation across the region. A recent study in a reserve forest in southern Assam, bordering eastern Meghalaya, reported the previous extirpation of sloth bears and recent extirpation of sun bears, but the continued presence of black bears (with the caveat that this study was based on local interviews, so subject to misclassification of species [107]). In Bangladesh, sloth bears were extirpated and sun bears nearly extirpated, while black bears persist [15]. In Bhutan, black bears are common and sloth bears were thought to occur, but extensive camera trapping yielded just a single photo of a sloth bear near the Indian border [18]. In Vietnam, sun bears seem to have declined to lower numbers than black bears [108]. Hence, there seem to be a number of parallels with what may have occurred, or is occurring, in our study site. As such, BNP could provide valuable lessons insofar as assessing the presence of a rare species. In closing, we offer the following guidance, based on experiences from this study:

1. Information from local ecological knowledge should be evaluated cautiously when the species look somewhat alike. We obtained intriguing information on the possible

- existence of sun bears, but none was definitive, and all could have stemmed from stories told within the communities.
2. The sign of ecologically similar species can be misleading. We used a key that worked well to differentiate between the two species when investigating their habitat use in Southeast Asia; however, that key turned out to be less useful for detecting the presence of a potentially rare species whose sign was the same as juveniles of the common species.
 3. Camera trap photos would provide the most definitive evidence of presence, but a significant effort may be necessary to obtain a photo of a rare species. Neither our camera trapping effort nor a more extensive effort before ours was sufficient. Directed camera trapping in areas where a person claimed to have seen the rare species would be more practical than a general survey.
 4. The absence of proof that a species exists is not necessarily evidence of the species' absence. Our study was largely a documentation of the failure of the methods of detection. We note that sun bears had not been known to exist in Arunachal Pradesh (the northern-most state of NE India) until a single camera trap photo was obtained in Namdapha National Park in 1996–1997 [109]; however, since then it has been realized that a significant population resides there [1].
 5. Whereas it can be difficult to assess whether a certain species still exists in any given area, this is just the beginning of the important process of learning what happened to them and why. We hope that sun bears are eventually documented in BNP, but even if they are deemed not to occur there anymore (presuming they once did), the timing and reasons for their disappearance would lend insights into what is occurring across the region.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d14090717/s1>, Tables S1–S3: Excel file with 2018–2019 data, 2020 data, and key to claw mark sizes; Table S4: Trees with claw marks identified to scientific name.

Author Contributions: Conceptualization, D.L.G., N.D., T.R.S. and K.E.P.; methodology, D.L.G., N.D., T.R.S. and K.E.P.; validation, D.L.G., N.D., T.R.S. and K.E.P.; formal analysis, D.L.G.; investigation, D.L.G., N.D., T.R.S. and K.E.P.; data curation, D.L.G.; writing—original draft preparation, D.L.G.; writing—review and editing, D.L.G., N.D., T.R.S. and K.E.P.; visualization, D.L.G.; funding acquisition, D.L.G., N.D., T.R.S. and K.E.P. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the International Association for Bear Research and Management, and by the IUCN SSC Bear Specialist Group.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this study are available in the Supplementary Materials.

Acknowledgments: The authors are thankful to the International Association for Bear Research and Management (IBA) for financial support. We are also grateful to the IUCN SSC Bear Specialist Group (BSG) for additional support for field surveys, and to a number of BSG members who provided useful insights that aided in the collection and interpretation of data. We sincerely acknowledge the Chief Wildlife Warden of Meghalaya and the Field Director of Balpakaram National Park (BNP) for permission and logistical support, and Maureen Sangma, Conservator of Forest, Meghalaya, for her support in getting the proper permissions and assisting us during field surveys. We would like to thank the forest field staff for participating in field work and for translating the interviews from Garo to Hindi. A special thanks goes to the following individuals for assisting us in our field efforts: Arzoo Malik, Nilmani Rabha, Tushar Sangma and Shikha Srikant. Many thanks also to Kashmira Kakati and Shikha Srikant for in-depth discussions about the data from their mammal biodiversity study, and for sharing their experiences about BNP and the surrounding landscape. Their input was critical to our follow-up survey. The designation of geographical boundaries in the maps presented in this

paper do not imply the expression of any opinion whatsoever on the part of IUCN or the authors concerning the legal status of any country or delimitation of its frontiers or boundaries.

Conflicts of Interest: The authors declare no conflict of interest.

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