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continued on the back inside cover

Caption: The Philippine Sailfin Lizard *Hydrosaurus pustulatus* shot at Luzon Island, Philippines. © Emerson Y. Sy.

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CONSERVATION APPLICATION

First attempt at rehabilitation of Asiatic Black Bear cubs to the wild in Thailand

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Abstract: Returning orphan bear cubs to the wild can benefit bear welfare and conservation but is hindered in Asia by the scarcity of documented experience. We experimented with rehabilitation of two Asiatic Black Bear cubs in Thailand using the assisted method of soft-release. We raised the 5-month old cubs for 11 months with minimal human contact in a remote enclosure in high quality habitat, letting cubs out periodically to walk with caretakers in the forest. The caretakers acted as surrogate mothers, allowing cubs to safely acquire foraging skills and familiarity with the forest. Supplementary feeding resulted in the cubs' rapid weight gain (average 157g/day), faster than would occur in the wild. Faster growth allowed the cubs to be released sooner, reducing the likelihood of long-term habituation. After three months of rehabilitation, the bear cubs started showing signs of being wary of the caretakers (e.g., cautious when we approached their enclosure) and their focus during walks switched from play to foraging. After seven months they began to spend nights away from their enclosure, thus declining the supplemental food. This sequence and timing of increasing separation and independence from people matched other assisted soft releases in the region. The cubs went missing in month 12, shortly before planned collaring and release. They were seen together 2.5 months later on a fruiting tree and ran away when approached. Assisted soft releases might be a promising option for bear rehabilitation in Asia but more data are needed to evaluate their effectiveness relative to other methods. This method affords direct observations of bears in the wild that can augment our knowledge of bear behavior and ecology.

Keywords: Reintroduction, soft release, *Ursus thibetanus*, walking with bears.

บทคัดย่อ: การปล่อยลูกหมีคืนสู่ธรรมชาติถือเป็นกระบวนการสำคัญที่เอื้อประโยชน์ด้านสวัสดิภาพและส่งเสริมการอนุรักษ์หมีในธรรมชาติ แต่อย่างไรก็ตาม ในภูมิภาคเอเชียยังมีการศึกษาเกี่ยวกับงานด้านนี้อยู่น้อยมาก สำหรับการศึกษาในอุทยานแห่งชาติแม่วงก์-ประเทศไทยครั้งนี้เป็นการทดลองการปล่อยลูกหมีควายจำนวน 2 ตัว คืนสู่ธรรมชาติโดยใช้วิธี assisted soft-release ตลอดระยะเวลา 11 เดือนลูกหมีควายอายุ 5 เดือนถูกเลี้ยงอยู่ในกรงที่ตั้งอยู่ในป่าเพื่อหลีกเลี่ยงการมีปฏิสัมพันธ์กับมนุษย์ แต่มีการปล่อยให้ลูกหมีได้ออกมานอกกรงเป็นระยะโดยมีพี่เลี้ยงดูแลอย่างใกล้ชิด พี่เลี้ยงจะทำหน้าที่เหมือนแม่หมีคอยดูแลและให้ลูกหมีได้ฝึกทักษะการหารอาหารและใช้ชีวิตในธรรมชาติ การให้อาหารเสริมช่วยให้ลูกหมีเติบโตอย่างรวดเร็ว (เฉลี่ย 157 กรัม/วัน) ซึ่งมีค่ามากกว่าการเจริญเติบโตของลูกหมีในธรรมชาติ การเติบโตที่รวดเร็วนี้จะช่วยให้กระบวนการปล่อยลูกหมีคืนสู่ธรรมชาติเป็นไปได้เร็วขึ้นและยังช่วยลดโอกาสที่ลูกหมีจะเรื่องหรือคุ้นเคยกับมนุษย์ได้อีกด้วย ภายหลังกระบวนการผ่านไปสามเดือนพบว่าลูกหมีเริ่มแสดงอาการระมัดระวังตัวเมื่อพี่เลี้ยงเข้าไปใกล้ หรือเปลี่ยนพฤติกรรมจากการเล่นเป็นการหาอาหาร แต่จากนั้นหลังเจ็ดเดือนลูกหมีก็ไม่กลับมาที่กรง ออกหากินเองตามธรรมชาติและกินอาหารเสริมน้อยลง กระบวนการและช่วงระยะเวลาในการแยกตัวและพยายามอยู่ห่างจากมนุษย์ของลูกหมีสอดคล้องกับผลการศึกษาในวิธีการเดียวกันจากพื้นที่อื่น ๆ ทั้งนี้ ลูกหมีได้หายตัวไปเมื่อเข้าสู่เดือนที่ 12 ก่อนที่จะมีการปล่อยคืนสู่ธรรมชาติและติดตามอย่างเป็นทางการ โดยลูกหมีทั้งสองตัวปรากฏตัวอีกครั้งหลังจากผ่านไปสองเดือนครึ่งบนต้นผลไม้และวิ่งหนีทันทีเมื่อมีคนเข้าไปใกล้ ดังนั้น การปล่อยหมีคืนสู่ธรรมชาติวิธีนี้ถือเป็นทางเลือกที่น่าสนใจในการฟื้นฟูประชากรของหมีในภูมิภาคเอเชีย แต่จำเป็นต้องมีข้อมูลเพิ่มเติมเพื่อนำมาประเมินผลเมื่อเทียบกับวิธีการปล่อยหมีแบบอื่น ๆ นอกจากนั้น วิธีการนี้ยังสามารถสังเกตพฤติกรรมหมีในธรรมชาติได้โดยตรง อันจะช่วยเพิ่มองค์ความรู้ในด้านพฤติกรรมและนิเวศวิทยาของหมีได้อีกด้วย

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Author contribution: All authors contributed equally to the design and implementation of the project and writing of the paper.

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INTRODUCTION

Orphan bear cubs are common in southeastern Asia due to widespread hunting of adult females with cubs and trade in young bears as pets (Tumbelaka & Fredriksson 2006; Vinitpornsawan et al. 2006). Orphan cubs often end up at rescue centers, following confiscations and donations. In Thailand for example, one center (Banglamung) has 87 Asiatic Black Bears *Ursus thibetanus* and 26 Sun Bears *Helarctos malayanus*, and these numbers grow each year, straining available resources (P. Chotiwatpongchai pers. comm. 2016). This abundance of captive bears, combined with a desire to improve animal welfare and conserve wild bear populations, has generated widespread interest among governments and non-government organizations in the idea of reintroducing captive bears to the wild in southeastern Asia, but there is a scarcity of knowledge to guide this challenging undertaking.

Releases of Asiatic Black Bears to the wild have been conducted in Russia (Skripova 2013), South Korea (Han & Jung 2006), India (Ashraf et al. 2008), and Lao (Scotson & Hunt 2008). Both soft and hard release approaches have been used. In soft releases, bears are released after a period of acclimation and supplemental feeding, typically within an enclosure at the release site. In hard releases, bears are transported and released without acclimation to the release area. A few projects have experimented with both approaches and had greater success (higher post-release survival and lower conflict with humans) with soft releases. Two unique soft-release projects are those of Ashraf et al. (2008) with Asiatic Black Bears in India, and Fredriksson (2001) with Sun Bears in Indonesia. Both these projects employed an assisted soft release, a variant of a soft release, in which the bear cubs are held in an enclosure at the release site at night but regularly let out to forage and explore the surrounding forest under the protection of caretakers during the day (Beecham et al. 2016). This option, also called 'walking with bears', is less commonly employed than the other methods and its efficacy is relatively unstudied.

In February 2016 two orphan Asiatic Black Bear cubs, a male and female (presumably siblings), were found by park staff in Mae Wong National Park, Thailand. They were about three months old. The mother may have been killed by hunters or separated from the cubs during the extensive fires that occurred at the time. Such small cubs were unlikely to survive in the wild without protection by their mother. We (WWF and Mae Wong National Park) decided to rehabilitate them to the park using this assisted soft-release approach. Our goals were to: (i) take advantage of an opportunity to observe bear behavior in the wild, (ii) conserve the local bear population, (iii) generate lessons and experience in rehabilitation procedures that could inform future bear releases, and (iv) save the two bears from a lifetime in captivity.

Study site

The present orphan bear rehabilitation project was conducted in Mae Wong National Park, northwestern Thailand (99.07–99.37E, 15.65–16.10N; Fig. 1). The 894-km^2 park is covered with tropical evergreen and deciduous forest types and is inhabited by wild Asiatic Black Bears and Sun Bears. Elevations range 150–1,964 m; the area has a monsoonal climate with a dry season (November–May) and a wet season (May–October). Average annual rainfall is 1,200mm and mean temperature is 27°C.

MATERIALS AND METHODS

The cubs weighed about 3kg and appeared healthy (active, hungry, no injuries) when first acquired in February 2016. Before rehabilitation, the park staff had kept the bears for nine weeks at their park headquarters in a cage. They were fed rice, milk, and fruits. During this time, the bears received generous attention from the park staff, interacting daily with numerous people who played with them.

We initiated the rehabilitation program in April 2016. The cubs weighed 6.7 (female) and 4.2 kg (male) and were about five months old at this time. In subsequent months we could only visually estimate their weights, as they were too unruly to hold on a scale; thus, all but our first weight measurement are estimates, not actual weights. The cubs were transferred to a chain-link fence enclosure (3 × 1.5 m) at a remote site in the park, 20km away from the nearest village. In July 2016, we transferred the bears to an adjacent larger enclosure (16 × 8 m) as they had outgrown the space available in the initial one. The site was in mixed deciduous forest, a habitat that harbored many fruiting trees and other food items that bears feed in the wild (Steinmetz et al. 2013). Perennial streams were present. Wild bears occurred in the release area but were not abundant, as evident from the direct observation of bear signs. Leopards *Panthera pardus* and Tigers *Panthera tigris* also inhabited the surrounding forest, though we never encountered them directly at the rehab site.

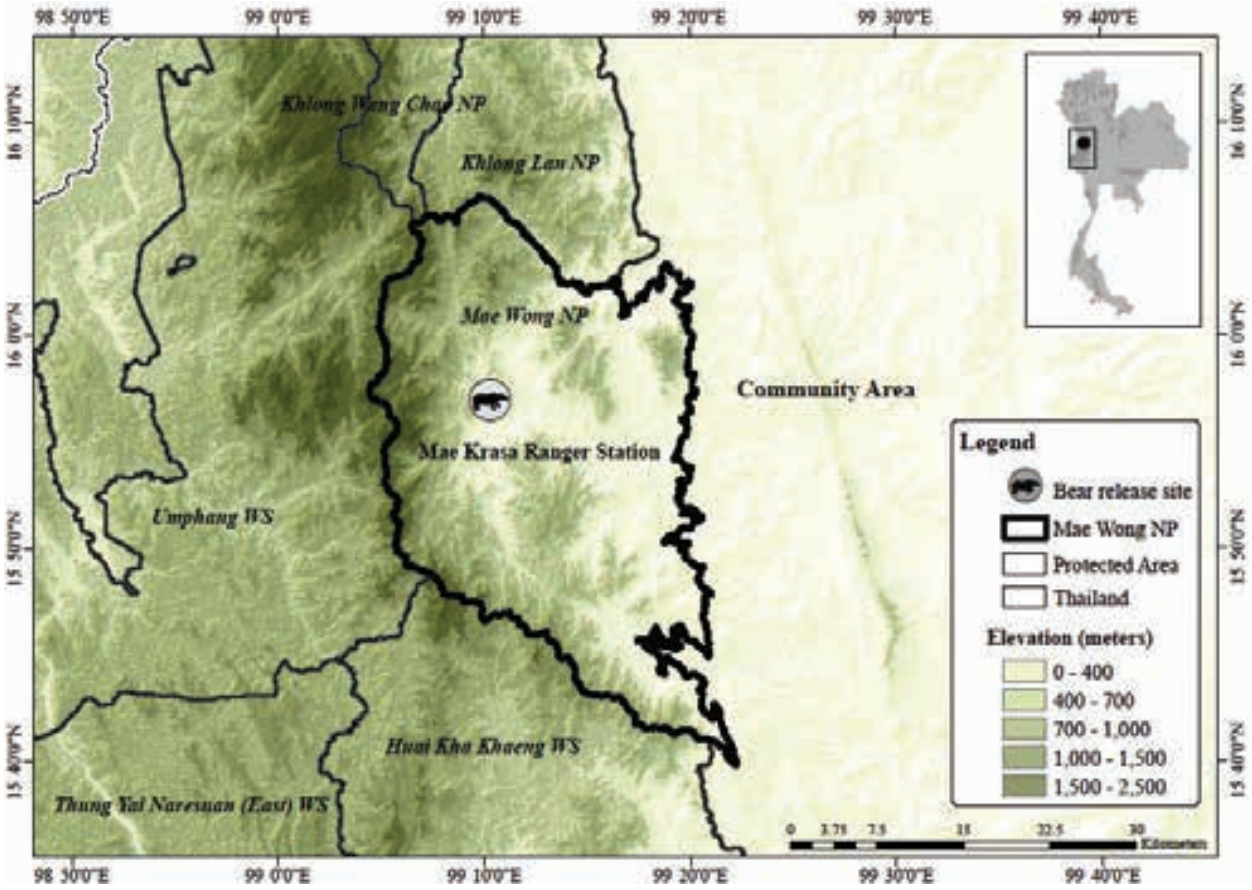

Figure 1. Map of Mae Wong National Park, Thailand, showing Asiatic Black Bear rehabilitation and release site.

The enclosures had a water trough for bathing. Logs and a raised wooden platform were available for climbing and resting, and plastic buckets and balls were used as enrichment to keep the bears occupied, promote cognitive development, and prevent stereotyped behaviors from developing (Beecham et al. 2016). Shade was available from surrounding trees. The two bears were kept together so they could socialize with each other.

The enclosures were 150m from a ranger station manned by three rangers. Together with the first two authors, these five people were the main caretakers of the bears. Because of the enclosure's proximity to the station, the bears were aware of human smells and sounds, but this proximity also gave us convenient access for daily feeding and other tasks.

Feeding

Rice was discontinued once rehabilitation began in April 2016. On days that we walked the bears, they were fed once, in the afternoon after their walk. On days without a walk, the bears were fed twice per day, in the morning and afternoon. Each meal was dry dog food and milk. Fruit or vegetables were also given 4–6 times per week (watermelon, pumpkin, papaya, banana). The milk was store-bought whole cow's milk meant for humans. Milk and dog food were poured into bamboo feeding troughs, whereas fruits and vegetables were scattered in the enclosure to stimulate foraging. In the first three months of rehab (bears 5–7 months old) we fed each bear about 3,000g of milk and 300g of dog food each day. In the next three months (bears 8–10 months old) we reduced milk to 2,000g/day and increased dog food to 800g/day. Thereafter (11–16 months old), we ceased milk and increased dog food to 1,000g/day/bear.

Rehabilitation

We employed an assisted soft-release approach to prepare the bears for eventual release. In this approach the bears were fed and cared for in an enclosure at their eventual release site, but periodically let out to forage and explore the surrounding forest under the watch of dedicated caretakers. After walks the bears were returned to the enclosure for the night. The caretakers

acted as surrogate mothers, allowing the cubs to safely acquire foraging skills and familiarity with their future home. Human contact was otherwise minimized, and limited to a small core group of caretakers. Caretakers did not receive formal training. Prior to the project, we familiarized ourselves with bear rehabilitation techniques by reading the literature (Beecham 2006; Beecham et al. 2016) and consulting with experienced rehabilitators.

We set the following protocol to minimize human contact. Five people interacted with the bears throughout the project: three rangers and the first two authors. The bear enclosure was surrounded by black netting to minimize the bears' view of the caretakers as they approached (Beecham et al. 2016). Talking to the bears or playing with them was not allowed. Food was funneled down a tube from outside the cage, behind the black netting.

We began walking the bears after two months in captivity, when they were about 7 months old (June 2016; Table 1). Two to four people walked the bears each time. We used a whistle to communicate with the bears, avoiding vocal communication. We carried bamboo poles to repel attempts by the bears to interact with us, prodding them away to prevent physical contact. We led the bears to food sources as available, including fruiting trees, termite and bee nests, and rotten logs (which hold insects). We made qualitative observations of their behavior inside their enclosure, and outside the enclosure during walks, noting their level of caution and wariness towards us, and whether their predominant activity was playing, foraging, or other (Table 1). During the walks, we also documented the food items they ate (Image 1).

We planned to radio-collar and release the bears in April 2017, which coincided with the start of the annual high-fruit season in this habitat (Steinmetz et al. 2013); however, the bears escaped on 14 March 2017, before we could collar them.

RESULTS

During the first three months of rehabilitation the bears consumed up to 3,500g of food per day in captivity, averaging approximately 29% of their body mass daily. During the six months that they were fed milk, average daily consumption was estimated at 20% of body weight. And over the course of the entire rehabilitation, average food consumption was estimated at 14% of body weight per day. The bears also foraged during walks but we could not quantify the mass of wild foods they ate. The bears grew rapidly, increasing from about 3kg to 50kg in 10 months (Fig. 2), an estimated average gain of 4.7kg/month, or 157g/day. We did not estimate their weights in the final two months, but by their escape in March 2017, when they were 16 months old, the bears appeared to weigh over 50kg.

At the time of escape, the bears appeared healthy, with thick glossy pelage, and a blocky appearance, full-bodied over all bony areas, with some fat over the rump and shoulders (Image 2). These physical characteristics correspond to a body condition score of 4 (out of 5) in the index used to assess the physical suitability of bears for release (Lintzenich et al. 2006); this score exceeded the level deemed suitable for release (Beecham et al. 2016).

We walked the bears 14 times in the 11 months (April 2016 to March 2017) before escape (Table 1). During walks the bears instinctively fed on foods such as termites, beetle larva, and fruits of *Ficus benjamina*, *Cassia fistula*, and *Dillenia indica*. They also fed on foods not previously documented in the species' diet in southeastern Asia: bamboo shoots, stems and leaves of wild ginger *Zingiber* sp., aroids (Araceae), the herb *Costus* sp., and tree seedlings of *Spondias* sp.

The bears became increasingly wary and independent over time (Table 1). In the first 3–4 four months, the bears eagerly approached us when we came near their enclosure and initiated repeated contacts with us (> 2 per walk) during walks, particularly attempts to smell or play with our legs. But in the later months, they appeared cautious when we approached the enclosure, and they became increasingly independent of us during walks, exploring under their own direction and initiating fewer contacts (0 or 1 per walk). Their focus of attention during walks also shifted during this time. In the initial four months, the bears spent most of their non-resting time playing with each other, both inside and outside the enclosure. By the 5th month of the rehab process (when the cubs aged nine months), however, their main interest during walks had switched to foraging, with bouts of play now intermittent (Table 1).

The bears repeatedly escaped from their enclosure after three months (July; Table 1), by clawing through the chain-link fence. After escapes, food was provided as usual inside the enclosure, and the bears entered for meals. After each escape, they slept in nearby trees (within 30m of the enclosure) until we repaired the enclosure and got them back inside. We continued to walk them after escapes, calling them down from their tree with a whistle to follow us. After the first two

Table 1. Behavior of two Asiatic Black Bear cubs during rehabilitation from April 2016 to March 2017, as observed inside and outside their enclosure. Behavior outside was observed during walks and whenever they escaped from the enclosure.

Month	Estimated bear age (months)	Number of walks	Behavior outside enclosure	Behavior inside enclosure
Apr 2016	5	0	n/a	Cubs approached caretakers eagerly.
May	6	0	n/a	Cubs approached caretakers eagerly.
Jun	7	1	· Predominant behavior is playing with each other (chasing, mock fighting, climbing trees). Some amount of foraging. · Follow us through forest. · Cubs made frequent attempts to interact with us.	Cubs approached caretakers eagerly.
Jul	8	10	· Escape from first enclosure. · Began sleeping on trees outside the enclosure; descend for feeding and walks. · During walks, bear cubs spent more time playing with each other. Limited foraging. · More independent than previous month- stayed further away from us and began exploring the forests on their own (we follow them). · Made fewer attempts to interact with us.	Cubs still approach caretakers eagerly. Soon moved into larger enclosure.
Aug	9	2	· Escape from second enclosure · Sleep in nearby trees as before; descend for feedings and walks · On walks, bears show little interest in us · Predominant behavior on walks has switched, from mostly play to mostly foraging. Frequently taste various plants.	Approach caretaker, but more cautiously than before.
Sep	10	0	· Enclosure repaired; bears back inside.	The cubs still approached caretaker, but cautiously.
Oct	11	1	· Escaped again. Using the nearby trees for sleeping. Would descend for daily feedings, but wait for caretakers to leave first.	n/a
Nov	12	0	· Bears forage on their own all day, returning to sleep in trees near enclosure at night. · We rarely saw the bears now; but they still come for meals inside enclosure (food disappears). · Bears begin to spend nights away from enclosure, including a 4-day period of complete absence (during which they did not come for meals). · Bears raid ranger station kitchen for two consecutive 2 nights.	n/a
Dec	13	0	· Enclosure repaired and bears enticed back in with food.	Cubs no longer approach the caretakers. Would move in the opposite direction when caretakers arrive.
Jan 2017	14	0	n/a	Cubs no longer approach the caretakers. Would move in the opposite direction when caretakers arrive.
Feb	15	0	n/a	Cubs no longer approach the caretakers. Would move in the opposite direction when caretakers arrive.
Mar	16	0	· Bears escape for final time, never to return again.	n/a

escapes (July, August), they spent most of their time (both day and night) in the nearby trees, descending mainly for meals and walks. In subsequent months, they foraged and explored on their own after escapes, but still returned to their regular sleeping trees in the evening. In month 8 (November) they began to occasionally sleep away from the enclosure altogether after escapes (not returning to their sleeping trees next to the enclosure), and declined to enter the enclosure for food for the first time. On one occasion, in the 8th month of acclimation, the bears raided the park ranger's station kitchen on two consecutive nights. Bear spray had little effect: the bears would retreat but return a short time later (American Black Bears have shown similar responses to bear spray (Herrero & Higgins 1998); however, no further raids occurred after this.

The bears went missing on 14 March 2017 before the radio-collars were ready. They were 16 months old. They broke through the enclosure and did not return. They were seen together 10 weeks later by a park ranger patrol, 1.5 km from the enclosure, feeding in the canopy of a fruiting tree. They descended the tree and ran away, a positive indication that they were not habituated and had acquired fear of people. They appeared healthy and were apparently sustaining themselves foraging in the wild. Despite their freedom and proximity to the ranger

Table 2. Key factors associated with successful bear releases, from Beecham (2006), and the degree to which they were achieved (subjectively ranked as high, medium, or low) in the rehabilitation and release of orphaned Asiatic Black Bears in Mae Wong National Park, Thailand, 2016–2017.

Key Factor	Level of achievement
1. Minimize frequency of contact and number of caretakers, particularly after weaning	**Medium-High**. Five people had primary contact with the bears during their captivity, whereas 1–2 people might have been ideal. After weaning, however, only two people regularly interacted with the bears (for feeding). Also, we implemented remote feeding techniques to minimize time at the enclosure during feeding.
2. Provide opportunity for cubs to socialize with other bears while in captivity	**High**. We were fortunate to have a pair of cubs—this is a crucial factor in preventing habituation.
3. Release bears close to age when family break-up occurs in wild	**Medium-High**. Our bears were released at about 16 months old, which is slightly earlier than they would naturally leave their mother in the wild. Bear releases have been successful with bears much younger, however, and our bears were large for their age, which aids survival prospects.
4. Release bears in good quality habitat	**High.** The release occurred in deciduous forest with bamboo. This habitat provides moderately abundant food, including fruit trees, bamboo, gingers, and insects.
5. Time release to coincide with availability of natural foods	**High.** The peak fruiting season began in April, soon after the bears were released.
6. Release bears when chance of encountering people is low	**High.** The release site is remote from villages. Occasional hikers pass through, but not until November, giving the bears eight months of immersion in the wild before possibly encountering people.

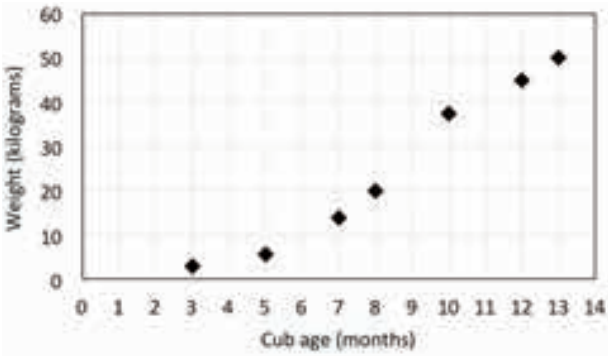

Figure 2. Weight gain of two Asiatic Black Bear cubs rehabilitated in Thailand, 2016–2017. Points are averages of estimated weights of the two cubs. Estimates were not made in some months so there are missing points.

station, the bears never raided the kitchen again.

DISCUSSION

Cub growth

Despite uncertainty in the visually-estimated weights of the bears, it was clear that the bears grew rapidly due to our feeding regimen. This was despite being fed cow's milk, which has substantially lower fat and protein, and higher carbohydrate content, than bear's milk (Oftedal & Gittleman 1989). Between the ages of 3 and 13 months, the bears gained an estimated 157g/day on average (Fig. 2), two times faster than the growth rate of wild American Black Bear *U. americanus* cubs (77g/day; Oftedal & Gittleman 1989). As a result, our cubs were roughly twice as heavy as wild bears would generally be at an equivalent age (e.g., Noyce & Garshelis 1998; Clark et al. 2002). Similar fast growth rates were observed for Brown Bears *U. arctos* and American Black Bears that were fed supplemental food (Rausch 1961; Huber et al. 1993; Komnenou et al. 2016).

Although orphan bear cubs can be released as early as 5 months old and survive, larger bears tend to have higher post-release survival rates and fewer conflicts with people (Beecham et al. 2015). An Asiatic Black Bear cub in Lao, which was rehabilitated using an assisted soft-release approach, was killed by a predator (possibly another bear) just weeks after release; its small size (< 30kg) might have rendered it particularly vulnerable to attack (Scotson & Hunt 2008). Our goal was thus to release heavy bears that could defend themselves, but we wanted to achieve this growth rapidly so bears could be released sooner and spend less time with humans, thereby minimizing the possibility of long-term habituation. Our effort appeared to have successfully balanced these goals.

Cub behavior and adaptation

Minimizing human contact is a critical determinant of successful bear releases. Bears that interact with too many people, or have too much human contact at the wrong time (after weaning), are more likely to become habituated to people, leading to conflict after release as they seek human food (Beecham 2006). Our bears began showing signs of wariness and independence after three months, and after seven months (at the age of 12 months), began to spend nights entirely outside the enclosure, foregoing their supplemental food. The timing of these behavioral changes corresponded to other assisted soft releases in Asia. In Lao, Asiatic Black Bear cubs showed wariness towards caretakers within four months of the rehabilitation process (Scotson & Hunt 2008). In India,

Image 1. Walking with two Asiatic Black Bear cubs during an assisted soft release in Thailand, 2016. The main purpose of walking with the bears is to prepare them for release to the wild. Walking with bears also affords the unique opportunity to observe bears in their natural habitat at close range, allowing researchers to obtain behavioral and ecological information that is not accessible otherwise. Here, caretakers observe foods the bears eat.

Image 2. Photo (January 2017) showing the healthy condition of two rehabilitated Asiatic Black Bears before final escape. The bears were about 14 months old in this photo. They were large for their age, with thick glossy pelage and full-bodied over all bony areas, indicating good body condition suitable for release.

cubs became reluctant to enter their enclosure after seven months of rehab (age 13–14 months) (Ashraf et al. 2008). And in Indonesia, Sun Bears refused to enter their enclosure after six months, choosing to live on their own in the forest but returning for food occasionally (Fredriksson 2001). In retrospect, we believe our bears were physically and behaviorally ready for release in month 8 of rehab (November 2016; they were about 45kg) but we kept them longer because natural food availability at that time of year was low (Steinmetz et al. 2013).

Caretakers in other assisted soft release projects typically walked their bears every day (Fredriksson 2001; Ashraf et al. 2008; Scotson & Hunt 2008). Our walking schedule was much less intensive, yet bears exhibited similar behavioral trends towards independence, separation, and wariness. Although our 'official' walks were more sporadic compared to other projects, the bears' frequent escapes allowed them to explore the forest on their own, which may have served a similar function as walks (but without protection afforded by the caretakers). Even including escapes, the bears spent more than two-thirds of their days completely inside the enclosure, far more than in other projects; thus, our project is a combination of soft release by acclimation at the release site and soft release by walking with the bears. Thus, it appeared that assisted soft releases can be successful with less intensive walking schedules than have been used previously. As long as cubs' habituation to humans declines over time (by minimizing contact), minor differences in rehabilitation methods appear to have little effect on the development of traits that cubs need to adapt to life in the wild after release (IFAW 2007; Beecham et al. 2015). Assisted soft-release projects should strive to have no more than 2–3 people interacting with the bears throughout the process (references above). Our project exceeded this, with five people interacting with the bears over time, due to changes in ranger staff at the rehab site. The fact that we had two bear cubs which could socialize with each other might have mitigated potential habituation problems arising from interacting with too many people. We recommend that number of caretakers be minimized as much as possible.

Socialization with other bears is a key factor underlying successful bear rehabilitation and release projects (Beecham 2006). A major asset in our project was having two bears of the same age to raise together. This allowed the bears constant opportunities for social interactions with each other, reducing attachment to caretakers at all stages of development (Beecham et al. 2016). A single cub might require more time in captivity to allow separation from caretaker to develop (Beecham 2006), although a single Asiatic Black Bear cub rehabilitated in Lao (Scotson & Hunt 2008) exhibited signs of separation at a pace similar to our two cubs.

During walks we observed the bears feeding on food items that were not documented in the literature on food habits of Asiatic Black Bear in the region (Steinmetz et al. 2013). The new foods observed were all herbaceous items, which are difficult to document without direct observation of feeding, because they do not leave

readily identifiable remains in scats (such as seeds or exoskeletons) and feeding signs associated with them are indistinct and not easily attributable to the bear species. Interestingly, bears fed on these plant materials in August when fruits (their main food) were naturally scarce (Steinmetz et al. 2013); these dietary items probably help to sustain the bears when their main food items are scarce. Assisted soft releases provide the unique opportunity to observe bears in their natural habitat at close range, allowing researchers to obtain behavioral and ecological information that is otherwise unavailable to researchers studying wild bears.

CONCLUSION

Two major limitations of our project were the small sample size (2 bears) and inability to assess long-term survival (because the bears escaped before we could collar or mark them). Their sighting 2.5 months after release and the fact that the bears did not come into conflict with resident humans, indicate that the bears were successfully finding food, avoiding people, and avoiding predators (other black bears, tigers, leopards). These can be considered as key longer-term indicators of post-release success. We rated our project against six key factors associated with successful bear releases (Beecham 2006). All factors were achieved to some degree. Scoring highest were: (i) socialization opportunities, (ii) release timing, and (iii) habitat quality at the release site (Table 2). But we caution that our project is not a definitive evaluation of the assisted soft release approach, especially given the small sample size and the lack of post-release monitoring data. More data are needed to draw conclusions about the value of this approach when compared to other rehab methods. Our intention is to document the experience, thereby contributing to the currently limited information available on bear rehabilitation in Asia.

Resources required for soft releases of bears, whether assisted or not, are similar in most respects: construction of an enclosure, purchase of sufficient food, dedicated staff, and telemetry equipment. An assisted soft release imposes an additional time cost on caretakers to walk the bears, although as we showed, the walking schedule need not be intensive. Assisted releases add the unique advantage of being able to closely observe bear behavior in the wild.

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Status of Sumatran Tiger in the Berbak-Sembilang landscape (2020)

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Abstract: Monitoring the status of the Critically Endangered Sumatran Tiger *Panthera tigris sumatrae* is a key component for assessing the effectiveness of conservation interventions, and thus informing and adapting strategic planning for the remaining 600 Sumatran Tigers on the island. The Berbak-Sembilang National Park is an integral part of the priority Berbak-Sembilang Tiger Conservation Landscape, in a unique habitat of mixed peat and freshwater swamp in eastern Sumatra. Our camera trap survey covered both the Berbak and Sembilang Tiger Core Areas (BTCA, STCA) over a period of 10 years, with surveys undertaken in 2010, 2015, 2018–2019. The most recent population density estimates (BTCA 1.33 adults/100 km^2, 95% CI 0.82–1.91 with 19 adults; and STCA 0.56 adults/100 km^2, 95% CI 0.45–0.89 with five adults) confirmed a small but stable population. A landscape level management approach is a priority for tiger population recovery, consolidating ground-based protection and establishing a well-maintained fire management system with reforestation of affected areas along with multi-stakeholder engagement and partnerships. The study also recommends extending the BTCA to include the primary swamp forest in the north of the national park, based on evidence from camera trap surveys.

Keywords: Abundance, camera trap, density, *Panthera tigris sumatrae*, Sumatra.

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INTRODUCTION

Among the six extant subspecies of tigers, the Sumatran Tiger *Panthera tigris sumatrae* survives in isolated populations across 27 forest patches in Sumatra (Figure 1, combined forest area ~140,226 km^2) (Wibisono & Pusparini 2010). It is listed as Critically Endangered on the IUCN Red List (Linkie et al. 2008), threatened by: 1) habitat loss and fragmentation, largely the result of regular forest fires and land clearance for agricultural use; 2) poaching, encouraged by the illegal wildlife trade and international illegal wildlife trade; and 3) human-tiger interaction (Nyhus et al. 2004; Ng & Nemora 2007; Linkie et al. 2008; Kartika 2017). To conserve the subspecies, six of the existing 12 tiger conservation landscapes (TCLs) in Sumatra have been designated as priority tiger landscapes in the National Tiger Recovery Plan, including the Berbak-Sembilang TCL (GTI 2012), the focus of the current study (forest patch number 26 in Figure 1).

The Berbak-Sembilang TCL comprises Berbak-Sembilang National Park (BSNP, 3,442km^2), Air Hitam Peatland Protected Forest (187km^2), Orang Kayo Hitam Forest Park (181km^2), timber concessions (622km^2), acacia plantation concessions (517km^2), and oil palm plantations (106km^2) (KLHK 2020). With over 3,800km^2 of wetland forest (Wibisono & Pusparini 2010), the landscape is a combination of mixed peat swamp, freshwater forest (Giesen 2004; GTI 2012) and mangrove forest (Silvius et al. 2018a). It is also an important carbon sink (GTI 2012), but it is experiencing deforestation caused by logging and human-caused fires (Giesen 2004).

Since 2007, a tiger conservation programme has been operational in Berbak-Sembilang TCL to monitor and protect the tiger population and its habitat. The adaptive patrol management system, SMART (Spatial Monitoring and Reporting Tool, https://smartconservationtools.org), has been implemented by BSNP since 2014, led by the Tiger Patrol and Protection Units (TPPUs), to tackle tiger poaching and habitat destruction. A Wildlife Conflict Response Team (WCRT) has been operational since 2011 and a Wildlife Crime Investigation Unit (WCIU) since 2015, combating the illegal wildlife trade, mitigating human-wildlife conflict and combating the illegal wildlife trade. Establishing and conserving a viable tiger population requires long term monitoring of tigers, co-predators, prey and their habitats to evaluate a conservation programme's effectiveness and inform management decision-making (Jhala et al. 2009; Goodrich et al. 2013). The objective of the study was to assess the status of the Sumatran Tiger in the Berbak-Sembilang TCL, as part of implementation of a tiger conservation strategy.

MATERIALS AND METHODS

Study area

The study was conducted in Berbak Tiger Core Area (BTCA, area 657km^2) and Sembilang Tiger Core Area (STCA, area 695km^2) within BSNP, located on the east coast of Sumatra island, Indonesia (1.08°–-2.45°S and 103.80°–-104.90°E). Berbak Tiger Core Area mainly consists of freshwater swamp forest and peat swamp forest. The topography is flat with elevation less than 15m (Giesen 2004). Sembilang Tiger Core Area contains the largest area of mangrove forest in the Indo-Malayan region (Silvius et al. 2018a). It is made up of peatland and mangrove forest in the east and peat swamp forest in the west. Both core areas come together in the small blackwater Benuh River*, and in a large peat dome in the west that forms the upper catchment of the Benuh River. Annual rainfall is c. 2,466mm with lowest and highest records of 933mm and 3,972mm, respectively (Silvius et al. 2018a).

Tiger prey species in Berbak-Sembilang TCL include Wild Boar *Sus scrofa*, Bearded Pig *Sus barbatus*, Southern Red Muntjac *Muntiacus muntjak*, Sambar Deer *Rusa unicolor* and two sympatric species of chevrotain: Greater Oriental Chevrotain *Tragulus napu* and Lesser Oriental Chevrotain *Tragulus kanchil*. The other felid species in the study area include Sunda Clouded Leopard *Neofelis diardi*, Marbled Cat *Pardofelis marmorata*, Leopard Cat *Prionailurus bengalensis*, and Flat-headed Cat *Prionailurus planiceps* (BSNP & ZSL 2018).

Field methods

Tiger population densities were estimated using standardized camera trapping procedures based on capture-recapture method (Karanth & Nichols 2002). Surveys were conducted in BTCA between 31 January 2018–22 August 2018, 14 February 2015–8 April 2016, and 23 June 2010–2 February 2011; and in STCA between 1 January–1 July 2019 and 5 September 2018–21 December 2018. A nine km^2 grid system was used, and paired camera traps (1 pair of camera traps= 1 camera trap station) were deployed in accessible tiger

* A blackwater river is a river with a slow-moving channel flowing through forested swamps or wetlands, whose water is tannin-stained, in this case from the peat.

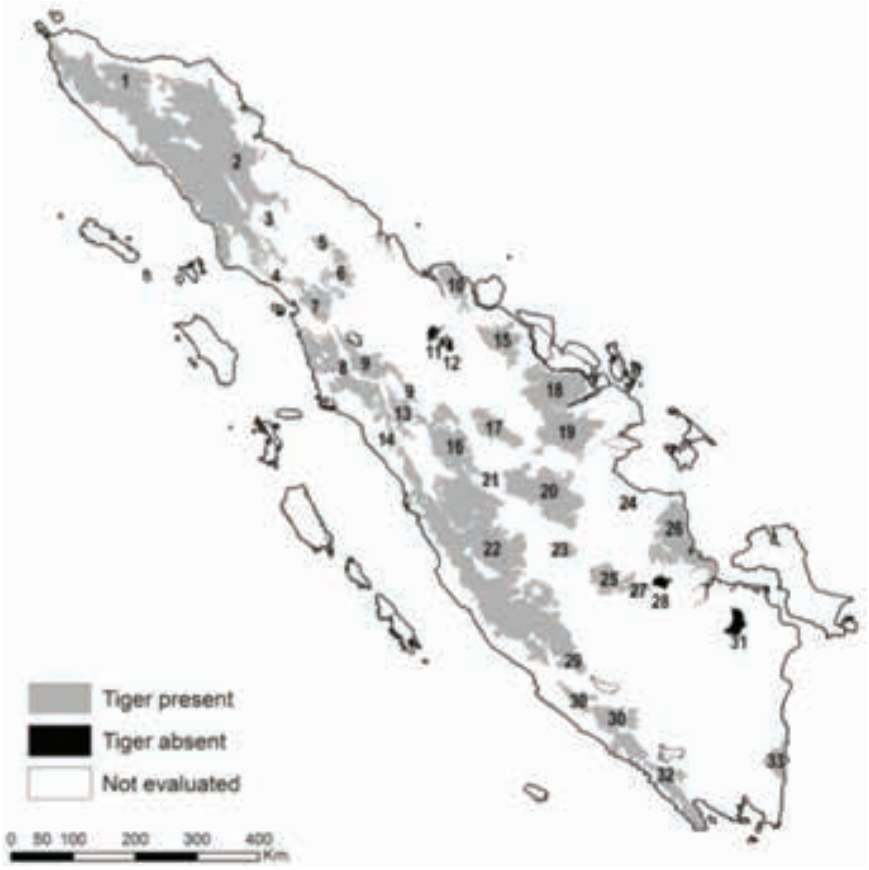

Figure 1. Distribution of the Sumatran Tiger: 33 of 38 forest patches have been assessed (figure from Wibisono & Pusparini 2010). Berbak-Sembilang TCL the focus in the current study is in forest patch 26.

habitat (Figure 2). Average Sumatran Tiger home range is estimated at 50–70 km^2 for adult female and 110km^2 for adult male (Franklin et al. 1999). Camera traps were placed along animal trails to maximise tiger detection (Sunarto et al. 2013). Camera traps were attached to trees and positioned approximately 40cm above ground with each of the paired camera traps about 7m apart and pointing towards each other, in order to capture both flanks of a tiger to facilitate individual identification. In total, 125 camera trap stations were placed in BTCA and 146 camera trap stations in STCA over the five surveys (Table 1). DLC Covert II, Panthera V4, and Reconyx Hyperfire HC500 digital cameras were used, programmed to take three photographs per trigger with no delay. All camera traps used white flash to obtain colour images at night to aid in individual tiger identification.

Data analysis

The metadata (i.e., image name, date and time) associated with all images were extracted with Exiv2 software (Huggel 2012) and compiled in an Excel spreadsheet (Microsoft Office Professional Plus 2010). Information on identified species was then added for all images obtained. Individual tigers were identified based on their unique stripe patterns and gender determined by secondary sexual traits.

Tiger population densities were estimated using the Bayesian Spatial Capture Recapture (SCR) method. A 90-day data subset for each survey was used for the analysis to avoid violation of the population closure assumption. Three data input files were created: a camera trap station activity file specifying camera trap station location and operation by 24-hour day; a tiger capture history file specifying capture events as a single detection of an individual tiger at a camera trap station in each 24-hour period; and a binary habitat mask file. The analysis was carried out in the program JAGS (Just Another Gibbs Sampler) accessed through the program R, version 3.6.0 (R Development Core Team 2019) using the package RJAGS (http://mcmc-jags.sourceforge.net). In data augmentation, M was set to 80 – larger than the largest possible population size (i.e., the number of activity centres). The centroid of capture locations of individual animals caught were used as the starting values for activity centres. Three MCMC (Markov Chain Monte Carlo) chains with 60,000 iterations, a burn-in of 1000, and a thinning rate of 10 were implemented. This combination of values ensured an adequate number of

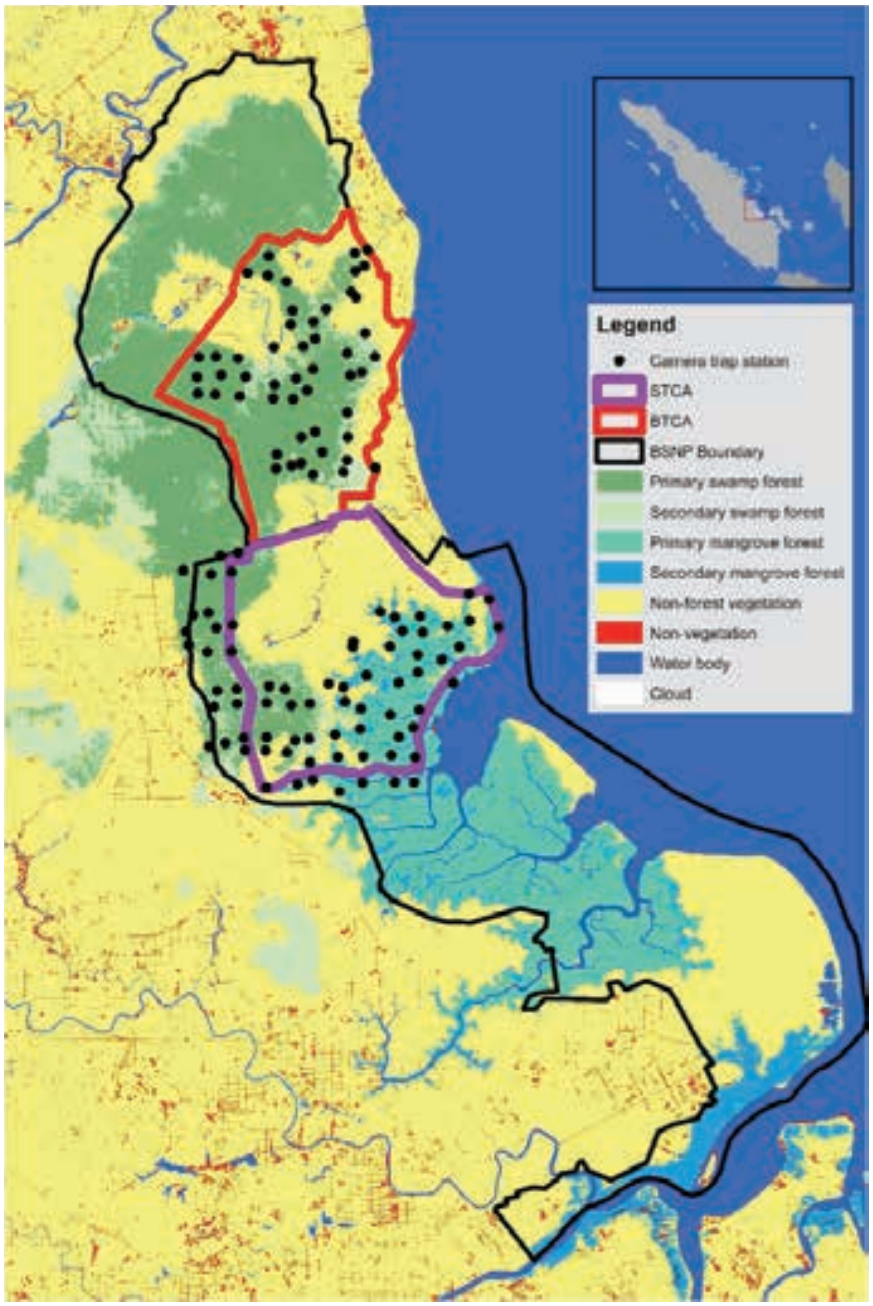

Figure 2. Location of camera trap stations in Berbak-Sembilang National Park (2018–2019), Sumatra. Berbak and Sembilang Tiger Core Areas are in red and purple outlines respectively.

Table 1. Camera trap sampling effort, number of tiger detections and number of individual adult tigers captured (sub-period of 90 days was used for the analysis - see methods).

Area	Survey year	Trap-nights (number of camera trap stations)	Number of tiger independent photo-captures	Number of adult tigers captured	Number of adult female tigers captured	Number of adult male tigers captured
Berbak Tiger Core Area	2018	2,885 (50)	63	10	5	5
	2015	3,731 (48)	31	6	4	2
	2010	1,152 (27)	16	6	2	4
Sembilang Tiger Core Area	2019	6,570 (73)	11	4	2	2
	2018	5,934 (73)	13	4	1	3

iterations to characterise the posterior distributions. Chain convergence was checked using the Gelman-Rubin statistic (Gelman et al. 2004), R-hat, which compares between and within chain variation. R-hat values below 1.1 indicate convergence (Gelman & Hill 2006). The approach of Royle et al. (2014) was used for the model goodness-of-fit test, calculating three statistics, all using Freeman-Tukey discrepancies: individual animal by camera trap station capture frequencies, aggregating the binary daily capture data by animals and camera trap stations; individual animal capture frequencies, aggregating for each animal; camera trap station animal capture frequencies, aggregating for each camera trap station.

For tiger prey species, trap rate for each species was calculated as the mean number of independent photographic 'events' per trap day x 100. An 'event' was defined as any sequence for a given species occurring after an interval of >60 min from the previous three-image sequence of that species (Amin et al. 2015).

RESULTS

Survey effort ranged from 1,152 trap nights (BTCA 2010 survey with 27 camera trap stations) to 6,570 trap nights (STCA 2019 survey with 73 camera trap stations; Table 1). The number of adult tigers captured at a study site ranged from 4 to 10 individuals (Table 1). One individual was captured in both BTCA and STCA in different years.

Given the small sample size, it was not possible to model differences in space use and movement range between the sexes. The STCA 2018 survey had only one individual tiger captured at more than one location and therefore it was not analysed. The Bayesian p0~1. sigma~1 model R-hat values for all estimated parameters were below 1.01 and fitted well to the data (P=0.3-0.5 for all three statistics). Berbak Tiger Core Area had a higher density of tigers (1.33 individuals/100km^2, 95% CI 0.82–1.91 in 2018) than STCA (0.56 individuals/100km^2, 95% CI 0.45–0.89 in 2019). The BTCA tiger population also showed a stable trend between the study years (Table 2, 2.78% per year, SE 1.18).

The most recent BTCA (2018) and STCA (2019) tiger population density maps, derived from the model, are not presented due to data sensitivity[2]. Several tigers were caught in 1–2 locations close to the northern periphery of BTCA, and the western and southeastern edge of the STCA, so there was greater uncertainty in their activity centres (Figure 3).

Our study provided evidence of breeding, with two adult females each with two cubs photographed in STCA (2018–2019), and one adult female with her two cubs in BTCA (2018) (Image 1). The surveys also indicated relatively good population of medium-to-large-bodied prey species, including Lesser Oriental Chevrotain, Wild Pig, and Bearded Pig in BTCA and STCA (Table 3).

DISCUSSION

Our study has shown that the tiger population within BSNP is small, and has remained stable over the past ten years despite facing significant threats (Giesen 2004). The estimated tiger density for BTCA was similar to those recorded in the mangrove habitat of the Sundarban landscape (1.08–4.79 tigers/100km^2, Jhala et al. 2016), while the estimated density of tigers in STCA was lower. Although we were unable to measure the scale of hunting or poaching in BSNP, patrol data between 2015–2019 show that snares were reported at a rate of 0.89 traps/100 km (BSNP 2020). A recent study on the spatio-temporal distribution of human-tiger interaction in Sumatra classified the relative distribution of conflict cases in the Berbak-Sembilang TCL as low to moderate (Kartika 2017). Furthermore, within the last five years, there has only been a single record of human-caused tiger mortality in the landscape (Zoological Society of London 2020). Evidence of tiger breeding also suggests a relatively healthy prey population to support lactating tigress.

Enhancing tiger recovery in the Berbak-Sembilang landscape

Within the forests and peatlands of Berbak Sembilang TCL, habitat loss, mainly by human-caused forest fires, is the current main threat (Abood et al. 2015). In just eight years between 2000 and 2018, there were 12,084 fire hotspots in BSNP (80% confidence level) occurring in both dry and wet seasons (Mora et al. 2019). Across the landscape, forest fires are changing the structure of the peat swamp forest (Wetland International-Indonesia Programme 2002), with large areas of closed canopy-tall trees with undergrowth being replaced by a mosaic of open patches of grasses and shrubs (Giesen 2004). The average rate of annual forest loss for the period 2010–2040 has been predicted to be 1.1–1.6 % (Elz et al. 2015).

Maintaining forest integrity is critical for the survival of tigers (Wibisono et al. 2011), and this requires increased protection from illegal logging and forest clearance. A comprehensive fire management plan

Table 2. Estimates of Bayesian spatial capture recapture model outputs. Sigma is the ranging scale parameter.

Area	Survey year	Tiger density (95% CI) per 100km²	Tiger adult female density (95% CI) per 100km²	Tiger adult male density (95% CI) per 100km²	Sigma (95% CI) (km)	Population size (95% CI)
Berbak Tiger Core Area	2018	1.33 (0.82–1.91)	0.66 (0.34–1.02)	0.66 (0.34–1.02)	4.16 (3.27–5.14)	19 (11–27)
	2015	1.09 (0.48–1.78)	0.70 (0.27–1.23)	0.39 (0.14–0.82)	3.02 (2.22–3.97)	16 (7–26)
	2010	1.36 (0.54–2.35)	0.49 (0.18–0.99)	0.87 (0.36–1.63)	3.82 (2.24–5.82)	15 (6–26)
Sembilang Tiger Core Area	2019	0.56 (0.45–0.89)	0.28 (0.22–0.45)	0.28 (0.22–0.45)	4.59 (2.67–6.97)	5 (4–8)

Table 3. Tiger prey species trap rates for Berbak Tiger Conservation Area and Sembilang Tiger Conservation Area. The trap rate was calculated as the number of independent photographic events per 100 trap days. We defined a camera trap 'independent photographic event' as any sequence of photographs of the species occurring after an interval of >60 minutes from the previous photograph of the species (Amin et al. 2015).

Species	BTCA 2010	BTCA 2015	BTCA 2018	STCA 2018	STCA 2019
Wild Boar *Sus scrofa*	0.66	0.79	1.81	6.07	5.80
Bearded Pig *Sus barbatus*	0.03	0.20	15.71	6.89	10.59
Sambar Deer *Rusa unicolor*	-	-	0.10	0.67	0.49
Muntjac Deer *Muntiacus muntjak*	-	-	-	0.16	0.01
Greater Oriental Chevrotain *Tragulus napu*	4.33	0.35	9.81	0.74	0.35
Lesser Oriental Chevrotain *Tragulus kanchil*	-	0.19	13.62	5.56	4.17
Long-tailed Macaque *Macaca fascicularis*	0.46	0.06	0.76	2.23	2.06
Pig-tailed Macaque *Macaca nemestrina*	2.14	0.83	4.19	3.37	2.36

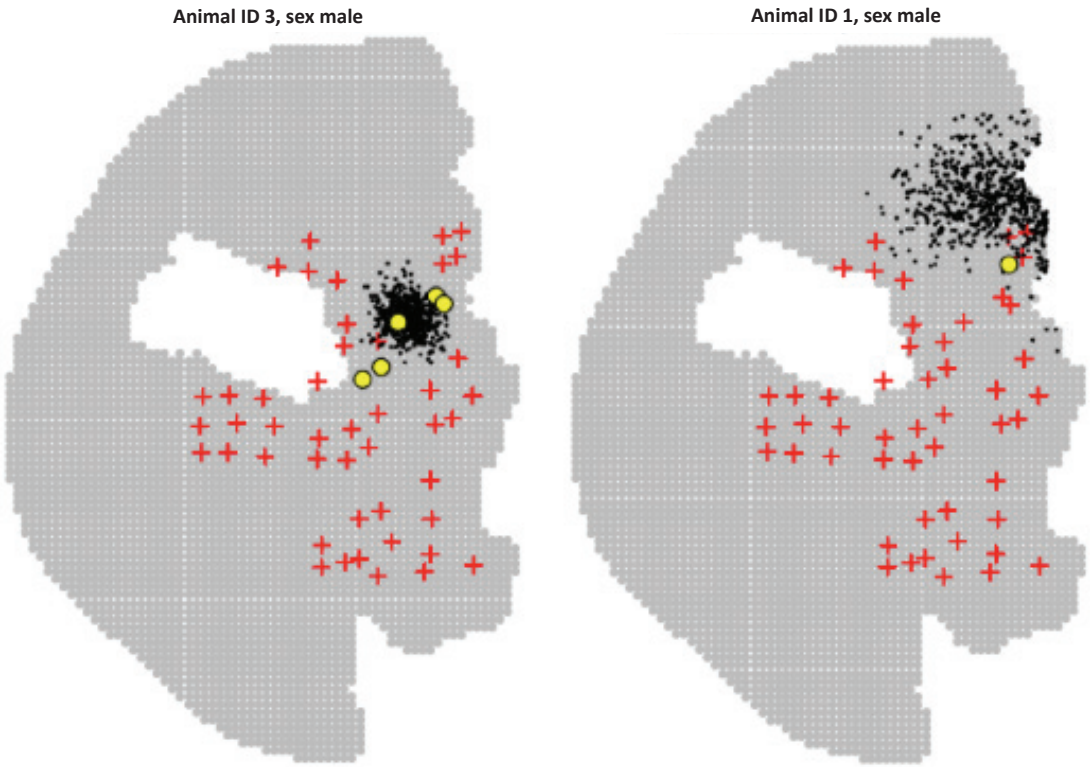

Figure 3. Activity centre posterior distributions (black dots); capture locations (yellow circles); and camera trap station locations (red cross) for an adult tiger caught in multiple locations (left) and an adult tiger caught in a single location close to the edge of the camera trap grid (right), Berbak Tiger Core Area (2018).

Image 1. Top: Tigress and her two cubs captured on camera trap in Sembilang Tiger Conservation Area in October 2018. Bottom: Another tigress and her two cubs captured in February 2019. Images of another tigress with two cubs in Berbak Tiger Conservation Area were also captured.

should also be created and implemented, based on suitable technologies such as remote sensing and appropriate levels of SMART patrolling in this physically challenging environment. A reforestation programme with replanting of indigenous trees needs to be urgently undertaken in the affected areas. The BTCA should be extended to include the primary swamp forest north of the area, following camera trap surveys. The delineation of the existing tiger core area was based on tiger occurrence detected by camera trap and sign surveys (Wibisono et al. 2011; Goodrich et al. 2013). A massive forest fire in 2015, however, has significantly altered forest cover in the core area, and our study revealed activity centres of several tigers lying north of the core area (Fig. 3).

Suitable habitat for tigers also needs to be expanded, increasing the chances for establishing a long-term viable tiger population. A landscape-based approach to the management of the area is being implemented by the Indonesia Government, combining the previously separate Berbak National Park and Sembilang National Park into a single national park (BSNP) under the management of a single authority (via MoEF decree No. P.07/2016). The peatlands of Sembilang remain contiguous with those of Berbak, and together they provide habitat for tigers in this unique ecosystem (Silvius et al. 2018a). As a next step, it should be a priority that government owned lands adjacent to the national park are protected, and incompatible land-uses prohibited (Silvius et al. 2018b). Ultimately, concession areas will need to be integrated into tiger managed habitats and habitat connectivity re-established if tigers and other threatened wildlife are to have a future in this unique landscape.

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Bahasa Indonesia: Harimau Sumatera telah mengalami menurun populasi sekitar 16,6% antara tahun 2000 dan 2012 yang sebagian besar disebabkan oleh hilangnya hutan dan degradasi habitat. Saat ini mereka sangat terancam punah dan pemantauan yang efektif terhadap populasi tersisa dalam lanskap prioritas sangat penting untuk menginformasikan rencana pengelolaan dan konservasi guna mengamankan masa depan spesies karismatik ini. Survei dengan kamera penjebak di bentang alam prioritas konservasi harimau Berbak-Sembilang di Sumatera timur, mencakup Area Inti Harimau Berbak dan Sembilang (BTCA, STCA) selama 10 tahun. Perkiraan kepadatan populasi 2018-2019 terbaru, yaitu di BTCA 1,33 indvidu dewasa / 100 km2 (95% CI 0,82 - 1,91) dan STCA 0,56 dewasa / 100 km2 (95% CI 0,45 - 0,89) dengan perkiraan kelimpahan, BTCA 19 individu dewasa (95% CI 11 - 27) dan di STCA 5 individu dewasa (95% CI 4 - 8),hasil ini telah mengkonfirmasi bahwa populasi kecil tapi stabil. Kepadatan populasi harimau Berbak-Sembilang lebih tinggi daripada lanskap Kerinci-Seblat di Sumatera Barat dan lanskap Lueser-Ulu Masen di Sumatera Utara, dan lebih rendah dari lanskap Bukit Barisan Selatan di Sumatera Selatan. Populasi harimau Berbak-Sembilang, seperti di lanskap konservasi harimau Sumatera lainnya, terancam oleh deforestasi, yang sebagian besar diakibatkan oleh kebakaran hutan secara rutin dan pembukaan lahan untuk pertanian, dan perburuan ilegal yang berkelanjutan, yang didorong oleh perdagangan satwa liar ilegal nasional dan internasional. Sejak tahun 2007, program konservasi harimau Berbak-Sembilang telah dilaksanakan melalui kerangka kerja sama antarlembaga. Pemantauan status populasi harimau merupakan komponen kunci untuk mengukur efektivitas intervensi konservasi di lanskap dan menginformasikan perencanaan strategis. Populasi harimau kecil lebih rentan terhadap fluktuasi demografis dan genetik, yang dapat memengaruhi kelangsungan hidup jangka panjang mereka. Oleh karena itu, pendekatan pengelolaan tingkat lanskap yang efektif menjadi prioritas, membangun koridor harimau yang berfungsi dengan lanskap harimau lainnya dan melindungi zona penyangga taman nasional. Sama pentingnya untuk meningkatkan kapasitas pemantauan, analisis data dan pelaporan di antara para pemangku kepentingan dan membangun basis data harimau tingkat nasional yang tersentralisasi untuk pemantauan status dan pengambilan keputusan.

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Author contributions: TA and YD conceived and designed the study; TA, ET, D, WS assisted in data collection; RA and TA performed the analysis; RA, TA and SK wrote the manuscript.

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COMMUNICATION

The diversity of small mammals in Pulau Perhentian Kecil, Terengganu, Malaysia

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Abstract: Islands are generally rich in marine biodiversity, but it also often hides unique and endemic terrestrial wildlife. The data of terrestrial wildlife in Malaysian islands are still severely lacking, notably from small islands. Hence, this study was conducted to survey and update the small mammal diversity (bats and non-volant small mammals) in Pulau Perhentian Kecil, a tourist destination famous for its magnificent, diverse marine life and white sandy beaches. Despite their touristic popularity, very few information is known about the faunal diversity in this island compare to their more massive neighbouring island, Pulau Perhentian Besar. The survey was carried out from 21 to 30 May 2014 recorded 56 individuals encompasses eight species of bats and five species of non-volant small mammals that were captured using mist nets, harp traps, and cage traps. The survey recorded 10 new species locality records for the island in which, five species were never recorded in Pulau Perhentian Besar. *Hipposideros dyacorum, Tylonycteris fulvida, T. malayana, Rattus exulans*, and *Sundamys annandalei* are also new distribution records for the Malaysian East Coast islands highlighting the importance of protecting island biodiversity. Nonetheless, it is hoped that this study not only highlights the species diversity on the island but also serve as a data for sustainable island tourism management planning, which will be crucial for the sustainable development and management of this ecologically sensitive area.

Keywords: Ecology, endemic species, island biogeography, South China Sea, tourism, wildlife.

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For **Author details, Author contributions, Acknowledgements** & **Malay abstract** see end of this article.

INTRODUCTION

Oceanic islands are well known to contain unique and endemic wildlife, contributing disproportionately 15–20 % of global terrestrial species which are available in one of the 3.5% planet's offshore landmass (Whittaker et al. 2017). Data on island mammals (bats and non-volant small mammals) in Malaysia are uncommon especially for small islands like Pulau Perhentian Kecil (Roslan et al. 2016; Jayaraj et al. 2019). Bats are found throughout the world continents except Antarctica with the highest diversity in equatorial territories (Taylor 2019). The wide distribution of bats coupled with the ability of flight allows bats to fill a plethora of niches making them the second most diverse group of mammals with 110 bat species documented in the Peninsular Malaysia alone (Lim et al. 2017). On top of that, bats are often the main native island mammals, providing seed dispersal and pollination services with their added mobility like flying foxes (Fujita & Turtle 1991).

In islands where there are other small mammals, they play ecological roles including consuming invertebrates and plant materials alongside becoming the prominent prey base for many predators (Pimsai et al. 2014). Malaysian non-volant small mammal diversity reports on islands remain limited by effort and funding simply because island trips are costly and climatic events are unpredictable. Past attempts have provided benchmarks but, due to irregular monitoring, species checklist on islands requires updating (Rahim et al. 2016). The data on the island mammals are not just important for planning conservation frameworks but also assessing introduced species and its estimated damage caused. One of the common introduced mammal culprits are rodents, causing harm to the natives to the point of extinction in islands all around the world such as New Zealand, French Polynesia, and Lord Howe Island, Australia (Towns et al. 2006; Harper & Bunbury 2015).

Threats facing island mammals including bats are mainly habitat loss and human disturbance (Jones et al. 2009). These threats are due to rapid growth of the tourism industry, which has put significant pressure on natural resources and land use in the Perhentian Islands (Aswani et al. 2018). In light of this lack of research on island mammal diversity in Malaysia, we have conducted a small mammal survey in Pulau Perhentian Kecil, the smaller neighbour and less studied island compared to Pulau Perhentian Besar in the state of Terengganu. This survey was aimed to determine the species diversity and update the mammal checklist on this island. Above all, it is hoped that this study not only highlights the species diversity on the island but also serve as data for sustainable island tourism management planning.

MATERIAL AND METHODS

Site description

The Perhentian Islands (comprising of islands like Besar, Kecil, Serenggeh, Rawa, Tokong Kemudi, and Susu Dara) are situated 21km seaward from mainland Terengganu with accessibility from towns like Kuala Besut, Merang, and Kuala Nerus. Pulau Perhentian Kecil is approximately 524 hectares (Farhana 2018). These islands are also well-known and popular tourism destinations for their stunning coral reefs and beautiful sandy beaches.

A nine-day study was conducted in Pulau Perhentian Kecil, from 21th till 30th May 2014. Two sampling sites (site A and site B) located in the northern part of the island were chosen for this study, as shown in Figure 1. The southern part of the island was not chosen mainly due to time constraints and the possibly uncontrolled anthropogenic disturbance from Kampung Pasir Hantu, a village settlement located there.

Site A (North end: 5.937^{0}N, 102.720^{0}E, South end: 5.922^{0}N, 102.720^{0}E) is a combination of primary and secondary lowland forest while site B (North end: 5.922^{0}N, 102.720^{0}E, South end: 5.916^{0}N, 102.718^{0}E) is a secondary forested area similar to site A but sandwiched between Perhentian Kecil's main tourist beaches which are Long Beach and Coral Bay. Site B is more subjected to anthropogenic disturbances due to the vicinity to tourist beaches with a main trail frequently used by tourists to travel between the two beaches and small patches of agricultural land mainly for rubber. For both sampling sites, the vegetation gradually changes into typical coastal forest nearing the coast and beaches.

Small mammals sampling

Bats were captured using mist nets (mesh size: 4cm), and harp traps (4 bank, 2m^2 metal frame) which were placed at suitable bat flyways whereas collapsible cage traps baited with banana were used to capture non-volant small mammals. Both harp traps and mist nets were set up approximately 1m above ground and adjusted to change based on place of trapping. Mist nets and harp traps were checked from 19.00h to 21.00h, closed for the night and reopened and checked from 05.00h to 07.00h in the morning. Cage traps were set placed on a grid of 10m x 10m per trap and checked twice daily with rebait applied for missing or

Figure 1. The location of Perhentian Islands (Pulau Perhentian Kecil & Pulau Perhentian Besar) in Terengganu (inset) and location of sampling sites in Pulau Perhentian Kecil: Site A and Site B.

rotten baits. Opportunistic sightings of small mammals in the sampling sites during netting and trapping were also made whenever possible. The total netting and trapping effort in this study summarized in Table 1. All standard body measurements (vernier caliper & metal ruler), weight (spring balance), gender and maturity state of each captured mammal taken for record and identification purposes based on the identification keys in species identification books (Francis 2008; Kingston et al. 2009). Selected individuals were euthanized and collected as voucher specimens by ethanol preservation (Permit number D-01052-16-19). These were deposited at Faculty of Earth Science, Universiti Malaysia Kelantan. Results are presented in the form of species composition at both sites with assessments of the most recent conservation status of these mammals (IUCN 2020; https://www.iucnredlist.org/) and Red List of Mammals for Peninsular Malaysia Version 2.0 (Perhilitan 2017). Lastly, we compared the results of this study with past studies in the Perhentian Islands (Kecil and Besar) plus other Malaysian east-coast islands including Pulau Bidong, Pulau Redang, Pulau Tenggol, and Pulau Tioman.

Table 1. Total netting and trapping effort for both sites A and B.

Sampling method	Site A	Site B	Time of collection (h)	Total per day/night
Mist nets	15	15	19.00–23.00 & 05.00–07.00	30
Harp traps	5	5	19.00–23.00 & 05.00–07.00	10
Cage traps	150	150	10.00 & 17.00	300
Total effort	170	170		340

Statistical analysis

Shannon-Wiener diversity index (H') is used to calculate the species richness of Site A and Site B and compare the diversity of both sites. We used Mann-Whitney U test to compare the relative abundance of small mammals between sites. To enhance the statistical analyses conducted, we used rarefaction curve to visualize and calculate the species richness for a given number of individual samples. All statistical analyses was calculated using Paleontological Statistics (PAST) software.

RESULTS

A total of 56 individuals belonging to 13 species from six families were recorded in this survey, with site A (12 species, H'= 2.35) being more diverse than site B (seven species, H'= 1.7). Bats had the highest individual count and species diversity compared to non-volant small mammals. *Pteropus hypomelanus* was also observed

to be abundant on the beaches of Pulau Perhentian Kecil during the sampling period. Civet droppings were also found in site B, but the species was unable to be determined during the sampling period. Both species is not included in our results due to insufficient capture details.

Table 2 shows the species composition of small mammals at both sites in this survey. The total number of small mammals captured in Site A (n= 20) was lower than the total number of small mammals captured in Site B (n= 36). The relative abundance of small mammals in Site A and Site B were not statistically significant (Mann Whitney U test, U= 69, df= 24, p> 0.05). The most abundant species caught are *Tupaia glis* and *Rhinolophus affinis* with each totaling to 12 individuals. In contrast, *Eonycteris spelaea, Hipposideros dyacorum, Tylonycteris fulvida, Tylonycteris malayana*, and *Rattus exulans* were recorded as singletons. Among the species captured, *E. spelaea* is listed as Near Threatened while *H. dyacorum* is listed as Data Deficient in the Red List of Mammals for Peninsular Malaysia Version 2.0. Interestingly enough, *H. dyacorum* was previously listed as Endangered for Criteria A (EN A4c) and Criteria B (EN B2ab(ii,iii) in the Red List version 1 in 2010 (Perhilitan 2017).

When the number of individual small mammals captured was standardized (n= 20), the rarefaction curve showed that the expected number of species found in Site A was higher than the expected number of species found in Site B (Figure 2). The rarefaction curve reinforces the relative abundance and species diversity results from Shannon-Weiner Index from both sites.

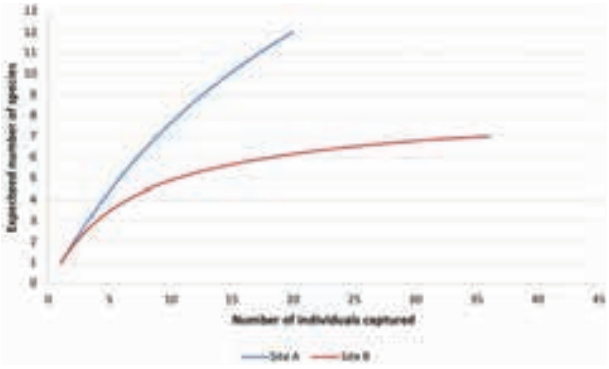

Figure 2. The rarefaction curve for the number of small mammal species in Site A and Site B of Pulau Perhentian Kecil.

Species Accounts

Family Tupaiidae

***Tupaia glis* (Diard, 1820) (Common Treeshrew)**

A total of 12 individuals were captured in the island with three at site A and nine at site B. The previous study conducted in the Perhentian Islands (Kecil and Besar) recorded a much higher capture at 21 and 56 respectively (Tamblyn et al. 2005). This species was observed throughout Pulau Perhentian Besar, including the island lowland forest, coastal forest and disturbed areas (Turner et al. 2003). It is common throughout Peninsular Malaysia, where individuals captured in Tasik Bera, Ulu Gombak, Pulau Pinang and Wang Kelian State Park (Jayaraj et al. 2013; William-Dee et al. 2019). According to Rahim et al. (2016), this species is not disturbed by tourists walking around the trails and beach and seen moving in their proximity. This diurnal species is commonly found in forests and nearby plantations as well as gardens. Their diet mainly consists of insects and the occasional sweet fruits (Francis 2019). Jayaraj et al. (2015) conducted a phylogenetic analysis on tree shrews of Peninsular Malaysia and described three genetically distinct forms of *T. glis* which coincides with the morphological analysis study from Yusoff et al. (2015). *Tupaia glis* from Perhentian Kecil is provisionally placed under *T. glis* morphotype two pending further taxonomic studies.

Family Pteropodidae

***Cynopterus brachyotis* (Muller, 1838) (Short-nosed Fruit Bat)**

Two individuals were captured in which both were from Site A. This species can be traced back to two distinct lineages which are Sunda lineage (*C. brachyotis*) and Forest lineage (*Cynopterus* cf. *brachyotis* Forest) by using two regression models from Jayaraj et al. (2012a). The nominate for *C. brachyotis* (see Abdullah & Jayaraj 2006) has been identified to be the form previously described as *C.* cf. *brachyotis* Sunda (Campbell et al. 2004; Jayaraj et al. 2004). Roslan et al. (2016) recorded 11 captures of this species in Pulau Perhentian Besar in which seven are *C. brachyotis* and three are from *Cynopterus* cf *brachyotis* Forest. Other previous studies include three individuals from Pulau Perhentian Kecil, four individuals from Pulau Perhentian Besar and three individuals from Pulau Susu Dara (Tamblyn et al. 2005) while three individuals of *C. brachyotis* from Pulau Perhentian Kecil (Campbell et al. 2004). *Cynopterus brachyotis* occurs in orchards, plantations, and disturbed habitats while *Cynopterus* cf *brachyotis* Forest can be found in primary forest. Both C. *brachyotis* and *C.* cf *brachyotis* Forest has been known to intersect one another at forest fringes like recorded in Gunung Stong (Jayaraj et al. 2013) and even high up at Mount Penrisen (1,000m) (Jayaraj et al. 2006). The presence of *C.* cf *brachyotis* Forest could be attributed to

Table 2. Small mammal species composition in site A and site B.

	Family Species	Site A	RA_b (%)	Site B	RA_b (%)	Total	IUCN (2020)	Perhilitan (2017)
	Tupaiidae							
1	*Tupaia glis*	3	15.0	9	25.0	12	LC	LC
	Pteropodidae							
2	*Cynopterus brachyotis*	2	10.0	0	0.0	2	LC	LC
3	*Eonycteris spelaea*	1	5.0	0	0.0	1	LC	NT
	Rhinolophidae							
4	*Rhinolophus affinis*	1	5.0	11	30.6	12	LC	LC
	Hipposideridae							
5	*Hipposideros cineraceus*	4	20.0	5	13.9	9	LC	LC
6	*Hipposideros dyacorum*	0	0.0	1	2.8	1	LC	DD
7	*Hipposideros larvatus*	1	5.0	6	16.7	7	LC	LC
	Vespertilionidae							
8	*Tylonycteris fulvida*	1	5.0	0	0.0	1	LC	LC
9	*Tylonycteris malayana*	1	5.0	0	0.0	1	LC	LC
	Muridae							
10	*Rattus exulans*	1	5.0	0	0.0	1	LC	LC
11	*Rattus tanezumi*	1	5.0	2	5.6	3	LC	LC
12	*Rattus tiomanicus*	2	10.0	2	5.6	4	LC	LC
13	*Sundamys annandalei*	2	10.0	0	0.0	2	LC	LC
	Total individuals	20	100.0	36	100.0	**56**	-	-
	Shannon-Weiner (H')	2.35		1.7				
	Total species	13		7		**13**	-	-

RA_b—Relative Abundance | LC—Least Corncern | NT—Near Threatened | DD—Data Deficient.

the island lowland forest where *Dipterocarpus* sp. and *Shorea* sp. are dominant (Turner et al. 2003).

***Eonycteris spelaea* (Dobson, 1871) (Cave Nectar Bat)**

One individual was captured only in Site A on the island. In comparison to past studies, Roslan et al. (2016) also recorded only one individual in Pulau Perhentian Besar while three captures were recorded on the same island previously (Tamblyn et al. 2005). This cave-roosting species occurs in a wide variety of habitat including primary forest (Krau Wildlife Reserve), mangroves, disturbed areas (Pulau Pinang) and plantations (Anwarali et al. 2008; Jayaraj et al. 2016; Francis 2019; William-Dee et al. 2019). As its name suggests, *E. spelaea* is a nectarivorous bat which feeds on nectar and pollen while pollinating a plethora of forest tree species including economically important ones such as durian, petai, and wild banana (Bumrungsri et al. 2013; Stewart & Dudash 2017). *E. spelaea* may roost in rock crevices as Pulau Perhentian Kecil has a hilly terrain with both south and northern region peaks 345m and 105m above sea level respectively with the latter region consist of rockier terrain (Turner et al. 2003).

Family Rhinolophidae

***Rhinolophus affinis* Horsfield, 1823 (Intermediate Horseshoe Bat)**

A total of 12 individuals were captured in the island with one at Site A and 11 at Site B. The previous study conducted in Pulau Perhentian Kecil, recorded one capture of this species (Tamblyn et al. 2005). As for Pulau Perhentian Besar, the number of *R. affinis* captured were two and seven individuals respectively (Tamblyn et al. 2005; Roslan et al. 2016). A common bat species in Malaysia, this insectivorous bat appears in most localities sampled in Peninsular Malaysia and it mainly roost in caves and forages in forests including dry forest, mature lowland forest and disturbed areas (Naharuddin et al. 2015; Ith et al. 2016; Jayaraj et al. 2016; Lim et al. 2017; Francis 2019).

Family Hipposideridae

***Hipposideros cineraceus* Blyth, 1853 (Ashy Roundleaf Bat)**

This species is a new record for Pulau Perhentian Kecil. A total of nine individuals were captured in the island in which four were at site A while five were at site B; however, there were two recorded *H. cineraceus* individuals at Pulau Perhentian Besar (Roslan et al. 2016). This species roost in caves in small to moderately sized colonies, together with other *Hipposideros* bats (Kingston et al. 2009). This species has been found roosting inside culverts; thus, it is safe to assume *H. cineraceus* roost in a tunnel-like structure whether in the hilly forest or rocky terrain in Pulau Perhentian Kecil (Francis 2019).

***Hipposideros dyacorum* Thomas, 1902 (Dayak Roundleaf Bat)**

This species is a new record for the Pulau Perhentian Kecil. One individual of this species was caught only in Site B on the island. On a slightly larger scale, there have been no records of *H. dyacorum* on Pulau Perhentian Besar either. This species is not commonly recorded in Peninsular Malaysia, with only eight recorded localities in the mainland such as Wang Kelian State Park (Jayaraj et al. 2013; Lim et al. 2017). This species roosts in a variety of roosting sites including caves, tree hollows and rock crevices. It mainly forages in the understory portion of the forest (Francis 2019).

***Hipposideros larvatus* (Horsfield, 1823) (Intermediate Roundleaf Bat)**

This species is the third new record of Hipposiderids for Pulau Perhentian Kecil. A total of seven individuals were caught in both of the sampling sites on the island. Six individuals of this species were captured in Pulau Perhentian Besar in recent years (Roslan et al. 2016) while 52 individuals captured in the previous survey (Tamblyn et al. 2005). Another common bat species throughout the nation from Wang Kelian State Park, Perlis, to Bako National Park in Sarawak (Jayaraj et al. 2013), this species mainly roosts in large colonies inside of caves, temples, old mines and rock crevices (Anwarali et al. 2008; Francis 2019; William-Dee et al. 2019). Though usually brown, this species occasionally has bright orange fur due to the effects of cave bleaching (Kingston et al. 2009).

Family Vespertilionidae

***Tylonycteris fulvida* (Blyth, 1859) (Mainland Lesser Bamboo Bat)**

This species is a new record in the Perhentian Islands including Pulau Perhentian Besar. One individual was captured only in Site A on the island. Formerly known as *Tylonycteris pachypus*, taxonomic revalidation separates the name as mentioned earlier to Borneo and Sumatra, while *T. fulvida* restricted to mainland Southeast Asia (Tu et al. 2017). As its common name suggests, this species roosts in the internodes of small live bamboo stems (Francis 2019). There are bamboo plots in the west coast of Pulau Perhentian Kecil adjacent to the pathway between Coral Bay and Long Beach (Tamblyn et al. 2005). Although bamboo is the major roost for this species, it had also been observed to roost in small rock crevices and abandoned tree holes (Eguren & McBee 2014).

***Tylonycteris malayana* Chasen, 1940 (Mainland Greater Bamboo Bat)**

This species is a new record for the Perhentian Islands including Pulau Perhentian Besar. One individual was captured only in Site A on the island. Like its smaller cousin, this species formerly called *Tylonycteris robustula* also undergo taxonomic revalidation (Tu et al. 2017). The distribution of *T. malayana* is in mainland Southeast Asia, while *T. robustula* confined to Borneo like in Kubah National Park and Sumatra (Anwarali et al. 2008; Tu et al. 2017). This species also roosts in bamboo internodes, entering through beetle created slits in which they prefer large dead stems (Francis 2019). The presence and abundance of bamboos usually signal a high possibility of this species and *T. fulvida* as in Gunung Stong, Gunung Reng and Gua Musang, Kelantan due to their roosting association with the bamboo plant (Jayaraj et al. 2012b, 2016). Both species regularly change bamboo roosting sites, usually lasting for a short time only (Medway & Marshall 1972).

Family Muridae

***Rattus exulans* (Peale, 1848) (Pacific Rat)**

One individual was caught only in Site A on the island. This species is a new confirmed record in the Perhentian Islands (Kecil and Besar). This species is a new confirmed record in Pulau Perhentian Kecil but may have already been recorded by Tamblyn et al. (2005) as the study listed three distinct *Rattus* spp. This species is the smallest among the *Rattus* sp. but tends to be larger on smaller islands (Francis 2019). Although this species is known to occur in anthropogenically modified habitats (cultivated lands, shrublands, and gardens), it can also

be found in forest edges, swamp forest, and limestone areas (Jayaraj et al. 2016; William-Dee et al. 2019).

***Rattus tanezumi* Temminck, 1844 (Asian House Rat)**

A total of three individuals were captured (one was at Site A while two were at Site B). This species is a new confirmed record for Pulau Perhentian Kecil; however, a total of 15 *R. tanezumi* individuals were captured in Pulau Perhentian Besar (Rahim et al. 2016). This species has a generalized diet and is a major pest of plant crops in plantations. This species spends much time on the ground but can also climb well whether on trees or inside buildings (Francis 2019). Although *R. tanezumi* is expected to be confined to anthropogenically modified habitats, there were previous records of this species in rainforests and limestone areas of Borneo and Kelantan. This intrusion may be due to the encroachment of human settlements or plantations, even small ones into the vicinity of natural habitats (Wells et al. 2006; Jayaraj et al. 2016).

***Rattus tiomanicus* (Miller, 1900) (Malaysian Wood Rat)**

A total of four individuals were recorded on the island in which two individuals were caught in both sites respectively. This species is a new confirmed record in Pulau Perhentian Kecil. However, three individuals of *R. tiomanicus* were captured in Pulau Perhentian Besar (Rahim et al. 2016). This species has a widespread distribution on Malaysian islands like Pulau Tenggol, Pulau Pangkor and its namesake, Pulau Tioman (Sen 1971; Pimsai et al. 2014; Jayaraj et al. 2019). This nocturnal species occurs in a wide range of habitats including coastal forests, grasslands, plantations, secondary forests but rarely inside houses. Just like other *Rattus* spp., the diet includes a wide range of animal and plant matter (Jayaraj et al. 2016; Francis 2019).

***Sundamys annandalei* Bonhote, 1903 (Annandale's Rat)**

Previously assigned to the genus Rattus, this species has recently undergone a taxonomic revision, placing it in the genus *Sundamys* (Camacho-Sanchez et al. 2017). Two individuals were caught only in Site A on the island. This species is a new confirmed record in the Perhentian Islands (Kecil and Besar). This nocturnal species can be found in rubber plantations and secondary forest, mainly on the lower levels of the tree. Contrary to its appearance, this species is not known to be a significant pest like other rat species (Francis 2019).

DISCUSSION

Notably, the majority of the small mammals recorded in Pulau Perhentian Kecil were bats, conceivably due to the rockier terrain mainly in Site A and presence of an exposed sea cave in Tanjung Kerma near both sampling sites (Turner et al. 2003). While caves are the main roosting site for cave roosting bats, some of them also roost in rocks crevices and hollow trees like *R. affinis, H. larvatus*, and *H. dyacorum* (Ith et al. 2015; Francis 2019). As previously stated, Site A has a higher species diversity than Site B even though Site A has lower relative abundance (refer to Table 2). This pattern is possibly due to Site B experiencing a higher degree of human disturbance with tourist trails and small patches of agricultural land. Our study shows that this site is largely dominated by generalist mammal species which can adapt and forage in disturbed habitats such as *T. glis, R. affinis*, and *Rattus tanezumi.* Other similar studies reported lower species richness of small mammals when the habitat subjected to human disturbance (Shafie et al. 2011; William-Dee et al. 2019).

To get a clearer picture of the island mammal diversity in Pulau Perhentian Kecil, we have compared our results with the past studies in the Perhentian Islands (Kecil and Besar) and other islands in East Coast Peninsular Malaysia comprising Pulau Bidong, Pulau Redang, Pulau Tioman, and Pulau Tenggol. Past studies in the Perhentian Islands include Campbell et al. (2004) and Roslan et al. (2016) for bats and Rahim et al. (2016) for non-volant small mammals while Tamblyn et al. (2005) and Turner et al. (2003) recorded both bats and non-volant small mammals.

For Pulau Perhentian Kecil, the small mammal species checklist updates with 10 new locality records for *E. spelaea*, *H. cineraceus*, *H. dyacorum*, *H. larvatus*, *T. fulvida*, *T. malayana*, *R. exulans*, *R. tanezumi*, *R. tiomanicus*, and *S. annandalei*. In contrast, the small mammal species checklist only increases with five species (*H. dyacorum*, *T. fulvida*, *T. malayana*, *R. exulans*, and *S. annandalei*) when including Pulau Perhentian Besar data to our study. As the distance between Pulau Perhentian Besar and Pulau Perhentian Kecil is roughly 1.5km (Kampung Nelayan Jetty to Perhentian Besar Ferry Terminal), there is a possibility of species interchange between these two islands. Table 3 shows the small mammal species comparison with other islands in eastern coast Peninsular Malaysia. Incomplete species data in Tamblyn et al. (2005) and Turner et al. (2003) like *Rhinolophus affinis*/*R. stheno, Rattus* spp. 1 and *Hipposideros* sp. are not included in the

Table 3. Small mammal species comparison with other islands in east coast Peninsular Malaysia.

	Species	PPK	PPKp	PPB	PB	PR	PTi	PTe
	Erinaceidae							
1	*Hylomys suilus*	-	-	-	-	-	+	-
	Soricidae							
2	*Crocidura fuliginosa*	-	-	-	-	+	-	-
3	*Crocidura negligens*	-	-	-	-	-	+	-
4	*Crocidura malayana*	-	-	+	-	-	-	-
	Tupaiidae							
5	*Tupaia glis*	+	+	+	-	+	+	-
	Cynocephalidae							
6	*Galeopterus variegatus*	-	-	+	-	-	+	-
	Pteropodidae							
7	*Cynopterus brachyotis*	+	+	+	+	+ (1911)	+	+
8	*Cynopterus* cf. *brachyotis* Forest	-	-	+	+	-	-	-
9	*Cynopterus horsfieldii*	-	-	-	-	-	+	-
10	*Eonycteris spelaea**	+	-	+	-	+	+	-
11	*Pteropus hypomelanus*	-	-	+	+	-	+	-
	Emballonuridae							
12	*Emballonura monticola*	-	-	+	-	+ (1911)	+	-
13	*Taphazous melanopogon*	-	-	+	-	+	-	-
	Nycteridae							
14	*Nycteris tragata*	-	-	-	-	-	+	-
	Megadermatidae							
15	*Megaderma spasma*	-	+	+	+	-	+	-
	Rhinolophidae							
16	*Rhinolophus affinis*	+	+	+	-	+ (1911)	+	-
17	*Rhinolophus borneensis*	-	-	-	-	-	+	-
18	*Rhinolophus lepidus*	-	-	+	-	-	+	-
19	*Rhinolophus luctus morio*	-	-	-	-	-	+	-
20	*Rhinolophus macrotis*	-	-	-	-	-	+	-
21	*Rhinolophus megaphyllus*	-	-	-	-	-	+ (1899–1927)	-
22	*Rhinolophus pusillus*	-	-	-	-	-	+	-
23	*Rhinolophus stheno*	-	-	-	-	-	+	-
	Hipposideridae							
24	*Aselliscus stoliczkanus*	-	-	-	-	-	+	-
25	*Hipposideros bicolor*	-	+	+	-	-	+ (*H. kunzi*?)	-
26	*Hipposideros cineraceus**	+	-	+	-	+	-	-
27	*Hipposideros dyacorum***	+	-	-	-	-	-	-
28	*Hipposideros larvatus**	+	-	+	-	-	+	-
	Vespertilionidae							
29	*Myotis muricola*	-	-	+	-	-	-	-
30	*Tylonycteris fulvida***	+	-	-	-	-	-	-
31	*Tylonycteris malayana***	+	-	-	-	-	-	-
	Molossidae							
32	*Cheiromeles torquatus*	-	-	-	-	-	+	-

	Species	PPK	PPKp	PPB	PB	PR	PTi	PTe
	Lorisidae							
33	*Nycticebus coucang*	-	-	-	-	-	+	-
	Cercopithecidae							
34	*Macaca fascicularis*	-	-	EX	-	+	+	-
35	*Trachypithecus obscurus*	-	-	+				
	Viverridae							
36	*Paradoxurus hermaphroditus*	-	-	-	-	-	+	-
	Tragulidae							
37	*Tragulus kanchil*	-	-	-	-	+	-	-
38	*Tragulus napu*	-	-	-	-	-	+	-
	Sciuridae							
39	*Callosciurus notatus*	-	+	+	-	+	+	+
40	*Callosciurus nigrovittatus*	-	-	-	-	-	+	-
41	*Iomys horsfieldii*	-	-	-	-	-	+	-
42	*Lariscus insignis*	-	-	-	-	-	+ (1962)	-
43	*Petaurista petaurista melanotus*	-	-	-	-	-	+	-
44	*Ratufa bicolor*	-	-	-	-	-	+	-
45	*Rhinosciurus laticaudatus*	-	-	-	-	-	+ (1899-1927)	-
46	*Sundasciurus tenuis*	-	-	-	-	+	+	-
	Muridae							
47	*Leopoldamys sabanus*	-	-	-	-	-	+	-
48	*Maxomys rajah*		-	+	-	-	-	-
49	*Maxomys surifer*	-	-	+	-	+	+	-
50	*Maxomys whiteheadi*	-	-	+	-	-	-	-
51	*Niniventer cremoriventer*	-	-	-	-	-	+ (1962)	-
52	*Rattus argentiventer*	-	+	+	-	-	-	-
53	*Rattus exulans***	+	-	-	-	-	-	-
54	*Rattus tanezumi**	+	-	+	-	-	+ (1962)	-
55	*Rattus tiomanicus**	+	-	+	-	+	+	+
56	*Sundamys annandalei***	+	-	-	-	-	-	-
57	*Sundamys muelleri*	-	-	+	-	-	-	-
	Hystricidae							
58	*Atherurus macrourus*	-	-	-	-	-	+	-
	Total number of species	**13**	**7**	**25**	**4**	**14**	**41**	**3**

PPK—Pulau Perhentian Kecil (This Study) | PPKp—Pulau Perhentian Kecil past studies (Tamblyn et al. 2005; Campbell et al. 2004) | PPB—Pulau Perhentian Besar (Roslan et al. 2016; Rahim et al. 2016; Tamblyn et al. 2005; Turner et al. 2003) | PB—Pulau Bidong (Roslan et al. 2016) | PR—Pulau Redang (MNS 1990 as cited in Turner et al. 2003) | PTi—Pulau Tioman (Lim BL et al. 1999) | PTe—Pulau Tenggol (Sen 1971) | +—present | -—absent | EX—Extirpated | *—New record from this study in Pulau Perhentian Kecil | **—New record in the islands of East Coast Peninsular Malaysia.

comparison table.

On the other hand, *H. dyacorum*, *T. fulvida*, *T. malayana*, *R. exulans*, and *S. annandalei* are new species locality records for the East Coast islands. *H. dyacorum* is a more common species in Borneo compared in Peninsular Malaysia but has been recorded on the offshore island of Balambangan, Sabah (Benda 2010; Jayaraj et al. 2011). The nearest locality of this species in the mainland is at Gunung Stong, Kelantan (Lim et al. 2014). Both *T. fulvida* and *T. malayana* are associated with bamboo plants in which many of the localities where they have been found have bamboo plots including our study site in Pulau Perhentian Kecil (Medway & Marshall 1972; Norsham et al. 1999; Sapura 2010; Chooi et al. 2014; Nur

Shahidah 2014; Mohd-Hanif et al. 2015; Lim et al. 2016; Morni et al. 2016).

Furthermore, the Pacific Rat, *R. exulans* is the most prosperous island colonizers among rodents in which this species is ubiquitous in East Coast Peninsular Malaysia and East Malaysia. Due to its smaller size in comparison with other larger rodent species, this species would often opportunistically seek competition-free environments even at primary forests like in Royal Belum (Tamrin et al. 2010; Lim BL 2015). As for *S. annandalei*, its known distribution mainly restricted to West Coast Peninsular Malaysia, eastern Sumatra and Singapore. Although usually found in the mainland, *S. annandalei* can also be found in the islands of Padang and Rupat, Riau. Currently, it is still unclear on why *S. annandalei* has such a restrictive range compared to *Sundamys muelleri* which has an extensive range across southeastern Asia including on Sundaic islands as there are no evident ecological barriers for S. annandalei to expand its range (Pimsai et al. 2014; Camacho-Sanchez et al. 2017). Therefore, the capture of this species in Pulau Perhentian Kecil is quite surprising, possibly being the key to answer *Sundamys annandalei* ecological range puzzle. Further sampling in the future is needed to discern whether the two individuals captured in this study were stowaways or an established population of *S. annandalei* thrived on Pulau Perhentian Kecil.

Overall, Pulau Perhentian Besar has a higher number of species (12 for bats and 13 for small non-volant small mammals) compared to Pulau Perhentian Kecil (10 for bats and seven for small non-volant small mammals) probably due to its larger size enabling support of a broader range of niches (Kisel & Barraclough 2010). Despite this, human economic activity may influence the translocation of species, particularly non-volant small mammals across these two islands (Helmus et al. 2014). In comparison with other Malaysian east coast islands, Pulau Tioman amassed the highest number of mammal species at 41 which is not surprising, considering the island is also the largest (13,360ha) and has extensive flora and fauna surveys conducted since 1899 (Lim et al. 1999). While Pulau Redang is bigger than both Perhentian Islands combined at 1909ha, the lower number of mammal species recorded in this island is probably due to undersampling efforts, hence this island requires an updated mammal species checklist. The same goes to Pulau Bidong and Pulau Tenggol which has no published small mammal diversity records.

CONCLUSION

This short study managed to record 10 new species locality records of small mammals in Pulau Perhentian Kecil, with five are new records for Malaysian east coast islands indicating that there is much to research and document on island fauna particularly on mammalian species diversity in the future. Pulau Perhentian Kecil is not only rich in marine biodiversity but also plentiful in terrestrial wildlife for its small size. Therefore, it is paramount that this area is not only protected for its island flora and fauna but there is also a need to conduct sustainable tourism practices in order to preserve the beauty of these islands.

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Malay abstract: Pulau secara amnya, kaya dengan biodiversiti hidupan laut, tetapi juga menyembunyikan hidupan liar unik dan endemik di daratan. Maklumat berkaitan hidupan liar di pulau-pulau yang terdapat di Malaysia terutamanya pulau-pulau kecil masih kekurangan. Oleh itu, kajian telah dilaksanakan untuk membuat inventori kepelbagaian mamalia kecil (terbang & bukan terbang) di Pulau Perhentian Kecil. Pulau ini merupakan sebuah destinasi pelancongan yang terkenal dengan pelbagai jenis hidupan laut yang mengagumkan dan pantai berpasir yang indah. Meskipun pulau ini merupakan lokasi tumpuan pelancong, informasi yang diketahui mengenai kepelbagaian fauna di pulau ini amat terhad dibandingkan dengan jirannya yang lebih besar, Pulau Perhentian Besar. Survei yang telah dilaksanakan pada 21 hingga 30 Mei 2014 berjaya mencatat 56 individu haiwan merangkumi lapan spesies kelawar dan lima spesies mamalia kecil bukan terbang yang ditangkap dengan jaring burung, perangkap kelawar (*Harp trap*) dan perangkap sangkar tikus. Survei ini telah mencatatkan 10 rekod spesies tambahan bagi pulau ini berbanding laporan sebelum ini. Lima spesies daripada rekod tambahan ini belum pernah dijumpai di Pulau Perhentian Besar. Penemuan spesies *Hipposideros dyacorum*, *Tylonycteris fulvida*, *T. malayana*, *Rattus exulans* dan *Sundamys annandalei* di Pulau Perhentian Kecil juga merupakan rekod taburan baharu yang belum pernah di laporkan di mana-mana pulau di Pantai Timur Semenanjung Malaysia. Penemuan ini secara tidak langsung mengangkat kepentingan melindungi biodiversiti pulau yang penuh dengan keunikan. Diharap hasil kajian ini dapat digunakan dalam merancang pengurusan pelancongan di pulau ini untuk pembangunan secara lestari di samping menguruskan kawasan ekologi yang sensitif ini.

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Appendix 1. Data set - Bats

Field No.	Date	Genus	Species	State	Locality	Sex	Age	FA	E	TB	HF	T	TL	WT	Liver	Muscle	Small instestine	Notes
PP14-001	21/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site A	F	Adult	49.01	19.43	23.25	11.34	28.53	79.36	13.00	1	1	1	
PP14-002	21/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site A	F	Adult	55.74	18.01	23.74	11.00	28.64	94.70	16.00	1	1	1	
PP14-003	21/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site A	M	Adult	41.84	17.37	20.17	8.30	27.88	81.06	8.00	1	1	1	
PP14-005	22/05/14	*Eonycteris*	*spelaea*	Terengganu	Pulau Perhentian, Site A	M	Adult	67.93	20.48	31.26	14.55	11.36	116.36	44.00	1	1	1	
PP14-006	22/05/14	*Cynopterus*	*brachyotis*	Terengganu	Pulau Perhentian, Site A	F	Adult	57.91	18.41	21.29	13.05	10.47	90.47	20.00	1	1	1	
PP14-008	22/05/14	*Cynopterus*	*brachyotis*	Terengganu	Pulau Perhentian, Site A	M	Adult	59.70	18.03	22.47	13.69	8.97	88.97	22.00	1	1	1	
PP14-009	22/05/14	*Tylonyteris*	*pachypus*	Terengganu	Pulau Perhentian, Site A	F	Adult	25.22	10.15	11.52	4.95	27.00	92.00	5.00	1	1	1	
PP14-011	22/05/14	*Tylonyteris*	*robustula*	Terengganu	Pulau Perhentian, Site A	M	Adult	26.50	10.94	11.99	5.05	30.00	75.00	4.50	1	1	1	
PP14-019	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site A	F	Adult	44.00	19.00	19.00	8.00	28.00	78.00	6.00	1	1	1	
PP14-020	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site A	F	Adult	44.00	20.00	19.00	9.00	28.00	76.00	6.00	1	1	1	
PP14-021	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site A	M	Adult	43.00	20.00	18.00	8.00	30.00	81.00	6.00	1	1	1	
PP14-022	23/05/14	*Hipposideros*	*dyacorum*	Terengganu	Pulau Perhentian, Site B	F	Adult	45.00	19.00	17.00	8.00	21.00	72.00	6.00	1	1	1	
PP14-024	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	M	Adult	57.00	23.00	22.00	11.00	31.00	99.00	15.00	1	1	1	
PP14-025	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	M	Adult	53.00	23.00	26.00	11.00	24.00	88.00	12.00	1	1	1	
PP14-027	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	M	Adult	57.00	21.00	23.00	11.00	32.00	95.00	13.00	1	1	1	
PP14-028	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	M	Adult	57.00	21.00	22.00	11.00	32.00	96.00	15.00	1	1	1	
PP14-029	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	51.00	22.00	24.00	11.00	22.00	88.00	12.00	1	1	1	
PP14-030	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site B	M	Adult	44.00	20.00	19.00	9.00	27.00	80.00	7.00	1	1	1	
PP14-031	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	51.00	23.00	25.00	13.00	23.00	85.00	11.00	1	1	1	
PP14-032	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	M	Adult	51.00	22.00	24.00	12.00	22.00	85.00	12.00	1	1	1	
PP14-033	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.00	23.00	24.00	12.00	22.00	82.00	11.00	1	1	1	
PP14-034	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.00	23.00	24.00	13.00	22.00	85.00	10.00	1	1	1	
PP14-035	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.00	22.00	24.00	12.00	26.00	88.00	11.00	1	1	1	
PP14-037	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.00	22.00	24.00	12.00	22.00	82.00	10.00	1	1	1	
PP14-038	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.86	18.52	24.34	9.24	23.12	23.12	12.00	1	1	1	Released
PP14-039	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site B	F	Adult	44.82	15.87	21.16	8.29	31.87	31.87	7.50	1	1	1	Released
PP14-040	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	51.13	19.15	25.48	7.02	22.75	22.75	13.00	1	1	1	
PP14-041	23/05/14	*Rhinolophus*	*affinis*	Terengganu	Pulau Perhentian, Site B	F	Adult	50.42	20.85	23.29	11.30	23.09	23.09	12.50	1	1	1	
PP14-042	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site B	F	Adult	44.11	15.04	19.34	6.22	28.86	28.86	8.50	1	1	1	Released
PP14-043	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site B	M	Adult	43.81	14.42	18.58	6.46	26.89	26.89	7.00	1	1	1	

Field No.	Date	Genus	Species	State	Locality	Sex	Age	FA	E	TB	HF	T	TL	WT	Liver	Muscle	Small instestine	Notes
PP14-044	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	M	Adult	55.25	15.55	21.10	9.07	26.65	26.65	17.50	1	1	1	Released
PP14-045	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	M	Adult	56.99	15.16	25.63	8.03	28.11	28.11	16.00	1	1	1	Released
PP14-046	23/05/14	*Hipposideros*	*cineraceus*	Terengganu	Pulau Perhentian, Site B	M	Adult	43.88	15.77	19.89	7.11	29.15	29.15	8.50	1	1	1	Released
PP14-047	23/05/14	*Hipposideros*	*larvatus*	Terengganu	Pulau Perhentian, Site B	F	Adult	58.58	12.99	22.96	8.86	31.22	31.22	43.00	1	1	1	Released

E—Ear | FA—Forearm | HF— Hindfoot | TB—Tibia | T—Tail | TL—Total length (head to tail) | WT—Weight.

Appendix 2. Data set - Rodents and Scadentia

Field No.	Date	Genus	Species	State	Locality	Sex	Age	E	HF	HB	T	TL	WT	Liver	Muscle	Small intestine	Skin
PP14-004	22/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	M	Adult	17.00	45.00	180.00	189.00	369.00	150.00	1	1	1	1
PP14-007	22/05/14	*Rattus*	*rattus*	Terengganu	Pulau Perhentian, Site B	F	Adult	21.00	35.00	174.00	191.00	365.00	105.00	1	1	1	1
PP14-010	22/05/14	*Rattus*	*tiomanicus*	Terengganu	Pulau Perhentian, Site B	F	Adult	21.00	38.00	170.00	190.00	360.00	100.00	1	1	1	1
PP14-012	22/05/14	*Rattus*	*annandalei*	Terengganu	Pulau Perhentian, Site A	M	Adult	22.00	36.00	177.00	194.00	371.00	155.00	1	1	1	1
PP14-013	22/05/14	*Rattus*	*tiomanicus*	Terengganu	Pulau Perhentian, Site A	F	Adult	20.00	31.00	120.00	145.00	265.00	47.00	1	1	1	
PP14-014	22/05/14	*Rattus*	*rattus*	Terengganu	Pulau Perhentian, Site B	F	Adult	21.00	32.00	160.00	186.00	346.00	90.00	1	1	1	
PP14-015	22/05/14	*Rattus*	*tiomanicus*	Terengganu	Pulau Perhentian, Site B	F	Adult	20.00	33.00	155.00	181.00	336.00	85.00	1	1	1	
PP14-016	22/05/14	*Rattus*	*exulans*	Terengganu	Pulau Perhentian, Site A	M	Adult	19.00	32.00	125.00	139.00	264.00	44.00	1	1	1	
PP14-017	22/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	M	Adult	16.00	46.00	189.00	145.00	334.00	135.00	1	1	1	
PP14-018	22/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site A	M	Adult	21.00	47.00	179.00	190.00	369.00	150.00	1	1	1	
PP14-023	23/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	F	Adult	17.00	45.00	186.00	167.00	353.00	170.00	1	1	1	
PP14-026	23/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	M	Adult	11.00	44.00	185.00	187.00	372.00	135.00	1	1	1	
PP14-048	23/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	F	Adult	16.00	45.00	177.00	197.00	374.00	125.00	1	1	1	
PP14-049	23/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	M	Adult	17.00	48.00	184.00	203.00	387.00	135.00	1	1	1	
PP14-050	23/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	F	Adult	18.00	48.00	193.00	191.00	384.00	180.00	1	1	1	
PP14-051	24/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site B	M	Adult	15.00	47.00	193.00	163.00	356.00	140.00	1	1	1	
PP14-052	25/05/14	*Rattus*	*tiomanicus*	Terengganu	Pulau Perhentian, Site A	M	Adult	21.00	36.00	164.00	187.00	351.00	125.00	1	1	1	
PP14-053	26/05/14	*Rattus*	*rattus*	Terengganu	Pulau Perhentian, Site A	F	Adult	22.50	37.00	184.00	213.00	397.00	145.00	1	1	1	
PP14-054	27/05/14	*Rattus*	*annandalei*	Terengganu	Pulau Perhentian, Site A	M	Adult	23.00	37.00	190.00	202.00	392.00	145.00	1	1	1	
PP14-055	28/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site A	F	Adult	16.00	46.00	178.00	190.00	368.00	120.00	1	1	1	
PP14-056	29/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site A	F	Adult	16.00	46.00	195.00	180.00	375.00	125.00	1	1	1	
PP14-057	30/05/14	*Tupaia*	*glis*	Terengganu	Pulau Perhentian, Site A	F	Adult	17.00	47.00	193.00	220.00	413.00	185.00	1	1	1	

E—Ear | HF— Hindfoot | HB— Head to Body | T—Tail | TL—Total length (head to tail) | WT—Weight.

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COMMUNICATION

Patterns, perceptions, and spatial distribution of human-elephant (*Elephas maximus*) incidents in Nepal

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Abstract: Nepal has an estimated population of 109 to 142 wild Asian Elephants *Elephas maximus* L.. We carried out a survey of human-elephant incidents (HEI) of conflict in the buffer zones of Chitwan National Park and Parsa National Park Nepal, using a structured questionnaire, focal interviews, and secondary data collection. Furthermore, data of HEI were also extracted from published literature in order to analyse spatial-temporal patterns of competition throughout Nepal. Elephant related incidents were higher in the pre-winter season and concentrated along the southern forest boundary; incidents decreased with increasing distance from the park/reserve. Crop damage by elephants occurred in pre-monsoon and winter seasons with the most impact on rice (the major crop). Bulls (single or in pairs) were involved in crop raids (44%), property damage (48%), and human casualties (8%); family herds were only recorded to have raided crops (39%) and damaged properties (36%). The average herd size recorded was 10 individuals, with a maximum group size of ≤22 elephants. Generally, incidents per elephant was high in western Nepal, whereas human and elephant casualties were higher in central and eastern regions. To reduce human–elephant incidents 53% of local residents suggested restoring core and boundary areas with native elephant food plants, 40% suggested planting alternative crops along park boundaries, 6% favoured elephant translocation, and only 1% percent was in favour of culling elephants. Mitigation measures already in place include wooden watch towers used by villagers to detect elephant incursions. Low impact traditional averting techniques, such as drumming and the use of flame torches, were used to deter intruding elephants at the areas surveyed. In conclusion we suggest potential mitigation measures such as identifying elephant refugia and mitigate the impact and assessing the year-round availability of preferred foods; in addition, we advocate for introducing an equitable compensation to gain support from local communities adjacent to protected areas.

Keywords: Asian Elephant, human-wildlife incidents, endangered species, conservation, questionnaire, stakeholder solutions.

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Author contributions: RKK and WJ designed the study; RKK collected the data; RKK, DR, YT and WJ analyzed the data. RKK wrote the manuscript, and all authors contributed to the editing of final version of the paper. All authors read and approved the final manuscript.

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INTRODUCTION

The Asian Elephant *Elephas maximus* is among the largest living land mammals and is 'Endangered' according to IUCN Red List (Williams et al. 2020). Global estimated population of Asian Elephants is 41,410–52,345 in the wild and 16,000 in captivity, distributed across 13 Asian countries (Sukumar 2003; Choudhury et al. 2008). Elephant populations in most of their natural ranges have been declining with the increase in human populations and land development causing erosion and degradation of forest habitats (Choudhury et al. 2008). Such habitat degradation in the form of deforestation, increases the frequency of incidents with Asian Elephants (Riddle et al. 2010; Puyravaud et al. 2019), which is hindering conservation efforts in some regions (Hoare 1999; Perera 2009). Thus, averting habitat destruction and fragmentation is probably most important in reducing problems with elephants (Hoare 2000; Sukumar 1989, 2006; Puyravaud et al. 2019).

Nepal provides habitat for an estimated 120–215 Asian Elephants (Pradhan et al. 2011; Koirala et al. 2016). The recent loss of over 80% of elephant habitat to human settlement (Joshi & Singh 2007), however, has eroded the carrying capacity. In the past, elephants were distributed throughout the Terai forests (Pradhan & Wegge 2007). These forests, which spanned Nepal from east to west, have now been reduced to 24% of their original size of 593,000ha (Satyal 2004). The country's elephant population is now limited to only four areas due to vast anthropogenic pressure and dwindling resources (Pradhan et al. 2011). Human activities, which encroach on elephant habitat, also force elephants into direct contact with humans, which results in adverse incidents (Hoare 1999; Sukumar 2006).

The spatial and temporal nature of incidents varies within Nepal (Koirala et al. 2016). In central Nepal, the elephant population is mostly resident. Incidents arising from crop raids were first recorded in the Parsa Chitwan area in 1994, when a single bull elephant moved into cultivated agricultural lands (Velde 1997). Incidents have increased substantially since then, which poses a serious threat to local people as well as to resident elephant populations (Pant & Hockings 2013). In Nepal alone, 66 people and 18 elephants have died as a result, over a period of 16 years, from 1986 to 2002 (Yadav 2007). In central Nepal, nine people were killed over a period of five years, from 2008–2012 (Chitwan National Park 2012).

Incidents caused by elephants is the main conservation issue throughout the elephant's home range (Hoare 1999). The nature and extent of damage caused by these animals to humans and vice versa is not clear. In the present study, we examine multiple aspects of human-elephant incidents in Nepal mostly focussing on central Nepal. To the best of our knowledge, one study has identified the spatiotemporal distribution of human–elephant incidents (HEI) at a national level in Nepal through an indirect measure: by way of newspaper articles (Neupane et al. 2013). The present study, however, has quantified the spatio-temporal pattern and perception of elephant problems by residents using a questionnaire surveys and secondary data. We consider data reliability for the former study to be greater for the reporting of human casualties, and elephant deaths, while our study aimed to generate reliable data on all types of human-elephant incidents including peoples' perception on human-elephant coexistence. Thus, the aim of this study was, therefore, to assess the magnitude and nature of the human-elephant incidents and to obtain the opinions and perceptions of local people on mitigating elephant impacts and on enhancing elephant conservation. To explore these topics, research questions were asked in relation to type, frequency, and trends in elephant visitations and damages, with an overall goal of finding local solutions to minimise competition with humans.

In addition, for the purposes of comparison, we explored spatial and temporal distribution patterns and the driving forces of human-elephant incidents in other regions in Nepal.

MATERIALS AND METHODS

Data were collected between July 2012 and December 2014 in villages distributed throughout the northern and southern buffer zones of the Chitwan and Parsa National Park (Fig. 1).

Information on human-elephant incidents was collected through a structured questionnaire designed to document the personal details of the respondent, their occupation, agricultural practices if any, problems encountered with elephants, major forms of damage sustained from elephant visitations (Appendix 1). The details of the spatio-temporal nature and extent of crop and property damage and human and elephant casualties, alsthe timing and frequency of damage, major crops and also plant parts eaten, and locals' mitigation methods were requested.

In total, we surveyed 302 households, focussing more on villages near park boundaries. Every fifth household

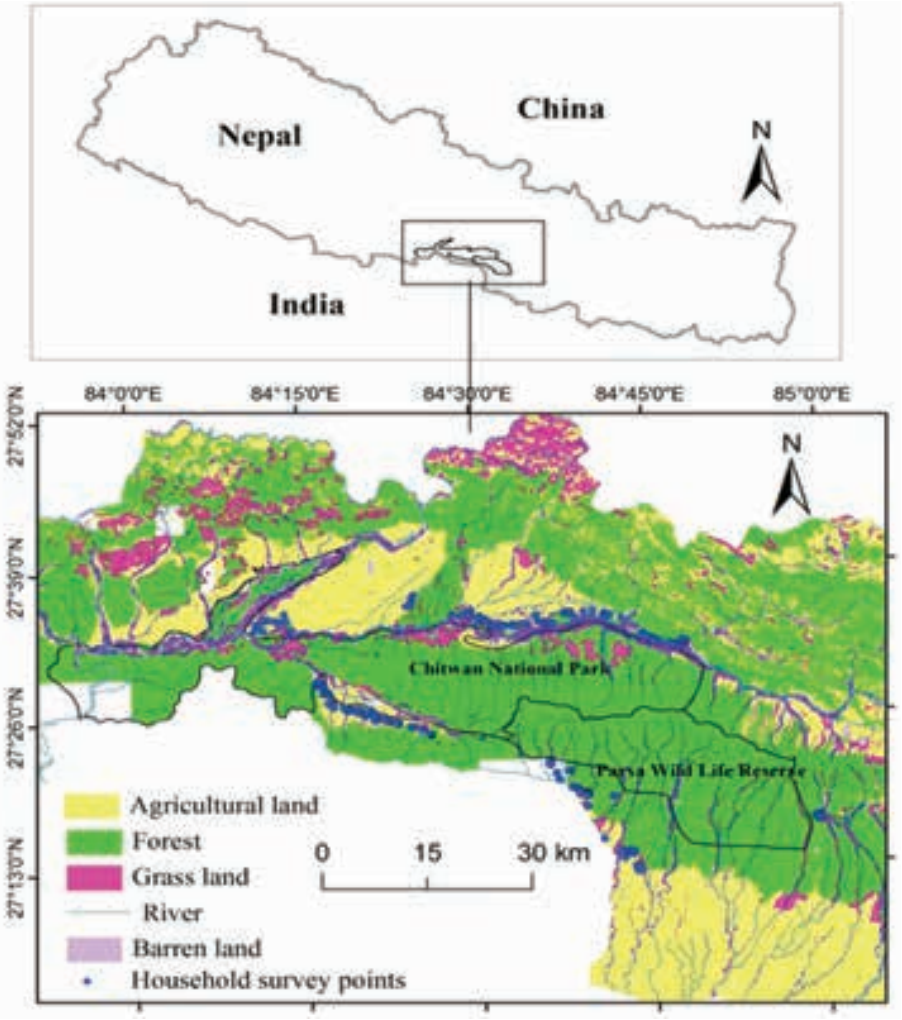

Figure 1. Study area: blue circles are the spatial position of the households surveyed in the buffer zones of Chitwan and Parsa national parks. Parsa National Park was established as a wildlife reserve in 1984. Since 2017, it has had the status of a National Park.

within each village was selected, and interviews were conducted with the head of the household. If the head of the household was not present, the most senior member of the family was chosen for interview. If no one was at home, the next house was selected for interview. Verbal consent of the respondent was obtained before conducting the interview (Pant & Hockings 2013), and none of the respondents declined to participate in the survey. All information received was treated as approximate, since it was based on respondents' estimates and recollections (Kulkarni et al. 2010). Altogether, 75 villages under the auspices of 17 village development committees (VDC) were surveyed within four districts (Chitwan, Parsa, Makwanpur, and Bara). VDCs were local government bodies in rural Nepal, equivalent to municipalities in urban areas till 2016. The Gaunpalika system was established in 2017, replacing the VDC system that was in use since 1990. The geographical coordinates of the households where interviews were conducted were obtained by marking their location using a Garmin eTrex Venture global positioning system (GPS) unit.

Kangwana (1995) has cautioned that conclusions cannot be drawn based entirely on farmers' and householders' replies to a questionnaire. To validate the household survey records, secondary interviews information was collected from existing record of incidents in the park and buffer zone office and focal interview were conducted with key informants from community and park and buffer zone committee officials. Their experience and knowledge of existing elephant populations, HEI causes, measures taken and potential solution to the problem were recorded.

Furthermore, data of HEI were also extracted from published literature in order to analyse spatio-temporal patterns of competition throughout Nepal. Among four elephant distribution areas, the eastern region was covered by forest remnants and only 175km^2 was under protection. Edge habitat covered 12,892ha (Nepal WWF 2007) while in central Nepal intact forest

under protection totalled 3,549km^2 with 28,500ha edge habitat in the Chitwan National Park buffer zone (Baidya et al. 2009). While in western region covering Bankey and Bardia National Parks, patchy forest remnants were distributed in the south and south-western part of the parks. A total area of 1,437km^2 was under protection at the time of our study. Forest edge habitat totalled 12,979ha. The far western area in Shuklaphanta Wildlife Reserve supported a 305km^2 area of intact, fully protected forest. Forest edge habitat covered 33,554ha, the largest forested edge habitat in Nepal (Nepal WWF 2007).

Data analysis

We examined data over a 10-year period (2003–2012). Relative incident intensity among villages was calculated by the relative frequency of different categories of incidents (crop depredation, property damage, human casualty, and elephant casualty). The intensity of 3 was the lowest and 1 was the highest intensity with a combination of different types of incidents.

The per capita elephant damage rate calculated using the equation below and used as an index of incident intensity (II).

$$\text{Incident intensity (II)} = \frac{\text{Frequency of incidents/year}}{\text{Total number of elephants}}$$

GPS location data of HEI were used to prepare a detailed map in ArcGIS version 10.1. Chi-square test was used to assess trends in elephant damages, the respondents' attitudes towards elephant caused damage and the local perceptions on elephant conservation. Pearson correlation tests were conducted to determine the relationship between the number of crop raiding/property damage incidents and human casualties and the spatio-temporal relationships between elephant damage and the spatial location of villages. The IBM statistical package for social sciences (SPSS) version 22 was used to analyse data.

RESULTS

Respondents and their major incident experiences

Of 302 respondents, 258 (85%) were males and 44 (14.6%) were females. A total of 170 (56%) interviewees resided in the buffer zone of Chitwan National Park, and 132 (44%) were within the buffer zone of the Parsa Wildlife Reserve. The mean age of respondents was 45 years (n= 302 ± SD= 10) and ranged from 21–73 years. Interviewees were distributed unevenly between the 17 village development zones: representation by zone ranged from a low of 1.7% in the Bhandara area in Chitwan to a high of 12.6% in the Nirmal Basti village development committee in the Parsa buffer zone.

Respondents reported crop raids to be the most common form of elephant damage, comprising 77% of total HEI, followed by property damage (22%) and human casualties (1%) (Fig. 2). Nearly half (45%) of the respondents indicated that property damage had increased in the last 10 years, 46% of interviewees had not noticed any changes in HEI trends, 8% had observed a decrease in incidents and 3% of respondents did not answer the question. Similarly, 72% of respondents noted increased crop raids, 21% did not notice any change and 6% indicated a decreasing trend.

A minority of respondents (22%) indicated an increase in human casualties, 60% did not notice any change, and 10% indicated a decreasing trend. More than 80% of respondent could not provide information about elephant mortality in relation to HEI, and only 10% indicated a decreasing trend in elephant casualties (Fig. 3). Most of the respondents (72%) reported an increasing trend in crop raids over the past years. In summary, local perceptions indicated a more significant increase in crop raids than in other types of damage (χ^2= 95.0, df= 3, P= <0.001).

Crop type, damage incidence, and seasonal changes

Rice was the most common crop grown by 99% of the interviewed households, followed by maize (79%) and wheat (43%). More than half (55%) of the households, located predominantly to the south of the reserves, produced one crop of rice per year, while 45% of the households, situated mainly to the north of the reserves, produced two crops a year. Only one crop of wheat and maize were grown per annum throughout the buffer zones of both reserves.

Just over half of the respondents (51%) indicated that elephants raided rice, over more than a quarter of the respondents (34%) had witnessed elephants raiding maize regularly, and 15% of respondents reported that wheat was a regular food choice for raiding elephants. Most of the respondents reported that the crop damage by elephants occurred in the pre-monsoon and pre-winter seasons.

Forty-four percent of reports of HEI involving single bulls or two bull elephants were of crop raids, 48% were of property damage and 8% were human casualties. Family herds were found to raid crops (38%) and damage property (36%), but there were no records of a human casualty caused by a family herd (25%).

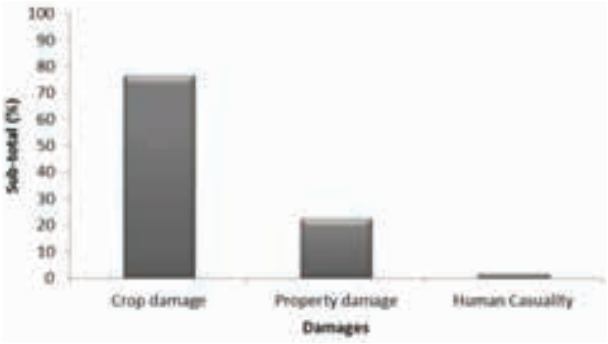

Figure 2. Respondents' view on the trend of damage by types of HEI in the buffer zones of Chitwan National Park and Parsa Wildlife Reserve.

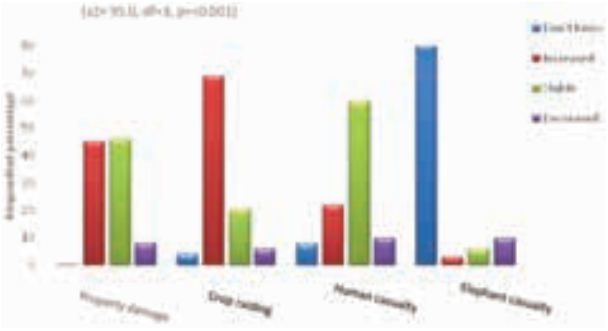

Figure 3. Distribution of respondents' views on the trend of human-elephant incidents from 2004 to 2014.

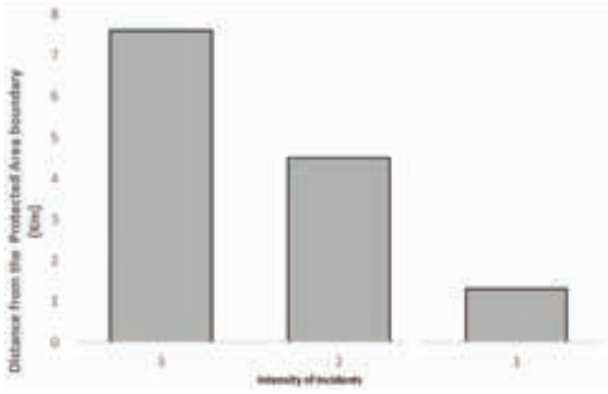

Figure 4. Incident intensity with increasing distance from the periphery of the parks.

There was significant correlation between the number of crop raiding/property damage incidents and human casualties (r^2= 0.8, P= <0.01). There was a significant difference in the number of incidences of HEI relative to the time of day, with almost 95% of all incidences occurring during the night (18.00–02.00 h) (χ^2= 108.30, df= 3, P= <0.001).

Plant parts preferred by elephants

Altogether 23% of interviewees described rice grain with husks as the food most targeted by Asian elephants, followed by whole rice plants without roots with 13% (χ^2= 181.79, df= 2, p= <0.001). Twenty-eight percent of the interviewees reported maize grain with husks as likely to be selected by crop-raiding elephants (χ^2= 274.89, df= 2, p= <0.001). Eight percent of the respondents reported that whole wheat plants without roots were also favoured, and 7% described wheat grain with husks was also part of the raiding elephants' diet while 21% of the respondents could not answer on preference for any of the foods.

Incidents distribution by village

Overall, 55% of incidents were centred in southern and southwestern parts of the park buffer zones. Over half of the incidents (56%) occurred in the Chitwan National Park buffer zone, and 44% occurred in the Parsa Wildlife Reserve buffer zone. Ayodhyapuri Village in Chitwan reflected the highest frequency of incidents (12%), followed by Gardi Village (11%). In the Parsa Wildlife Reserve buffer zone, Manahari Village suffered the highest frequency of incidents (9.78%), followed by Nirmal Basti (8.0%). There was significant negative correlation between the distance of a village from park boundaries and the Incidences (r= –0.42, P= 0.02) (Fig. 4).

Regional trends

In the easternmost region, incidents per elephant was 1.74 (Fig. 5), and the number of human and elephant casualties was with 5.75 per annum (4.45 human casualties and 1.3 and elephant casualties). Human and elephant casualties were high across all four known elephant distribution areas, however, the intensity of casualty per elephant was only 0.06 as the number of elephants in this region was the highest (around 100 individuals) within the four elephant distribution regions in Nepal (Pradhan et al. 2011) (Fig. 5) at the time of this study.

In central Nepal (the Chitwan and Parsa areas, Fig. 5), intensity of incidents was 1.53. The casualty per elephant (0.17) was highest in this region (Fig. 5). The elephant population was estimated at 25–30 individuals (DNPWC 2009; Pradhan et al. 2011) and they are mostly residents.

Incident intensity excluding casualties was highest in Bardia and Banke National Parks in western Nepal (3.08), however, the rate of human and elephant casualties per elephant was the lowest among all regions of the

country (0.04) (Fig. 5). The population was estimated to be around 80 individuals in Bardia National Park only (Pradhan et al. 2011).

In the far western region (Shuklaphanta National Park and surrounding areas), the Asian Elephant population was low at the time we conducted the research, with approximately 10 mixed migratory and resident individuals (Velde 1997; Pradhan et al. 2011). Incident intensity per capita (i.e., per elephant) was the lowest (0.19) among all the regions. Human casualties were low at the time of the present study.

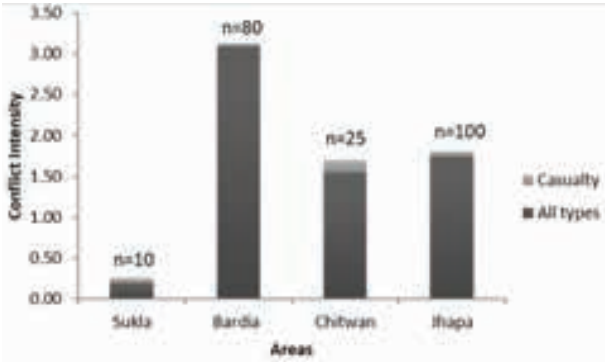

Figure 5. Spatial distribution of elephant population represented by numbers with the intensity of all types of damage represented by black bars and the intensity of human and elephant casualty represented by grey bars.

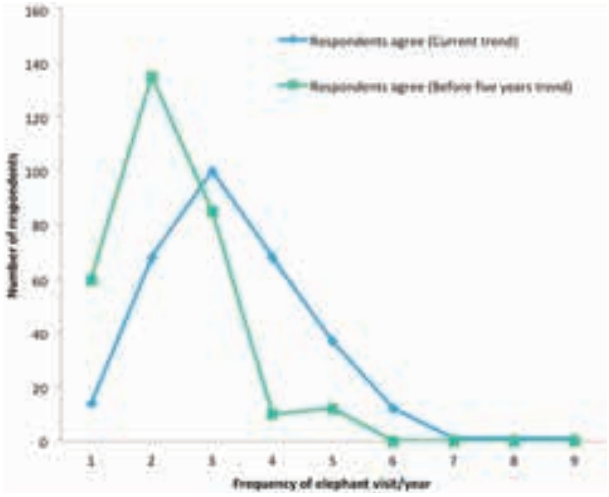

Figure 6. Frequency of elephant visitation over time.

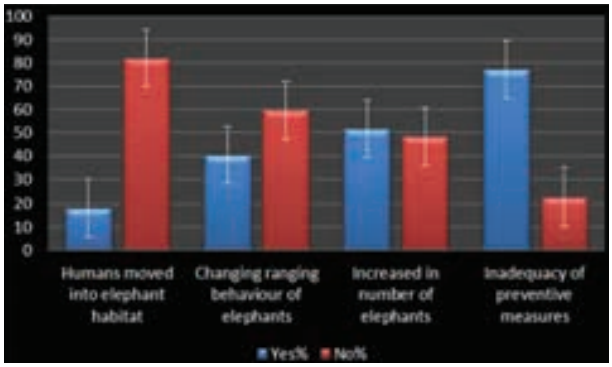

Figure 7. Responses to the questions on the prime cause for the increased human-elephant incidents.

Minimising incidents

Of the questionnaire respondents, 46% of questionnaire respondents reported a decrease in elephant abundance over the past 10 years, while just under half (53%) of the participants reported an increase. Half of respondents were of the view that the frequency of elephant visitations had been steady before five years, ranging from one to three visits per year. However, 47% of respondents thought that the frequency had increased from only one to three to six visits per annum over the most recent 5-year period, while 3% of respondents did not answer this question (Fig. 6).

When asked which of the given determinants they think is the prime cause for the increased human-elephant incidents in this region, many village residents (78%) identified the ineffective and inadequate elephant deterrents such as trenches and electric fences as one of the causes of increased HEI in the Chitwan-Parsa region. Half (50%) of the residents interviewed believed that a higher number of elephants was the major cause of increased problems (Fig. 7). The responses were analyzed by categorized favour and disfavour proportions using z test of proportion. Parametric large sample z tests showed that there were statistically significant differences between favour and disfavour proportions on 'human moved into elephant habitat' ($z = -14.5$, $p < 0.01$), 'changing ranging behavior of elephants' ($z = -3.6$, $p < 0.01$) and 'inadequacy of preventive measures' ($z = 11.17$, $p < 0.01$) but responents perceived the statistically equal proportion of favor and disfavour proportions on increase in the number of elephants ($z = 0.35$, $p > 0.1$). Overall, more respondents disfavoured responses on the 'human moved into elephant habitat' and 'changing ranging behavior of elephants', but they perceived the more favour on inadequacy of preventive measures.

The proximity of agricultural lands to forest fringes allowing easier access to elephants was regarded by 50% of respondents as being the primary reason for elephants moving into human-occupied areas. A total of 45% of respondents believed that depletion of natural wild foods in the forests resulted in elephants moving

into human habitats. An additional 5% of respondents believed that human disturbance of elephant habitats was the cause of elephants visiting villages in search of foods (χ^2= 244, df= 13, p= <0.001)

Many of the respondents thought that food supply should be a key focus in conflict mitigation: over half (53%) felt that the regeneration of natural food plants in the forests would help reduce the frequency of elephant visitations to cropped fields, and 40% were in favour of growing alternative crops and pursuing other livelihoods. Six percent of respondents favoured translocation of problematic elephants to remote areas and 1% of participants suggested culling repeat offenders.

In response to questions about how elephants could be protected, 59% of the respondents were in favour of habitat management inside parks, 33% supported raising people's awareness about elephant conservation and 32% suggested strong legal protection. A clear majority of local respondents (87%) were positive about coexisting with elephants. Responses about how human-elephant coexistence could be sustained in the region included a 74% majority who favored a compensation program to replace income lost to elephant damage. Over half of the participants (56%) suggested electric fences as a way to reduce HEI and to enhance peaceful coexistence.

DISCUSSION

Our data showed that the scale of human-elephant interactions differ according to the type of incident. Crop damage was the most common type of incident. Of the most heavily cultivated crops, rice was the most frequently raided. Crop raiding by elephants is a major issue in many parts of Asia and is caused by many factors, including elephant migration patterns, shifting water resources, habitat depletion and seasonally dependent nutritional requirements (Sukumar 1990). In our study area, rice was cultivated twice per annum, and was the crop of choice for local farmers. The primary reason for elephants' preference for rice could be related to the proximity of rice fields to their seasonal migration routes (Neupane et al. 2017). In addition, our study has shown that the spatial distribution of crop-raiding activity was not uniform in either buffer zones of Chitwan or Parsa. Documented crop raids were mostly concentrated in the southern buffer zone regions of the park areas, especially in areas where cultivated crops were closer to park boundaries (Fig. 1). Therefore, proximity plays a vital role in crop-raiding activity.

Elephant raids of rice during the grain producing season (pre-winter) occurred more frequently than raiding of other crop types. This may be due to nutritional drivers. Our unpublished data shows higher protein content in the grains of cereal crops compared to wild grass species.

Elephants' preferences for certain grain crops can be explored further by identifying repeat raiders. Most crop raids were by a single adolescent or a few bull elephants identified by local villagers as repeat visitors that returned multiple times over a period of several years. This repeat crop-raiding behaviour could be correlated with adult bulls having higher nutritional requirements than other elephants because of their size and the high-energy behaviours associated with the male drive for reproductive success (Sukumar & Gadgil 1988).

Our study also found that family herds ventured into agricultural fields and caused damage. This group behaviour could be predicted based on changed migration patterns and home ranges (Pamo & Tchamba 2001), as some of them have been found to visit new areas (Piple and Manahari VDC) in the northern parts of the Parsa Wildlife Reserve and Chitwan National Park where there had been no record of visitation by family herds in the past. The changing behaviour of elephants could be triggered by resource constraint in the area. The exploration of new areas is likely to be due to habitat shrinkage, water depletion and the increasing proximity of rice fields are consistent with elephant habitats. Such behaviour change cannot be denied as there has been a recent report by Srinivasaiah et al. (2019) that young male elephants in India, which are typically solitary, are now forming large male herds to protect themselves from human retaliation. Our results showed that elephant visitations have substantially increased in some areas during the last five years, especially in the non-traditional migration regions.

The spatial distribution of village households and their agricultural lands also played a crucial role in influencing HEI. Households in the forest fringe within <5km of the periphery of national parks/reserves were more frequently affected than more distant villages. This was irrespective of their crop's stage of growth, what type of crop was cultivated or what type of property villagers held. A similar trend has been reported by Sukumar (1990) in southern India and by Pant & Hockings (2013) in Nepal.

Interviewees' perceptions of elephant conservation were found to be unanimously positive in this study. People viewed natural food sources and habitat restoration as the main areas to be addressed to achieve conservation goals and to mitigate incidents.

Existing mitigation measures such as electric fences and traditional herding techniques were seen to be least effective. The cultivation of elephant deterrent plants in villages in the forest fringe was deemed not to be practical by surveyed residents, as alternative income streams would be needed to replace the loss of income from crops displaced by non-edible deterrent flora. Villagers suggested that night patrols during peak crop-raiding times might not be feasible because of a lack of resources.

The spatial and temporal nature of incidents and incidence intensity varied with region countrywide (Koirala et al. 2016). Our results indicated that eastern and western regions were incident hotspots, while medium and lower incidence intensities were typical in central and far western regions, respectively. The eastern region, which extends from Jhapa District in the far east through to Udaipur District in the far western portion of the eastern-most quarter of the Asian Elephant's home range, was a critical conflict area. The elephant population was as large as 100–115 individuals, mostly migratory (DNPWC 2009; Pradhan et al. 2011). In addition, incidence was high in this region in terms of elephant and human casualties, but the intensity of damage per elephant was less than in other regions because this region contained a higher number of migratory elephants. The higher number of casualties was attributed to the smaller area of forest-edge habitat (Nepal WWF 2007). There was also a higher probability of raids occurring whereever there was a longer perimeter of cultivated habitat (Sukumar 1990). People in this area grew a variety of crops. Some of these were high-profit cash crops, and frequent elephant raids of such valuable crops may have been intolerable to residents. As a result, retaliatory killings of elephants and human casualties had occurred. In contrast, in the western region (Bardia and Banke areas), the Asian Elephant population was estimated at ≤80 individuals at the time of study, most of them migratory, with few permanent residents. Where elephants were fewer in number, human casualties were less.

It was expected that this study would yield a detailed account of crop and property damage caused by elephants in Nepal. Because the study period was short (just over two years), comparing long-term trends was not possible. We expected that we would find that different deterrents were used by locals in different regions, and that evaluations of their effectiveness would lead to recommendations for novel damage mitigation measures. We further expected to obtain information about other mitigation measures from the literature and from other parts of Nepal with similar HEI problems.

In addition, another of our goals was to understand local people's perception and attitudes towards the conservation of elephants, in order to shed light on the scale of the problem and what measures would be appropriate to introduce to reduce incidence in the future. Furthermore, information on the historic distribution and threat status of Asian Elephants in Nepal would allow us to draw conclusions on how the situation has changed over the past 10 years, and which factors have contributed significantly to the current situation. Overall, results from this study were expected to provide some basis for planners and conservationists to design innovative approaches to reducing HEI in Nepal, because the dearth of information available, makes conservation of the species extremely difficult.

In summary, our study suggests that in central Nepal, the Asian Elephant population is increasing, and animals are mostly resident, and the intensity of casualties was highest compared to other elephant populations of the country. Crop raids by elephants were the primary cause of HEI. A combination of factors, including the depletion of natural food in the forests, the higher nutritional content of crops and the proximity of rice fields to elephant movement routes appeared to trigger crop raids, and HEI.

Based on our results, we have identified factors that need to be assessed further to realise Asian Elephant conservation outcomes and peaceful coexistence with humans. We recommend the following measures in the form of an integrated approach to minimise incidence and to conserve these endangered animals and their habitat for promotion of peaceful coexistence.

1. Identify elephant refugia and migration routes and assess the year-round availability and nutritional content of preferred food plants in and around those areas.

2. Extension of effective electric fences in all major agricultural areas of the buffer zones and consideration of digging elephant deterrent trenches along remote park boundaries.

3. Introduce fair and workable compensation schemes to address losses suffered from crop and property damage and to gain support from local communities.

4. Restore degraded lands with a full suite of food species preferred by elephants (Dharmaratne & Magedaragamage 2014) including bamboo, banana, and other palatable plants.

Note: The most widely used term 'conflict' was minimized and replaced with term 'incident', 'competition', and 'coexistence' (Davidar 2018).

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Appendix 1. Survey questionnaire to assess human-elephant interaction, focusing on crop raiding pattern in Persa-Chitwan region, Nepal.

- Date:
- Questionnaire Number:
- Interviewer Name:

Part One: Basic Information about the Interviewee:

1. Name----------; Age----; Sex; Male ☐ Female ☐
2. VDC/Municipality----------Ward No-------- Village Name----------
3. GPS Location: (Way point)-----

Part Two: Human Elephant conflict:

4. Since how long ago have you been living in this village? ..... years

5. Have you or your family member experienced conflict with elephant over the last ten years:
   a) Yes b) No
6. If yes you have experienced conflict, what type of conflict was it?
   1) Property damage; 2) Crop raiding; 3) Human casualty 4) Human injury 5) successfully chased without any damage.
7. Did you or your fellow villagers injure or kill any wild elephants that attacked the villagers and raided crops?
   a) Injured b) Killed c) No

8. Of the problems 1-5 above caused by wild elephants, what are the most serious problems experienced by your village (in order of frequency and severity)?

9. Do you have crop fields? a) Yes, b) No
   If Yes-- What are the different crops/ vegetables and fruits you grow?
   Paddy, Wheat, Maize, Mustard, millet, Sugarcane, Banana --- others (tick or write)

10. What is the extent of different crops cultivated?

11. Which months you cultivate these crops?

12. Which crops were perceived by the respondents to be the most raided (in order)?
    Paddy, Wheat, Maize, Mustard, millet, Sugarcane, Banana --- others (tick or write)

13. Parts Eaten/ Trampling:
    a) Whole plant b) Whole plant without root, c) Only grain with husk d) Leaves e) stem
    Parts eaten: Paddy, ... Wheat,..... Maize, ... Mustard,..... Millet,.....Sugarcane ..... Banana..... others....
    Parts Trampled: Paddy, ... Wheat,..... Maize, ... Mustard,..... Millet,.....Sugarcane ..... Banana..... others....

14. Which growth stage?
    a) Vegetative b) reproductive c) Heading d) Maturity

Growth Stage: Paddy, ... Wheat,..... Maize, ... Mustard,..... millet,.....Sugarcane,..... Banana,.....Others.....

15. Which months of the year elephant damages occur?

a. Property damage b. Crop Raiding c. Human/ Elephant casualty.

16. What is the frequency of elephant visit and crop raiding?

17. What is the time of the day the damage by elephants most likely occurred (early morning 2 am to 6 am; morning 6 am to 10 am; day 10 am to 2 pm; afternoon 2 pm to 6 pm; evening 6 pm to 10 pm; night 10 pm to 2 am)?

18. What is the trend of elephant damage over the last ten years?

I. Property damage (Mark)
   a. Increased (.....)
   b. Steady (.....)
   c. Decreased (.....)

II. Crop raiding (Mark one)
   a. Increased (.....)
   b. Steady (.....)
   c. Decreased (.....)

III. Human casualty (Mark one)
   a. Increased (.....)
   b. Steady (.....)
   c. Decreased (.....)

IV. Elephant casualty (Mark one)

   a. Increased (.....)
   b. Steady (.....)
   c. Decreased (---)

Part three: Causes of conflict

19. What are the major causes of human-elephant conflict? (In order of priority)

a. b. C.

20 Why do you think elephant move to human habitation (Circle one or more)?

a. In search of better nutritive forage
b. Easy access to agriculture field near elephant habitat
c. Depletion of natural food plants in the forests
d. Problem elephant
e. Traditional elephant range
f. Others (describe)----------

21. Which of the following do you think is the prime cause for the increased human-elephant conflict in this region (Circle one or more)?

a. Increase in number of elephants
b. Changing ranging behaviour
c. Human moved into elephant habitat
d. Inadequate preventive measures
e. Others (describe)----------

22. What is the composition of the raiding group (Single male or Family herd) caused the most damage? (Rank 1-high damage, 2-medium damage, 3- lesser damage)

Single Male	Family herd
a. Property damage: ……..a	Property damage: ……
b. Crop raiding: ……	b. Crop raiding: ……
c. Human casualty: ……	.c. Human casualty:----------
d. Human Injury ----------	d. Human injury----------

23. How do you know?

a. I've seen them;

b. Household member has seen them;

c. Have seen tracks;

d. Have seen feeding sign,

e. Have seen elephant dung;

f. Have heard elephant sound.

g. Have seen elephant damaged property;

h. Have seen other signs.

24. Do elephants move to your area from a specific route or from different routes?

25. Can you show the elephant use area to the interviewer on a map or through participatory mapping? (Record the locations through GPS and mark in the map)

Part four: Peoples Attitude towards elephant conservation:

26. What do you think is the relative abundance of Elephants in your area?

a) Today: rare----- ( ) fairly common----- ( ) abundant ( ) (Tick one)

b) 10 years ago: rare---- ( ) fairly common------ ( ) abundant ( ) (Tick one)

27. Do you think elephants should be protected?

Yes ------- No

If Yes, How?

28. What should be done to minimize conflict between people and elephant in this area?

a. Translocation of problem elephant

b. Culling

c. Shift to alternative crop and livelihood option.

d. Help regenerate natural food plants in the forests

29. Do you want human-elephant coexistence in this area? a). Yes b). No

30. If yes how?

a. b. c.

b.

31. If no what should be done?

a. Culling of elephants

b. Relocate elephants

c. Relocate affected villages.

d. Others

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COMMUNICATION

Assessing spatio-temporal patterns of human-leopard interactions based on media reports in northwestern India

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Abstract: Large carnivores in human-use areas make for sensational print media content. We used media reports to examine human-leopard interactions in Rajasthan, India. We extracted news reports on leopard-related incidents from January 2016 to December 2018. Incidents (n= 338) were categorized, mapped, and analysed to understand their nature and extent. We found leopard-related news from 26 of 33 districts; a majority of these were in the eastern region of the State. Most of the reported interactions appeared to be non-negative, despite losses to both leopards and people. Our results provide a synthesis of spatio-temporal patterns of leopard-related incidents, which could help wildlife managers in better addressing negative interactions. The study also demonstrates how news reports could be useful for examining human-wildlife interactions across large spatial scales.

Keywords: Carnivores, conflict, conservation, human-wildlife interactions, management, Rajasthan.

Hindi: बड़े मांसाहारी जानवर जो मानव-बहुल क्षेत्रों में रहते हैं, आमतौर पर सनसनीखेज समाचार के रूप में अधिक ध्यान आकर्षित करते हैं। हम ने भारत के राजस्थान राज्य मेंमानव-तेंदुए के संबंध एवं परसपर अंतर्क्रिया की जांच के लिए मीडिया रिपोर्टों का उपयोग किया। हम ने जनवरी 2016 से दिसंबर 2018 तक तेंदुए से संबंधित घटनाओं पर रिपोर्टों को निकालीं। उनकी प्रकार और गुण को समझने के लिए घटनाएं (338) वर्गीकृत, नक्शा की गई और उनका विश्लेषण किया। राजस्थान के 33 जिलों में से 26 से तेंदुए से संबंधित समाचार पाए गए, जिनमे से अधिकांश राज्य के पूर्वी भाग में थे। तेंदुए और लोगों को नुकसान होने के बावजूद, अधिकांश सूचित मानव-तेंदुए के बीच संबंध गैर-नकारात्मक दिखाई दिए। हमारे परिणाम तेंदुए से संबंधित घटनाओं के प्रतिरूप का संश्लेषण प्रदान करते हैं, जो नकारात्मक अंतर्क्रिया को संबोधित करने में वन विभाग और वन्यजीव अधिकारियों की मदद कर सकते हैं। अध्ययन में यह भी दिखाया गया है कि बड़े स्थानिक पैमाने पर मानव-वन्यजीवों के संबंध की जांच के लिए मीडिया रिपोर्ट कैसे उपयोगी हो सकती है।

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Author contributions: VA and KC conceived the idea, KC compiled the data, all authors critically evaluated the data, KC and AS performed the analyses. All authors contributed towards writing the manuscript.

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INTRODUCTION

Conserving wildlife while simultaneously balancing human welfare presents several challenges (Peterson et al. 2010), especially when large, potentially dangerous wildlife share spaces with humans (Treves & Karanth 2003). Besides ecological considerations, conserving such wildlife species requires an understanding of social contexts such as local politics, culture, religion, and ethnic attributes (Dickman 2010; Chapron & López-Bao 2014). Large carnivores are generally wide-ranging, and many species live in human-dominated landscapes (Ripple et al. 2014). Predators like Coyotes *Canis latrans* in Canada, Tibetan Black Bears *Ursus thibetanus* in Japan, Grey Wolves *Canis lupus* in parts of North America & Europe, Jaguars *Panthera onca* & Pumas *Puma concolor* in South America, and several carnivore species in Africa have been documented to share spaces with humans (Vynne et al. 2011; Alexander & Quinn 2012; Sakurai et al. 2013).

'Shared spaces' by their very nature entail some amount of negative interactions between humans and carnivores (Peterson et al. 2010). When these negative interactions intensify, they transform and perpetuate as negative attitudes, especially when people perceive that state agencies or managers prioritise wildlife over human safety and wellbeing (Madden 2004). Historically, conservation policies across countries and regions have approached the issue by considering carnivores and their habitats, and humans to be disparate entities with little to no overlap (Athreya et al. 2013; Chapron et al. 2014). But over time, studies have quelled this notion and provided empirical evidence for an evolving concept of human-carnivore associations that demonstrate the fluid nature of the dimensions they share (Ghosal et al. 2013; Athreya et al. 2015; Dhee et al. 2019).

Three of the four large felid species in India—the Asiatic Lion *Panthera leo persica*, Tiger *Panthera tigris*, and the Common Leopard *Panthera pardus*—share space with high densities of humans and livestock (Banerjee et al. 2013; Joshi et al. 2013; Athreya et al. 2015). Among them, leopards show the highest overlap with human-use areas in the country (Karanth et al. 2013; Athreya et al. 2015; Kshettry et al. 2017). Leopards are highly adaptable, wide-ranging predators occurring in a variety of landscapes, from forested protected areas to densely human-populated urban centres (Jacobson et al. 2016). Their body size, hunting strategies and highly eclectic dietary preferences allow them to thrive on a broad spectrum of prey species (wild and domestic). They can potentially live in human-dominated landscapes with relatively low levels of damage to human life and property under certain conditions (Athreya et al. 2013, 2016; Kshettry et al. 2018; Puri et al. 2020). Their populations, however, continue to dwindle due to habitat loss, direct persecution or illegal trade of body parts across the distribution range; the IUCN Red List therefore categorizes them as Vulnerable (Stein et al. 2011). A combination of (a) limited knowledge about their interactions with humans, (b) absence of viable mitigation strategies to counter negative interactions in shared landscapes, and (c) consequences from damages caused to people and livestock (Stein et al. 2011) create conservation concerns, necessitating the exploration of approaches to foster human-leopard co-existence in human-dominated landscapes.

Print media holds immense power and clout in creating and sustaining narratives based on how it represents human-leopard interactions in human-dominated areas (Crown & Doubleday 2017). Previously, studies have addressed this by assessing the type, nature and tone of content communicated through the media (Bhatia et al. 2013; Hathaway et al. 2017) and asserted that issues related to large carnivores are more 'worthy' of a news report if the incidence represents an overall negative view. This can potentially create a bias against wildlife and undermine conservation goals to an extent (Bornatowski et al. 2019). The public who consume such content get an incomplete understanding of the actual gravity of the incident(s) and this can either attenuate or amplify their perception of risk, leading to diminished human acceptance of wildlife (Knopff et al. 2016). Other studies have used media reports to map the distribution of the leopards and patterns of depredation using spatial models, while also assessing social and management factors associated with negative interactions (Athreya et al. 2015). Therefore, media is not only a source of information but can also provide a broader view of human-leopard interactions and can potentially inform conflict mitigation strategies.

In this study, we examined human-leopard interactions reported in the media from the state of Rajasthan in northwestern India. The State's local print media extensively covers leopard-related incidents, and has a considerably wide readership. We used media records to assess spatial and temporal patterns of leopard-related incidents in the State, and then analysed negative interactions in terms of losses or damages faced by leopards and people. Finally, we examined current management strategies that involve leopard captures and translocations, providing an analysis of the locations of physical captures, the reasons behind the captures,

and the relevance of these interventions for leopard conservation in human-use areas.

MATERIAL AND METHODS

Ethics Statement

The study was implemented using archived reports from print media and some forest department records. The study does not contain personal information of any human subjects. Approval of animal care and use committee and of human ethics committee was not required.

Study area

The State of Rajasthan in northwestern India covers an area of around 350,000 km^2 (10.4% of the country's total geographical area; Fig. 1), and supports a population of 68,900,000 people with a density of ~200 humans per km^2. The literacy rate in the State stands at 66.11%, with 75% of the population—mostly agricultural and pastoral communities—residing in rural areas (Census of India 2011). The State has 33 districts (administrative units) and 241 sub-districts (locally called 'tehsils'). Major geographic features of the State include the Thar Desert in the west, and the Aravalli Hill range that spans more than 850 km from the south to the northeastern parts. The vegetation in the State is diverse, ranging from desert dunes, scrub, deciduous forests, forest plantations, saline or swampy grasslands with a mosaic of seasonal agriculture belts, urban settlements, and barren lands. The region is largely arid/semi-arid, with low rainfall throughout the year (100–1,000 mm).

The print media in the State frequently covers leopard-related incidents. The types of reports vary from leopard sightings outside protected areas to attacks on humans & livestock and leopard deaths. They also report on the presence of leopards in human settlements, which often leads to capture/rescue and translocation operations. Reports of these incidents are primarily in Hindi, which is the most widely-spoken language in the State. The wide readership of print media, and its role in reporting leopard-related incidents, lend themselves to two considerations from a management perspective: first, it is important to analyse the content that is represented in newspapers; and second, the spatial and temporal patterns or trends of these reported incidents, particularly outside protected areas.

Data collection and processing

We selected Rajasthan Patrika (published in Hindi) as an ideally suited media publication for our study,

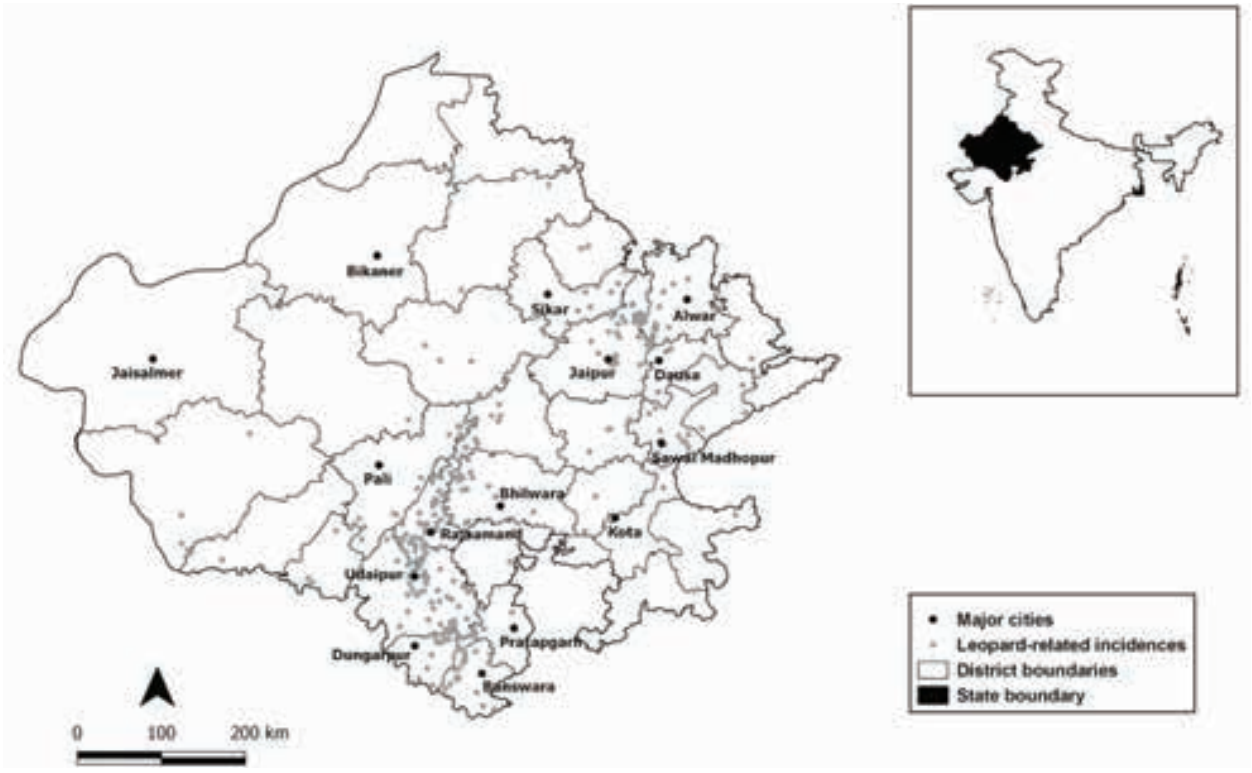

Figure 1. Locations of leopard-related incidents in the state of Rajasthan (January 2016–December 2018) mapped based on media reports.

because it has high readership across the State with an average issue readership of 7,586,000 people (Indian Readership Survey 2017) as compared to average issue readership of other regional publications (Punjab Kesari with 3,252,000 and Navbharat Times with 2,327,000 people). All the reports pertaining to leopard-related incidents were collected from the publication's online portal (www.patrika.com/rajasthan-news/), from January 2016 to December 2018. We extracted detailed information on various aspects of human-leopard interactions (see Table 1), including precise geographic location (name of village/town/city, sub district, district), date of event, time of event and type of event, along with associated details about the leopard(s) involved in the incident, and livestock/human victims. Media reports were classified into major thematic categories, multiple reports pertaining to the same incident were combined, and each incident was assigned a unique identification code before being archived (see Supplementary Table 1).

Spatial patterns of leopard-related incidents

Our objective was to use media reports to identify spatial patterns of human-leopard interactions in the State. We spatially mapped the number of media reports by assigning incidents to the corresponding districts and determined geographic coordinates of the village/town/city named in each media report using Google Earth (version 7.3.2). To minimize errors arising from villages with same/similar names, we used a directory of village names (from government records), tracing their locations by sub-district and district names as additional qualifiers. Reports for which we could not reliably assign spatial locations were excluded from the spatial maps; other relevant information from such reports was nonetheless used for examining aspects related to leopards and/or the livestock/human victims. We used geospatial software QGIS (version 3.4.6) to generate spatial maps for each category of leopard-related incidents as detailed in Table 1.

Characterizing human and livestock attacks

We undertook detailed analyses of specific cases where leopard attacks on livestock/humans were reported. First, we sought to identify temporal patterns (if any) in these attacks. Using date and month information as reported in the newspapers, we broadly classified unique incidents of leopard attacks based on seasons (Summer—March to June, Monsoon—July to October, and Winter—November to February). Next, we analysed information on the specific locations of human attacks, the activity of humans during the attack and the demographics of human victims (sex and age group, i.e., male/female, infant/young/adult; where, infant: <5 years, young: 5–18 years, and adult: >18 years). Similarly, we also created a profile of all the livestock attacked, as presented in individual reports (species/breed, and young/adult).

Fate of leopards outside protected areas

We examined three aspects related to the fate of leopards outside protected areas in Rajasthan. Given that mortality can severely impact leopard populations, we examined the causes of leopard deaths based on reportage. Second, we examined the reasons for management interventions that involved physical captures of leopards. For these events, specifically, we used data from forest department records of leopard captures and releases in the State to corroborate information reported in the media. Finally, we also recorded the locations where leopard cubs were reported and measured their distance to the nearest protected area. While doing so, we included protected areas from Rajasthan and also from the neighbouring states of Madhya Pradesh and Gujarat, since some locations could have been closer to the protected areas within these states rather than in Rajasthan.

RESULTS

Systematic searches of Rajasthan Patrika e-newspapers, available from the publication's online portal, yielded 306 media reports pertaining to leopard-related incidents that occurred between January 2016 and December 2018. We recorded a total of 338 leopard-related incidents, after thorough processing and separating out instances where multiple unique incidents were documented in the same report(s). Most incidents were reported within a day's time since the occurrence of the event. We found that 26 of 33 districts in the State of Rajasthan reported leopard-related incidents. Almost all incidents across categories were in the eastern half of the State (Fig. 2), and the highest frequencies of events were clustered in the southern districts (see Table 2). Of the reports related to human attacks (n= 78) during the period of our study, around 50% were in the southern districts of Udaipur, Rajsamand, Dungarpur, Banswara, and Pratapgarh. Udaipur had the highest percentage of reports on human attacks (18%) followed by Rajsamand (14%), Alwar (8%), Banswara (8%), and Jaipur (6%). Human deaths in the period from January 2016 to December 2018 (n= 15) occurred in Rajsamand

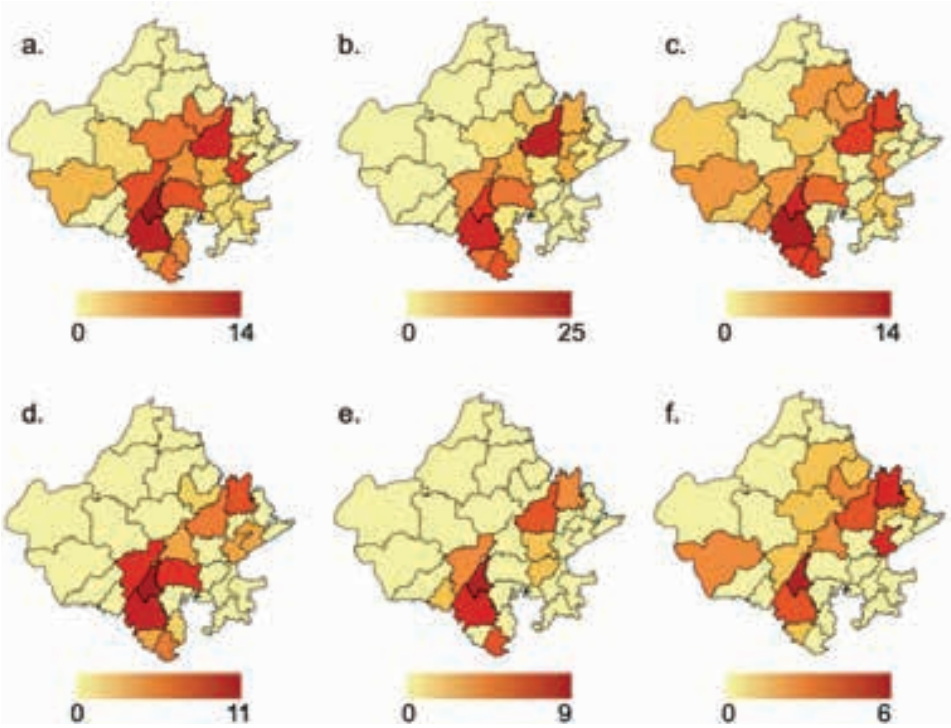

Figure 2. Spatial patterns of leopard-related incidents in Rajasthan based on media reports (January 2016–December 2018). a—leopard sightings | b—livestock attacks | c—human attacks | d—leopard deaths | e—leopard rescues | f—leopard captures.

Table 1. Major thematic categories of leopard-related incidents in Rajasthan, based on information extracted from media reports (January 2016–December 2018).

Category	Description
Leopard sightings	Leopards sighted by people outside Protected Areas; within village limits, on roads, inside livestock shelters, forested areas near villages, urban/industrial establishments, agricultural fields, or open/barren areas.
Livestock attacks	Attacks on domestic livestock– goat, sheep, cow, calf of a cow or calf of a buffalo– inside livestock shelters or during herding activity. Attacks on guard dogs were also included, separately.
Human attacks	Attacks in self-defense in a mob, incidental attacks on humans during attacks on livestock, deliberate attacks on children, attacks on adult humans in agricultural fields, attack on department personnel during capture operations.
Leopard deaths	Incidents involving leopard deaths: natural death, poaching (missing body parts such as nails or teeth), vehicular/train collision, electrocution, retaliatory killing, death during capture/rescue/translocation operations.
Leopard rescues	Incidents where Forest Department personnel rescued leopards from open wells, iron traps, following road collisions or rescues of cubs from human-use areas.
Leopard captures	Leopards captured by Forest Department from a village/town/city for translocation to other sites. Capture of leopards was usually a consequence of leopard sightings in human-use areas, attacks on livestock and/or attacks on humans.

(6), Alwar (3), Udaipur (2), Pratapgarh (2), and Jaipur (2). For livestock attacks (n= 79), the eastern district of Jaipur had the highest number of reports (28%) followed by the southern districts of Udaipur (14%), Rajsamand (12%), Banswara (7%), and Dungarpur (6%).

Attacks on humans and livestock

The number of human attacks reported was similar in summer and winter months; monsoon months had much fewer attacks. Most attacks on livestock were reported in the summer months, and least in the monsoon months (Figure 3). The 78 media reports on human attacks involved 120 people (85 male and 35 female). Fifteen of these 120 (5 male and 10 female) resulted in fatalities. Most of the victims attacked (76 of 120) were adults, while 20 were young and one was an infant; the age of the victim was not reported in 23 cases. Except for 12% of attacks on people in forest areas and 12% of attacks for which exact location was unknown/not reported, all other attacks took place in predominantly human-use areas. Attacks in farmlands were the highest, at 38% (Figure 4). Most (53%) of the victims were attacked while they were engaged in outdoor activities. About 11% and 14% of the people were attacked inside their

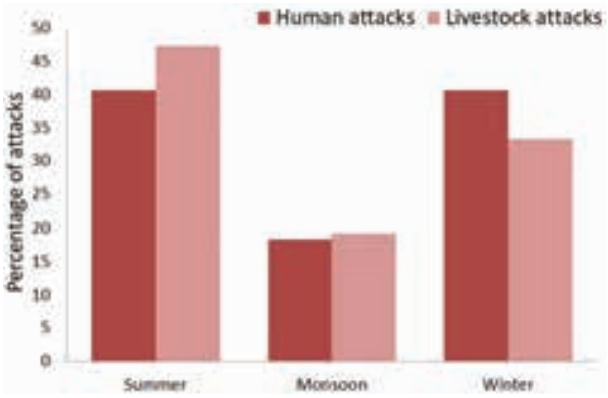

Figure 3. Seasonal patterns of leopard attacks on humans (n= 78) and livestock (n= 79) (Summer– March to June, Monsoon– July to October, Winter– November to February), based on reports during the study period (2016–2018).

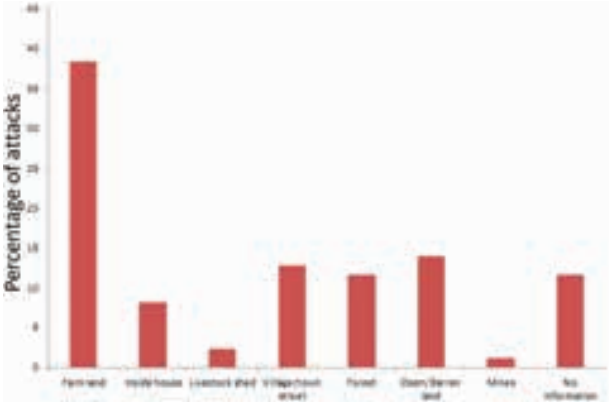

Figure 4. Proportions of leopard attacks on humans (n= 78) classified by location of attacks, during the three-year study period (2016–2018)

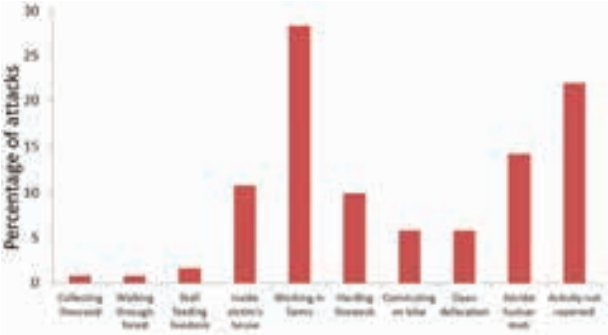

Figure 5. Activity of human victims (n= 120) during leopard attacks in Rajasthan, based on media reports, during the three-year study period (2016–2018)

house and during a mob commotion around a leopard, respectively. Around 21% of the attacks did not have any reported details regarding the activity of the victim (Figure 5).

More than 50% of media reports on livestock attacks pertained to goat and sheep deaths, followed by reports on calves of cows (~23%). A relatively lower number of reported attacks were on adult cows and buffalo calves (12% of reports each).

Leopard mortalities and physical captures

Media reports analysed in this study included 56 cases of leopard deaths (outside protected areas). Considering the subset that included reports where the cause of death was known (63% of total), 52% of deaths were due to vehicular collisions on roads or railway lines. Ten road-collision incidents occurred on national or state highways. The second most common cause was accidental deaths after falling into open wells (20%). Retaliatory killing by people accounted for 11% of deaths, and the other 17% of cases included electrocution, trapping and death following rescue operations. Three cases have been reported of probable death by poaching, with indications like missing nails, teeth, and heads. Around 37% of cases did not report the cause of death, or, indicated that the cause could not be conclusively determined.

We recorded a total of 32 cases of physical capture/removal of leopards through direct intervention of the forest department personnel. More than 50% of these captures were undertaken following a leopard sighting in human-use areas (indicating leopard presence, but no damage to human life or property). Captures/removals following attacks on humans and livestock occurred in 25% and 19% of the cases, respectively, with one case where the reason for capture was not reported.

The presence of breeding leopards was recorded from 15 sub-districts, where 36 cubs were rescued by the forest department and eight cubs were found dead during the study period. We found that the average distance between the location from where cubs' presence was reported and the nearest protected area was ~39 km (range= 0–104 km).

DISCUSSION

Information on species like leopards is hard to obtain from fully human-dominated landscapes, especially at broad spatial scales within a short duration and in a cost-effective manner (Athreya et al. 2015). We analysed media reports to better understand leopard-human interactions across Rajasthan. We show that media reports can serve as an important resource to obtain quick yet valuable information on wildlife across

Table 2. Top five districts in each category ranked based leopard-related incidents reported. Figures in parentheses are the actual numbers of reports from the corresponding district (January 2016–December 2018)

Rank	Leopard sighting	Livestock attacks	Human attacks	Leopard deaths	Leopard rescues	Leopard captures
1	Rajsamand (14)	Jaipur (25)	Udaipur (14)	Rajsamand (11)	Rajsamand (9)	Rajsamand (6)
2	Udaipur (13)	Udaipur (13)	Rajsamand (11)	Udaipur (7)	Udaipur (4)	Alwar (4)
3	Jaipur (12)	Rajsamand (11)	Alwar (6)	Bhilwara (5)	Banswara (3)	S. Madhopur (4)
4	S. Madhopur (7)	Banswara (6)	Banswara (6)	Pali (5)	Jaipur (3)	Udaipur (3)
5	Bhilwara (5)	Dungarpur (5)	Jaipur (5)	Alwar (4)	Alwar (2)	Jaipur (3)

a large landscape, where implementing other common field-based survey methods would be economically and logistically infeasible. The reports we analysed over the three-year duration indicated that leopard-related incidents were largely restricted to the eastern zone of the State panning two major areas. The first was in the southern districts of Rajsamand, Udaipur, Dungarpur, Banswara, and borders of Pali. The second area was in the northeastern districts of Jaipur, Alwar, Sikar, and Dausa. Both these areas constituted 50% and 22% of all reported incidents, respectively. This spatial pattern likely reflects habitat types and vegetation cover across the eastern and the northeastern zones, which have higher prey (wild and domestic) availability. The western zone of the State consists of largely open, barren, desert habitats, making it unsuitable for leopards, although, very few records were present from some parts of the western zone.

Telemetry studies of leopards from across their global range suggest that their home ranges could vary from 2 to 600 km^2 (average= 160km^2, median= 54km^2) (Simcharoen et al. 2008; Steyn & Funston 2009; Weilenmann et al. 2010; Grey 2011; Stein et al. 2011; Habib et al. 2014; Rozhnov et al. 2015; Fattebert et al. 2016; Kittle et al. 2017). Considered together with the fact that leopard cubs were found up to 104 km away from the nearest protected area, our assessment provides evidence in favour of resident, breeding leopard populations in human-dominated areas of the State. Studies in Karnataka and Maharashtra have reported similar cases of resident leopard populations in completely human-dominated areas (Athreya et al. 2013, 2015). Although most of the leopard-related incidents we report were in the rugged, hilly areas of the eastern region, some leopards were also reported from the relatively open, arid western region, indicating a rather widespread distribution of the species across the State.

Analysis of the reportage indicated that 29% (n= 90) was related to only leopard sightings. A total of 70% (n= 38) of the reports on livestock depredation involved attacks on goats and calves, indicating that the leopards are generally pursuing small or medium-sized domestic prey. With respect to human victims, we found that adult males accounted for 75% of all attacks. This may be due to two reasons: first, men generally intervened to 'handle' situations involving leopards in human-use areas before the arrival of the forest department personnel, and men were also more prone to the attacks in the open ruckus created amidst a mob during rescue operations; second, many attack incidents took place when the victims were grazing their livestock, which is almost always carried out by the men in the family. On the other hand, young children were typically attacked when they were asleep or were left unsupervised. Taken together, 15 of the 120 attacks resulted in the death of the victim, suggesting that loss of human life, although a very grave issue, is not the norm.

There were many reports regarding the death of leopards (n= 56), and among the known causes, 43% were because of road collisions on the state or national highways. Similar results were found in a study in Karnataka (Gubbi et al. 2014). Such linear infrastructures, besides causing direct mortalities, can also impact the gene flow of large carnivores like Tigers and Leopards (Thatte et al. 2019; Jayadevan et al. 2020). There is greater need to mitigate mortality due to linear infrastructure and information of high leopard mortality due to roads/railways from our analysis of media reports shows the same for the state of Rajasthan. Based on the district-wise maps of mortality we present, mitigation measures such as increasing the number of speed breakers, installing road signages of animal crossing/presence and vehicle patrols at the national or state highways may be implemented by management authorities.

Locations with frequent physical captures of leopards somewhat correlated with high numbers of human and livestock attacks. Studies have shown that removal of carnivores may increase conflict due to social

disruption, and is also ineffective in reducing population densities because new individuals immediately occupy these vacant territories (Linnell et al. 1997). These new individuals would further alleviate conflict situations since they are not familiar with the area (Lindzey et al. 1992; Cooley et al. 2009; Athreya et al. 2010). Around 53% of the captures reported were carried out following a leopard sighting (with no attacks on people or livestock). Such removals, generally executed by the forest department under media pressure, may affect the attitude of local residents and generate more intolerance towards leopards. We argue that removals which do not involve any negative interaction among human and leopards will not help mitigate conflict. Large carnivores typically require large spaces, invariably creating some overlap with human-use areas and it is highly important to accept these dynamics at the policy and management levels (MOEF Guidelines for human-leopard conflict management 2011).

CONCLUSION

Our study provides some key insights on leopard ecology and human-leopard interactions in the state of Rajasthan. A more rigorous, field-based approach in the areas of high conflict could have helped better understand the socio-political and economical aspects, while offering information on ecologically favourable, leopard-friendly landscapes. Despite the limitations in the overall scope because of the methods we chose, our findings still offer a broad understanding of the status of leopards at a state-wide scale. We show that media reports can be used for quick and cost-effective information to assess the spread of leopard incidences across wide spatial scales. Leopards are widely distributed across Rajasthan, and negative interactions between people and leopards, although widespread, are mainly in the eastern part of the State. The maps we present can be useful for prioritizing management efforts in managing leopard populations, conflict situations and channeling monetary resources. Our results could serve as a basis for wildlife managers and the government to initiate a detailed assessment of leopard populations in specific locations, focused on human-use landscapes.

Finally, the media acts as a frontier for disseminating information to the public. Since, print media is the main source of news across the State, it plays a key role in shaping public perception towards wildlife. In our study, it appeared to be portraying a level of conflict that was higher than what data-based analysis revealed. A more responsible and measured reporting of leopard-related incidents by the regional media outlets could go a long way in bettering people's perceptions towards and acceptance of leopards in shared landscapes. Considered together, these multiple, interlinked strategies could be helpful to adequately mitigate negative interactions between humans and leopards, and aid in leopard conservation in the long term.

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Supplementary Table 1. Raw data pertaining to leopard-related incidents complied from media reports in Rajasthan (2015–2018).

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R1	Leopard sighting	05-Jan-18	Bariya meda	Masuda (Ajmer)	Day	Village	Not given		Leopard chased by the villagers	
R2	Human attack	10-Jan-18	Jarpha	Kumbhalgarh (Rajsamand)	Dawn	Forest	Not given		Attacked on female who then died, was collecting timber in the forest	Female; Adult
R3	Dead Leopard	13-Jan-18	Lekri	Bansur (Alwar)	NA	Forest	Not given		Dead body found	
R4	Livestock attack	18-Jan-18	Bidara	Shahpura (Jaipur)	Night	Village	Not given		Attacked on a goat	
R5	Leopard sighting; Human attack; Captured	18-Jan-18	Panoria, Madawao, Fagaliya	Chohtan (Barmer)	Day (Captured from fagaliya)	Not given	Not given	Leopard sight; Attack on human	Leopard sight (Panoria), attacked on two people (Madawao), Captured (Fagaliya)	Not given; Not given
R6	Human attack	23-Jan-18	Hempura (Mandesara)	Bhainsrodgarh (Chittorgarh)	Not given	Open field	Not given		attack happened on a male while he was defecating	Male; Adult
R7	Human attack; Livestock attack	27-Jan-18	Kathar, Bamnia	Girwa & Salumbar (Udaipur)	Dusk (Kathar), Night (Bamnia)	Village	Not given		Attack on a male in livestock shed (Kathar), Attack on goat (Bamnia)	Male; Adult
R8	Rescued	29-Jan-18	Amberi	Girwa (Udaipur)	Dawn	Village	Not given			
R9	Leopard sighting; Human attack; Rescued	31-Jan-18	Kothun road, Lalsot town	Lalsot (Dausa)	Dawn	Town	Not given	Leopard sight; Attack on human	Attacks on multiple human (hotel owner and few other) in defense, got hardly beaten by people in retaliation	Male; Adult; Female; Young
R10	Dead Leopard; Captured	02-Feb-18	Kaya, Keora	Girwa & Salumbar (Udaipur)	Night (Keora)	Cropfield; Forest	Female (Both cases)	Leopard sight	Wheat cropfield in kaya, captured by FD	
R11	Leopard sighting	11-Feb-18	Kota thermal power plant	Kota	Night	Power plant	Not given			
R12	Human attack	15-Feb-18	Bawarla	Sanchore (Jalore)	Dawn	Open field	Not given		Probably strayed leopard, attacked on a young male	Male; Not given
R13	Dead Leopard	15-Feb-18	Baori chhota bhanuja	Khamnor (Rajsamand)	NA	Forest	Female		Electrocuted	
R14	Leopard sighting	17-Feb-18	Ghaghar valley (Near Daulatgarh, Asind)	Asind (Bhilwara)	Night	Forest	Not given			
R15	Dead Leopard	17-Feb-18	Bemali chauraha, Karera	Mandal (Bhilwara)	Not given	Cropfield	Not given		Leopard fallen in well with a dog	
R16	Livestock attack	20-Feb-18	Kemariya	Asind (Bhilwara)	Night	Village	Not given		Attacked on goats, Todgarh raoli wildlife sanctuary is nearby	
R17	Livestock attack	21-Feb-18	Kanela	Ghatol (Banswara)	Night	Village	Not given		Attacked on goats and killed a dog too	
R18	Human attack; Captured	22-Feb-18	Dhako ka tala (Navatala rathodan)	Chohtan (Barmer)	Day	Village	Not given	Human attack	attacked on 5 males, was searching for food and water Release in Machia safari park, Probably same strayed leopard of R12	Male; Adult
R19	Captured	23-Feb-18	Seth ji ki kundal	Girwa (Udaipur)	Not given	Village	Not given	Livestock attack	Captured from the village, killed a goat	
R20	Leopard sighting	23-Feb-18	Kherla	Khandar (Sawai madhopur)	Night	Cropfield	Not given		A Male fell down in a well and died, although just chased by the leopard	
R21	Leopard sighting	24-Feb-18	Amagarh	Jaipur urban	Day	Forest	Female (Cub)		Jhalana leopard conservation reserve is nearby	
R22	Dead Leopard	26-Feb-18	Ghasiyar (Pindwara highway)	Bargaon (Udaipur)	Dawn	Village	Not given			

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R23	Dead Leopard	28-Feb-18	Tolawas (Talvriksh range, Sariska)	Thanagazi (Alwar)	NA	Forest	Not given		Found dead on a tree	
R24	Livestock attack; Dead Leopard	28-Feb-18	Kothar and Bisalpur	Bali (Pali)	Night (Kothar)	Village; Forest	Not given		Attacked and killed multiple goat and sheep in Kothar, Leopard consevation area of Bisalpur	
R25	Dead Leopard	04-Mar-18	Kalimagri, (Kunwariya)	Rajsamand	Not given	Cropfield	One Female, One Male cub		Both died after falling in a well	
R26	Rescued	06-Mar-18	Chhora and Dudapura	Desuri (Pali)	Not given	Forest	Not given		Leopard was trapped in iron trap, Multiple other traps found by FD in the area	
R27	Livestock attack	14-Mar-18	Mohanpura, (Kundera range, Ranthambore)	Sawai madhopur	Night	Village	Not given		Attacked and killed 8 sheep	
R28	Leopard sighting	14-Mar-18	Jilda ki dhani, (Kho nagoriyan)	Sanganer (Jaipur)	Night	Cropfield	Female		Wheat cropfield, Killeda dog the same night	
R29	Leopard sighting; Livestock attack	17-Mar-18	Shyalodara	Neem ka thana (Sikar)	Dusk	Village	Not given		Leopard came in village and tried to get some livestock kill, killed 2 goats days back	
R30	Leopard sighting; Human attack; Livestock attack	19-Mar-18	Sewaradhani, Jodhoola, Talva, Galawas, Bihajar, Satana, Sar	Viratnagar, all except sar in amber (Jaipur)	Dawn (Sewaradhani), Night (Sar)	Village	Not given		Killed livestock in Sar, Spooted in livestock shed in sewaradhani, Attacked on female in Jodhoola, Livestock kill in other villages	Female; Adult
R31	Livestock attack	20-Mar-18	Nichli bhagal, (Khamnor)	Khamnor (Rajsamand)	Night	Town	Not given		Killed a goat	
R32	Captured	26-Mar-18	Hanumatpur, (Datooli panchayat)	Bonli (Sawai madhopur)	Day	Village	Not given	Leopard sight	Captured by ranthambore team and released inside the ranthambore national park	
R33	Livestock attack	08-Apr-18	Arampura forest range	Dhariyawad (Pratapgarh)	Night	Village	Not given		Attacked on a shepherd's herd	
R34	Human attack	09-Apr-18	Neelka	Viratnagar (Jaipur)	Dawn	Village	Female		Leopardess came in the village and attacked on a male got killed in retalliation by villagers.	Male; Young
R35	Human attack	10-Apr-18	Parawa	Sujangarh (Churu)	Dawn	Cropfield	Not given	Human attack	Attacked on a shepherd and shepherd's herd	Male; Young
R36	Dead Leopard	10-Apr-18	Jhar, (Banskhoh)	Bassi (Jaipur)	Night	Forest	Female		Leopardess hit by train	
R37	Dead Leopard	11-Apr-18	Umrakhal, (Kesarpura panchayat)	Banswara	NA	Village	Female		Found dead in a well	
R38	Leopard sighting; Human attack	14-Apr-18	Bhamod, Palari, Norangpura, Shyampura, Antela, Teori, Med	Viratnagar (Jaipur)	Not given	Cropfield	Not given		Leopard attacked a male in antela, sightings in other villages	Male; Not given
R39	Livestock attack	17-Apr-18	Sindoli, Bhanwata (Kundal)	Dausa and Bandikui (Dausa)	Night (Bhanwata)	Village	Not given		Buffalo calf (Bhanwata), Cow; 's calf (Sindoli)	
R40	Leopard sighting	17-Apr-18	Malviyanagar industrial area	Jaipur urban	Night	City	Not given		Jhalana leopard conservation reserve is nearby	
R41	Leopard sighting; Livestock attack	19-Apr-18	Khoonta, Bharkhundi	Dhariyawad (Pratapgarh)	Not given	Village	Female and two cubs		Killed goats, few sightings	
R42	Leopard sighting; Livestock attack	20-Apr-18	Bramaro ka badhia, (Karera)	Mandal (Bhilwara)	Dusk	Mines	Leopard couple and two cubs		Killed a cow's calf	
R43	Human attack	21-Apr-18	Sabdara	Asind (Bhilwara)	Dawn	Village	Not given		entered in village and attacked two males (adult) Retaliation from villagers	Male; Adult

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R44	Leopard sighting; Livestock attack	24-Apr-18	Satana, Jodhula, Antela, Johad villages	Viratnagar (Jaipur)	Dawn (Johad)	Village	Not given		Sight in Johad, Multiple kills of goats in other villages	
R45	Captured	25-Apr-18	Kelwa	Rajsamand	Not given	Mines	Not given	Leopard sight		
R46	Leopard sighting; Human attack; Livestock attack	25-Apr-18	Ven, Thoota mahoora, Kenar, Jhallara	Salumbar (Udaipur)	Night (Jhallara)	Village	Female & two cubs (Ven)		Killed 6 goats and cow in ven, Agoat and a sheep in thoota mahoora, spotted in jhallara, attacked on a female in kenar while defecating	Female; Adult
R47	Livestock attack	30-Apr-18	Roba, (Jagat panchayat), Mangthala	Girwa & Mavli (Udaipur)	Night (Both places)	Village	Not given		Killed a cow's calf in roba, goats in mangthala	
R48	Rescued	09-Jun-18	Beneshwar dham	Banswara	Night	Village	Not given		Critically injured leopard	
R49	Leopard sighting; Livestock attack	09-Jun-18	Jodhoola, Banganga, Sewaradhani, Tevri	Viratnagar (Jaipur)	Night (Jodhoola)	Village	Not given		Killed 3 goats in jodhoola, other villages reported with leopard sightings	
R50	Leopard sighting	11-Jun-18	Near Baleshwar dham	Neem ka thana (Sikar)	Day	Forest	Not given		Leopard was fallen in a well, Alive	
R51	Dead Leopard	11-Jun-18	Thana and Bagjana villages, (Karera)	Mandal (Bhilwara)	Not given	Cropfield; Village	Female (Thana)		**Female leopard**'s dead body found in an open well in cropfield in thana; another dead leopard found in dumping yard in bagjana	
R52	Leopard sighting; Captured	11-Jun-18	Gudla, (Nathdwara)	Nathdwara (Rajsamand)	Day	Village	Not given	Leopard sight	Leopard found inside a sewer pipe, captured by FD	
R53	Human attack; Captured	13-Jun-18	Theekariya	Sri madhopur (Sikar)	Day	Cropfield	Not given	Human attack	Found in wheat cropfield, attacked on FD guard and a villager in defense, later captured and released In neem ka thana forest area	Male; Adult
R54	Human attack	15-Jun-18	Adwas	Sarada (Udaipur)	Dawn	Cropfield	Not given		Attacked on a female while she was working in cropfield	Female; Adult
R55	Livestock attack	17-Jun-18	Gopalpura, Adwas	Sarada (Udaipur)	Night (Both cases)	Cropfield; Village	Not given		Killed acow in gopalpura, killeda cow's calf in adwas	
R56	Leopard sighting	20-Jun-18	Kolar, (Sarada)	Sarada (Udaipur)	Dawn	Village	Not given			
R57	Dead Leopard	28-Jun-18	Power house chauraha, Udaipur dabok highway	Mavli (Udaipur)	Night	Town	Not given		Leopard killed in road accident	
R58	Leopard sighting	01-Jul-18	Kelwa	Rajsamand	Dawn	Cropfield	Not given but a cub			
R59	Rescued	05-Jul-18	Khorlai, (Pratapgarh)	Thanagazi (Alwar)	Night	Village	Male		Leopard fallen in a well, rescued by FD and taken to nahargarh biological park	
R60	Livestock attack	07-Jul-18	Khadka, (Kalota)	Dausa	Night	Village	Not given		Killed a cow's calf	
R61	Livestock attack	12-Jul-18	Jhalra	Asind (Bhilwara)	Night	Village	Not given		Leopard killed 3 goats in multiple attempts in a night	
R62	Dead Leopard	20-Jul-18	Veerbala dhani, (Gaori)		Dawn	Open field	Male		Dead leopard found in mountains	
R63	Livestock attack	22-Jul-18	Itawada, (Khandar forest range, Ranthambore)	Khandar (Sawai madhopur)	Night	Village	Not given		Killed a cow's calf	
R64	Human attack	22-Jul-18	Doom khera	Rajsamand	Day	Cropfield	Not given		Attacked on a female while she was working in cropfield	Female; Young

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R65	Leopard sighting	03-Aug-18	Chirwa valley of flowers	Bargaon (Udaipur)	Day	Forest	Not given			
R66	Rescued	11-Aug-18	Ghewar, (Tehla forest range, Sariska)	Rajgarh (Alwar)	Not given	Village	Not given		Leopard fallen in a public use well in the village and rescued by FD	
R67	Captured	12-Aug-18	Cement factory area	Sawai madhopur	Not given	City	Not given	Leopard sight	Earlier 9 capturing also been done by FD	
R68	Leopard sighting	12-Aug-18	Baghera	Sahara (Bhilwara)	Dawn	Cropfield	Not given			
R69	Livestock attack	13-Aug-18	Thali, Dagota, Neemla, Shriramgopalpura, Bassi	Jamwa Ramgarh (Jaipur)	Night (Thali)	Village	Not given		54 sheep 15 goats in thali, cow's calf in neemla, cow in shri ramgopalpura, goats in dagota	
R70	Dead Leopard	20-Aug-18	Lakhola	Sahara (Bhilwara)	Not given	Cropfield	Not given		Leopard fallen in a well and died	
R71	Livestock attack	21-Aug-18	Mamtori kalan, Poorawala, Kukdela	Viratnagar (Jaipur), Mamtori kalan in shahpura	Night (All cases)	Village	Not given		Killed goats in every place.	
R72	Human attack	24-Aug-18	Bhalon ka guda, (Gudli)	Girwa (Udaipur)	Dawn	Cropfield	Not given		First case, Leopard attacked on a shepherd in a cropfield who was their with livestock, in other case, attacked a male in another cropfield who was also working	Male; Adult
R73	Leopard sighting	28-Aug-18	Behind dudhia balaji temple	Tonk	Dawn	Cropfield	Not given		Villagers claimed to have seen a female cub with the leopard	
R74	Leopard sighting; Rescued	03-Sep-18	Chaktodi chauraha, Nathdwara	Nathdwara (Rajsamand)	Not given	Cropfield	Not given		Spotted in an ill state	
R75	Leopard sighting	05-Sep-18	Agariya	Amet (Rajsamand)	Dusk	Cropfield	Not given		Leopard fallen in a well but FD failed to rescue it.	
R76	Livestock attack	07-Sep-18	Kundla, Aamloda, Badodia, Gheota, Talva, Berki, Pando	Viratnagar (Jaipur)	Night, Dusk (Pando)	Cropfield	Female &Female with two cubs (Pando)		Female leopard killed acow's calf in livestock shedin pando, Female leopard and two cubs in a cropfield in pando, Multiple other killings in other villages mostly goats	
R77	Dead Leopard	09-Sep-18	Netra	Sumerpur (Pali)	Dawn	Village	Male		Leopard killed in road accident	
R78	Livestock attack	16-Sep-18	Siras	Niwai (Tonk)	Not given	Not given	Femal with one female cub		Killed several livestock animals in the area, mostly around antariya balaji temple, Ranthambore NP is nearby	
R79	Rescued	19-Sep-18	kelwa	Rajsamand	Not given	Cropfield	Female cub		Leopard fallen in well, Rescued by FD and released in nearby forest area	
R80	Leopard sighting	27-Sep-18	Kalodar canal (Saroli)	Deoli (Tonk)	Night	Forest	Not given		Leopard spotted by shepherds near kalodar canal	
R81	Human attack	11-Oct-18	Hada khera, (Gopalpura panchayat, Dhariawad)	Dhariyawad (Pratapgarh)	Night	Village	Not given		Attacked on a girl while she was sleeping in house, she died (10 years old)	Female; Young
R82	Human attack	16-Oct-18	Parsola, Mayakhedi, Hada khera, (Dhariawad)	Dhariyawad (Pratapgarh)	Dusk (Mayakheri)	Cropfield; Forest	Not given		Attacked on a female while she was working in a cropfield, killed a cow in nearby forest of hadakhera	Female; Young

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R82a	Leopard sighting	18-Oct-18	Mayakhedi, Lambikalam (Dhariawad)	Dhariyawad (Pratapgarh)	Dusk (Lambikalam) Night (Mayakheri)	Forest	Not given		Leopard spotted in trap camera in mayakheri with the previous mentioned kill of cow, also killed a cow in lambikalam, karmeliya forest area	
R81a	Leopard sighting	19-Oct-18	Hada khera, Dhariawad	Dhariyawad (Pratapgarh)	Not given	Village	Not given		Leopard's continuous movement through the mentioned village	
R83	Human attack	21-Oct-18	Hada khera, (Gopalpura panchayat, Dhariawad)	Dhariyawad (Pratapgarh)	Night	Village	Not given		Leopard attacked on a female while she was defecating in the open	Female; Adult
R82b	Leopard sighting	22-Oct-18	Hadakhera	Dhariyawad (Pratapgarh)	Not given	Not given	Not given		Continuation of above reports	
R82c	Leopard sighting	24-Oct-18	Hadakhera, Mayakheri	Dhariyawad (Pratapgarh)	Not given	Not given	Not given		Continuation of above reports	
R82d	Leopard sighting	24-Oct-18	villages of above Karmelia forest range, Dhariawad	Dhariyawad (Pratapgarh)	Not given	Not given	Not given		Continuation of above reports	
R84	Leopard sighting	25-Oct-18	Naharpura, (Pratapgarh panchayat)	Raipur (Pali)	Night	Open field	Not given		Leopard spotted near Beawar Merta highway and vanished away	
R85	Human attack	01-Nov-18	Parsola deola road	Pratapgarh	Night	Open field	Not given		Attacked on a male who was on bike	Male; Adult
R86	Leopard sighting; Livestock attack	09-Nov-18	Amarsar, Khori	Shahpura (Jaipur)	Night (Both cases)	Village	Not given		Leopard killed 4 goatsfrom multiple sheds in amarsar, Another case whereby leopardis spotted byvillagers in khori many times	
R87	Livestock attack	11-Nov-18	Saledipura	Khandela (Sikar)	Not given	Village	Leopard couple			
R88	Dead Leopard	13-Nov-18	Kadmal	Gogunda (Udaipur)	Night	Village	Female		Leopard killed in road accident	
R89	Leopard sighting	13-Nov-18	Bari ghati, (Thanwala)	Riyan Badi (Nagaur)	Night	Forest	Not given		with a nilgai kill	
R90	Leopard sighting	14-Nov-18	Basant bihar colony, Ajeetgarh town	Sri madhopur (Sikar)	Dawn	Town	Not given		Entered inside the colony and later escaped away into the forest after being noticed	
R91	Human attack	17-Nov-18	Bagori dhani, (Kotputli)	Kotputli (Jaipur)	Dawn	Village	Not given		Attacked on threemales in defense and later villagers killed the leopard in retaliation	Male; Not given
R92	Leopard sighting	27-Nov-18	Manduthal , (Bhansol panchayat)	Mavli (Udaipur)	Night	Open field	Not given		Leopard spotted by villager in nearby road, another villager claimed about recent livestockkillings	
R93	Human attack	28-Nov-18	Keli	Dhariyawad (Pratapgarh)	Not given	Forest	Not given		Attacked on a shepherd while herding activity, Shepherd died	Male; Young
R94	Leopard sighting; Captured	29-Nov-18	Prithvi singh ji ka khera	Bhider (Udaipur)	Not given	Cropfield	Not given	Leopard sight	Leopard got stucked in barbed wire while chasing nilgai, Captured by FD and released in nearby forest area	
R95	Human attack; Livestock attack; Captured	01-Dec-18	Bharkala	Masuda (Ajmer)	Dawn	Village	Not given	Livestock attack; Human attack	Attacked on two males and three females and killed 2 goats	Male; Not given; Female; Not given
R96	Captured	04-Dec-18	Suradiya	Jawaja (Ajmer)	Not given	Village	Female	Leopard sight	Releasedback in nearby todgarh raoli forest	

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
R97	Dead Leopard	13-Dec-18	Khoja kakar, Udaipur jaisamand highway	Udaipur	Night	Forest	Male		Leopard killed in a road accident	
R98	Human attack	15-Dec-18	Mandhan	Behror (Alwar)	Dawn	Open field	Not given		Attacked on a shepherd while herding activity	Male; Adult
R99	Dead Leopard	16-Dec-18	Tikar Talab, near Amet	Amet (Rajsamand)	Not given	Open field	Not given		Leopard died after getting trapped in iron trap, although speculated to be for other animals.	
R100	Leopard sighting; Livestock attack	16-Dec-18	Banipura, (Barnaoda panchayat), Barod villages	Khandar (Sawai madhopur)	Night (Both cases)	Village	Not given		Leopard kiiled a cow's calf in barod, spotted in banipura	
R101	Dead Leopard	18-Dec-18	Bhagtol, (Ghatol forest range)	Ghatol (Banswara)	Dawn	Forest	Male		FD found scratches on its body and broken hind legs	
R102	Human attack	18-Dec-18	Jhotara ki rohi	Taranagar (Churu)	Dawn	Cropfield	Not given		Attacked on two males inside the cropfields and got killed in retaliation	Male; Adult
R103	Human attack	23-Dec-18	Laxmipura, (Ayana)	Pipalda (Kota)	Not given	Cropfield	Not given		Attacked on a male who initially shouted afterseeing the leopard, defense?	Male; Not given
R104	Dead Leopard	25-Dec-18	Upali odan road, (Nathdwara)	Nathdwara (Rajsamand)	Not given	Town	Not given		Leopard killed in road accident	
R105	Leopard sighting	27-Dec-18	Butati	Degana (Nagaur)	Day	Cropfield	Not given		Leopard spotted in puniya ki dhani	
R106	Dead Leopard	29-Dec-18	Vallabhgram	Mandawar (Alwar)	Dawn	Open field	Not given			
R107	Leopard sighting	29-Dec-18	Mundwa	Mundwa (Nagaur)	Dawn	Mines	Not given		probably the same leopard spotted in butati village	
S1	Leopard sighting	03-Jan-17	Bishanpur, (Arjunpura khalsa)	Pisangan (Ajmer)	Not given	Open field	Not given			
S2	Human attack; Captured	07-Jan-17	Manpura machedi	Amber (Jaipur)	Not given	Village	Not given	Leopard sight; Human atttack	Captured by FD	Not given; Not given
S3	Dead Leopard	10-Jan-17	Tonkepura balaji, (Dhaureta panchayat)	Mandrail (Karauli)	Dawn	Open field	Not given		Spotted by shepherds in an injured state, later leopard died	
S4	Human attack	20-Jan-17	Nada charanwas	Danta ramgarh (Sikar)	Day	Cropfield	Not given		Leopard attacked on 6 years old who was savedby his father	Male; Adult; Male; Young
S5	Human attack	Jan-17	Ojariya	Garhi (Banswara)	Dusk	Cropfield	Not given		Attacked on a female	Female; Young
S6	Livestock attack	01-Feb-17	Nawabpura ki dhani	Bhadesar (Chittorgarh)	Dusk	Village	Not given		Killed 5 goats	
S7	Livestock attack	06-Feb-17	Bheemapura		Night	Village	Not given		Killed 10 goats	
S8	Human attack	13-Feb-17	Jaitpur, (Silibaori panchayat, Sariska)	Thanagazi (Alwar)	Not given	Cropfield	Not given		Attacked on a female In cropfield and same day attacked on 2 other people, 2 victims died, declared maneater leopard and shooton sight is issued	Female; Adult; Not given; Not given
S9	Human attack; Dead Leopard	16-Feb-17	Bhanor, Kharpina villages	Salumbar & Girwa (Udaipur)	Dusk (Bhanor), Dawn (Kharpina)	Cropfield; Village	Not given		Attacked on a male and a female in bhanor, leopard died in road accident in kharpina	Male; Adult; Female; Adult
S10	Livestock attack; Captured	19-Feb-17	Banchhri, (Silibaori panchayat, Sariska)	Thanagazi (Alwar)	Night	Village	Female (Captured one)	Reason not given	Attacked on cow's calf and a dog, a female leopard was captured by FD a day before	
S10a	Captured	25-Feb-17	Silibaori area, Sariska	Thanagazi (Alwar)	Not given	Not given	Not given	Leopard sight	Leopard captured and thought to be the same maneater leopard	

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S11	Leopard sighting	26-Feb-17	Ghana magra, (Bhavi)	Bilara (Jodhpur)	Not given	Cropfield	Not given		Leopard inside a farm house from 2 days and killed 2 dogs , not captured	
S12	Human attack	Feb-17	Mathuravat, (Rajorgarh panchayat, Tehla)	Rajgarh (Alwar)	Not given	Cropfield	Not given		Attacked on female while she went for a check on livestock	Female; Adult
S13	Human attack	05-Mar-17	Bhadasiyan	Parbatsar (Nagaur)	Dawn	Village	Not given		Attacked on a male	Male; Not given
S14	Dead Leopard	06-Mar-17	Near galta temple	Sawai madhopur	Dawn	City	Male cub		Cub died after getting rescued	
S15	Leopard sighting	10-Mar-17	Kulish smriti van	Jaipur urban	Not given	Forest	Leopard couple and a cub		Entered and roaming around kulish van from few days, came from jhalana	
S16	Livestock attack	11-Mar-17	Pulan ki dhani, (Daulatpura)	Sapotra (Karauli)	Night	Village	Not given		Killed 14 sheep	
S17	Livestock attack; Captured	16-Mar-17	Gopalpura, (Sariska)	Thanagazi (Alwar)	Dawn (Captured), Night (Livestock attack)	Village	Not given	Livestock attack	Captured by FD and the night before it killed 3 goats	
S18	Dead Leopard	Mar-17	Baba kua forest, Garhi range	Garhi (Banswara)	Not given	Forest	Leopard cub		Probaby died in clash with other leopard	
S19	Dead Leopard	02-Apr-17	Hamadpura, (Mohanpura panchayat)	Mandalgarh (Bhilwara)	Not given	Forest	Not given		Leopard hit by a train and died	
S20	Leopard sighting	10-Apr-17	Giriraj parikrma	Nathdwara (Rajsamand)	Dawn	Forest	Not given			
S21	Human attack	10-Apr-17	Anatpura, (Khandar range, Ranthambore)	Khandar (Swai madhopur)	Dawn	Open field	Not given		Attacked on a male who was defecating in the open	Male; Adult
S22	Livestock attack	25-Apr-17	Baggar	Bhim (Rajsamand)	Night	Village	Not given		two leopards killed 18 sheep and 2 goats.	
S23	Human attack; Livestock attack	Apr-17	Jaspur	Aspur (Dungarpur)	Day	Forest	Female and two cubs		Attacked on two shepherds and also killed a goat	Male; Adult
S24	Livestock attack	Apr-17	Himmatsingh ka garha, (Asoda)	Garhi (Banswara)	Night	Village	Not given		Killed a cow's calf	
S25	Dead Leopard	03-May-17	Sanwata, (Talra range, Ranthambore)	Khandar (Sawai madhopur)	Not given	Open field	Not given		10 days olddead body, no conclusion of reason of death	
S26	Leopard sighting	21-May-17	Bonli	Bonli (Sawai madhopur)	Not given	Town	Not given			
S27	Livestock attack	22-May-17	Kumawato ki dhani, (Bhagwan nagar)	Jaipur urban	Night	City	Not given		Killed 2 goats	
S28	Leopard sighting	24-May-17	Bhawa	Rajsamand	Night	Village	Not given		Shepherd claimed to have seen leopard couple but otherssaw one leopard	
S29	Livestock attack	May-17	khoh nagoriyan	Sanganer (Jaipur)	Dusk	Village	Not given		Killed 7 goats	
S30	Human attack	May-17	Mohkampura forest area	Kushalgarh (Banswara)	Dusk	Forest	Not given		Attacked on 3 males who stopped near forest while travelling on a bike	Male; Adult
S31	Leopard sighting	01-Jun-17	Ghat ki guni	Jaipur urban	Dusk	City	Not given		Jhalana is nearby	
S32	Leopard sighting	02-Jun-17	Khoonta	Dhariyawad (Pratapgarh)	Dawn	Village	Not given		FD failed to capture the leopard	

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S33	Leopard sighting	05-Jun-17	Cement factory area	Sawai madhopur	Dawn	City	Not given		Leopard killed a cow's calf (maybe stray cow) and left the body there	
S34	Leopard sighting; Livestock attack	10-Jun-17	Kajawara	Salumbar (Udaipur)	Night	Village	Not given		Leopard spotted by owner which killed a cow too and escaped	
S35	Livestock attack	25-Jun-17	Himmatsingh ka garha, (Asoda)	Garhi (Banswara)	Dawn	Village	Not given		Killed a cow's calf	
S36	Dead Leopard	Jun-17	Navaghara	Garhi (Banswara)	Not given	Forest	Female		retaliatory killing of leopard by humans, FIR reported by people for animals	
S37	Livestock attack	Jun-17	varwasa mafi, (Sabla)	Aspur (Dungarpur)	Night	Village	Not given		Killed a cow's calf, earlier incidents too	
S38	Dead Leopard	Jun-17	Keora forest range, (Sarada)	Sarada (Udaipur)	Dusk	Forest	Female		Found dead in the forest, probably died of some disease	
S39	Human attack	01-Jul-17	Saroo	Girwa (Udaipur)	Not given	Not given	Not given		Killed a male	Male; Not given
S40	Human attack	08-Jul-17	Sela gurha	Amet (Rajsamand)	Night	Village	Not given		Attacked on a girl, saved by her father	Female'; Young
S41	Human attack	10-Jul-17	Loharia para	Garhi (Banswara)	Night	Cropfield	Not given		Killed a 8 year old boy	Male; Young
S42	Leopard sighting	20-Jul-17	Sajjangarh	Udaipur	Not given	Forest	Not given			
S43	Human attack	21-Jul-17	Malakhera	Alwar	Not given	Forest	Not given		Attacked while 2 shepherds tried to save their livestock	Male; Not given
S44	Human attack; Captured	31-Jul-17	Sawai madhopur urban	Sawai madhopur	Not given	City	Not given	Human attack		Male; Not given; Female; Adult
S45	Rescued	Jul-17	Kunwariya town	Rajsamand	Dusk	Cropfield	Two cubs		Cubs fallen in a well, rescued by FD	
S46	Human attack	Jul-17	Kika ki naal, (Miyasa panchayat)	Ghatol (Banswara)	Dawn	Cropfield	Not given		attacked on two males in chilli cropfield	Male; Adult
S47	Livestock attack	Jul-17	Bagatpura, (Narana panchayat)	Deogarh (Rajsamand)	Night	Village	Not given		Attacked and killed 29 sheep and goats	
S48	Leopard sighting	04-Aug-17	Mira sahab dargah	Nainwa (Bundi)	Day	Forest	Not given		Inside Ramgarh wildlife sanctuary	
S49	Livestock attack	04-Aug-17	Damor pada, (Jaulana)	Garhi (Banswara)	Dawn	Village	Not given		Killed 3 goats	
S49a	Livestock attack	13-Aug-17	Aneli pada, (Bhatar panchayat, Jaulana)	Garhi (Banswara)	Dawn	Village	Not given		Killed 3 goats, villagers claimed that a female leopard gave birth to three cubs in nearby babakuan forest	
S50	Human attack	01-Sep-17	Galata	Jaipur urban	Dawn	Open field	Not given		Attacked on a male priest	Male; Adult
S51	Dead Leopard	03-Sep-17	Mundol panchayat	Rajsamand	Dawn	Cropfield	Not given		Found dead in a cropfield, probably died trying crossing the sidewall	
S52	Leopard sighting; Livestock attack	11-Sep-17	Talawadi, Bamniawata (Jaulana)	Garhi (Banswara)	Night (Both cases)	Open field; Village	Not given		Leopard spotted in talawadi area under bushes, killed 2 goats in different houses in bamniawata area	
S53	Rescued	12-Sep-17	Sakarda	Amet (Rajsamand)	Night	Cropfield	Not given		FD rescued the leopard from a well but it instantly ran away into the forest after getting out	
S54	Leopard sighting	12-Sep-17	Jawar mines	Girwa (Udaipur)	Not given	Village	Not given		Leopard got stucked in a room next to livestock shed, rescued by FD	

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S55	Livestock attack	17-Sep-17	Dungariatalai, (Jaulana)	Garhi (Banswara)	Night	Village	Not given		Killed 3 goats	
S56	Livestock attack	18-Sep-17	Kelwa	Rajsamand	Night	Town	Not given		Killed 7 goats	
S57	Livestock attack	26-Sep-17	Kelwa	Rajsamand	Night	Town	Not given		Killed 16 goats	
S58	Captured	06-Oct-17	Cement factory area	Sawai madhopur	Not given	City	Male and a female	Leopard sight	Captured by FD, few others roaming the area	
S59	Rescued	08-Oct-17	Trilokpura, (Raisar panchayat)	Jamwa ramgarh (Jaipur)	Not given	Village	Not given		Found in a well, Rescued by FD	
S60	Dead Leopard	24-Oct-17	Fiawadi, Rajsamand Bhilwara highway	Rajsamand	Dusk	Not given	Female		Leopard died in a road accident	
S61	Leopard sighting	31-Oct-17	Kulish smriti van	Jaipur urban	Not given	City	Not given		Spotted in university area, jhalana is nearby	
S62	Captured	31-Oct-17	Goradia ka bhilwara dhani, (Samicha panchayat)	Kumbhalgarh (Rajsamand)	Dusk	Village	Not given	Livestock attack	was killing livestock from past few days, captured by FD	
S63	Rescued	21-Nov-17	Kelwa	Rajsamand	Dawn	Mines	Cub		It wasfound diseased and taken for medical care	
S64	Leopard sighting; Rescued	21-Nov-17	Jawas	Kherwara (Udaipur)	Not given	Open field	Cub		Spooted in the mountains, cub was diseased and rescued for medical care	
S65	Livestock attack	25-Nov-17	Jaisinghpura khor, (Brahmapuri)	Jaipur urban	Not given	Village	Not given		Killed 2 cows	
S66	Dead Leopard	06-Dec-17	Jawahar nagar	Jaipur urban	Not given	Forest	Not given		Probably died in a clash with other leopard	
S67	Rescued	09-Dec-17	Mahudi	Girwa (Udaipur)	Not given	Forest	Not given		leopard was spotted was villagers trapped in poachers trap and rescued by FD, taken to udaipur biological park	
S68	Dead Leopard	10-Dec-17	Jaitgarh (Sarveena panchayat)	Beawar (Ajmer)	Not given	Cropfield	Not given		Leopard dead body found in a well without a head, probably killed, Jawaja forest area is nearby	
S69	Dead Leopard	11-Dec-17	Gulzar bagh, (Aligarh)	Uniara (Tonk)	Dawn	Forest	Not given		Leopard hit by train on Delhi Mumbai tracks	
S70	Leopard sighting	12-Dec-17	Birantiya kalan, (Sendra)	Raipur (Pali)	Dusk	Cropfield	Not given		Leopard spotted by farmer, probably came for livestock tied nearby, rescue team came and leopard escaped	
S71	Dead Leopard	13-Dec-17	Pachmata	Nasirabad (Ajmer)	Dawn	Open field	Not given		Leopard found injured near a mountain, there were cuts on its front paw and body, probably attackedby someone/some poacher, FD tranquilized it and after a while the leopard died, state FD animals census marked zero number of leopards in the nearby forest area.	
S72	Human attack	14-Dec-17	Bhainsa kamed	Khamnor (Rajsamand)	Night	Forest	Not given		Attacked and killed on a female who was alone crossing the forest area in the dark	Female; Adult
S73	Leopard sighting	22-Dec-17	Gogunda town	Gogunda (Udaipur)	Day	Town; Cropfield	Not given		Leopard entered meghwal basti in gogunda and got spotted by many, **people retaliated with sticks and stones and leopard hid out in nearby cropfield, rescue is going on , conclusion of rescue is not given.**	
S74	Dead Leopard	26-Dec-17	Sendra	Raipur (Pali)	Night	Open field	Female		Leopard killed in a road accident	

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S75	Captured	29-Dec-17	Barna (Kaladera), Jawahar nagar	Amber & Jaipur Urban (Jaipur)	Not given	City	Not given	Leopard sight	Captured in both cases, Leopard prince came in jagatpura from jhalana	
T1	Leopard sighting	01-Jan-16	Baba kuan forest, garhi range, Jaulana	Garhi (Banswara)	Not given	Forest	Not given		Two leopards spotted by FD worker nearan installed cage, a dog was also tied up in the cage	
T2	Dead Leopard	01-Jan-16	Gothra	Aspur (Dungarpur)	Not given	Forest	Male		Cause of death is not concluded	
T3	Dead Leopard	02-Jan-16	sayra (rankapur)	Desuri (Pali)	Not given	Not given	Female		Leopard died in a road accident	
T4	Human attack; Livestock attack	03-Jan-16	Pheela (Girwa), Shyampura (Jaisamand)	Girwa & Salumbar (Udaipur)	Day (Pheela), Night (Shyampura)	Cropfield	Not given		Attacked on a female while she was on herding activity (Pheela), attacked on a male who was guarding cropfield in the night (Shyampura)	Female; Adult; Male; Adult
T5	Human attack; Livestock attack	05-Jan-16	Bemla, Barapal, Nal kagurha (Bhindar), Gurli	Girwa (Udaipur)	Night (Bemla, Nal ka gurha)	Village; Mines	Female with 2cubs (Bemla)		**Female leopard with two cubs** attacked and killed 5 **goats** in livestock shyed in Aada talai falan, Bemla; Leopard killed a **cow** in Gameti basti, Gurli; **Leopard attacked a female** in mines area, Nal ka gurha (Bhindar)**; Leopard attacked a female** in Geengla falan; **Leopard chased a female and a girl** in barapal, all human victims lived	Female; Adult; Female; Young
T6	Dead Leopard	08-Jan-16	Rajsamand lake	Rajsamand	Dawn	Open field	Not given		Last meal of aodog, no signs of poachers	
T7	Leopard sighting; Livestock attack	08-Jan-16	Tantiya, Kharodiya	Aspur (Dungarpur)	Dawn (Tantiya), Dusk (Kharodiya)	Open field	Not given		Leopard killed a livestock cow in Tantiya, claimed to be though; two leopards spotted in a cropfield, they later vanished away	
T8	Leopard sighting; Human attack	09-Jan-16	Usar, Giriraj parikrama (Nathdwara)	Kumbhalgarh & Nathdwara (Rajsamand)	Dusk (GP)	Forest	Not given		**Leopard attacked and killed a girl** in Usr 3 days before, Leopard also spotted by many people at giriraj parikrama, Nathwara	Female; Young
T9	Human attack	10-Jan-16	Baroda	Aspur (Dungarpur)	Day	Open field	Not given		attacked on a female while she was defecating	Female; Adult
T10	Human attack	12-Jan-16	Nimbada talab, Kelwa	Rajsamand	Dusk	Open field	Not given		Attacked on a male who was on a bike	Male; Adult
T11	Livestock attack	13-Jan-16	Jatwara kalan	Sawai madhopur	Dawn	Village	Not given		Killed a cow's calf	
T12	Captured	19-Jan-16	Usar	Kumbhalgarh (Rajsamand)	Night	Forest	Female	Human attack	Probably the same leopard which killed a girl in usar few days back	
T13	Leopard sighting	24-Jan-16	Cement factory (Batherda), Gopal temple (Sawai madhopur)	Sawai madhopur	Night (CF), Dusk (GT)	Cropfield; Open field	Not given		Leopard spotted at each place	
T14	Captured	26-Jan-16	Usar	Kumbhalgarh (Rajsamand)	Night	Forest	Not given	Leopard sight	**Another leopard captured by FD in usr after the female leopard, release site is not mentioned, Villagers were creating nuisance to see the leopard.**	
T15	Rescued	29-Jan-16	Nal	Banswara	Night	Forest	Not given		Leopard came out in search of water and fallen in an open well, FD came but due to lack of resources could not rescue the leopard for hours.	

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T16	Leopard sighting; Livestock attack	Jan-16	Rakampura	Amet (Rajsamand)	Dawn	Village	Not given		Leopard attacked and killed 2 **cow's calf** in a livestock shed early morning, also spotted by some villagers, earlier recent attacks on **goats and dogs too happened.**	
T17	Captured	Jan-16	Janawad	Kumbhalgarh (Rajsamand)	Dusk	Village	Not given	Leopard sight	Leopard captured by FD in Janawad , third ina row, villagers have claimed to have seen 3 more leopards, leopards residing in sugarcane fields	
T18	Human attack	06-Feb-16	Dolpura bandh, Was	Reodar (Sirohi)	Dawn	Cropfield	Not given		**Leopard found in a cropfield in dolpura bandh which attacked two males in there and escaped, later on found again in a cropfield in waas villager where it again attacked on two FD workers, All victims lived**	Male; Adult
T19	Human attack	09-Feb-16	Ratadiya	Raipur (Pali)	Night	Forest	Not given		Attacked on two males while they were on a bike	Male; Adult; Male; Young
T20	Livestock attack	09-Feb-16	Kahela	Sagwara (Dungarpur)	Night	Village	Not given		Killed 2 goats	
T21	Human attack	10-Feb-16	Van, kailashnagar	Sheoganj (Sirohi)	Day	Open field	Not given		Attacked on a shepherd on herding activity	Male; Not given
T22	Livestock attack	13-Feb-16	Manpura, Sumel	Raipur (Pali)	Not given	Not given	Not given		Leopard claimed to be moving around the mentioned villages and also killing livestock, Sendra forest is nearby harboring many leopards.	
T23	Livestock attack; Human attack; Captured	14-Feb-16	Lalpura	Raipur (Pali)	Night	Village	Not given	Livestock attack	Leopard (8 years old) entered in a livestock shed in the night and killed 2 **goats** but spotted by the owner and other villagers, so in defense the leopard attacked the owner and after that villagers captured him in a room by lighting fire around on their own and called FD, leopard rescued and taken to Jodhpur for medical care, found to have injury on the head.	Male; Adult
T24	Leopard sighting	15-Feb-16	Ratadiya	Raipur (Pali)	Night	Forest	Not given		Leopard spotted by a male who was coming on a bike near bari valley	
T25	Livestock attack	15-Feb-16	Bhoongra	Ghatol (Banswara)	Night	Village	Not given		Killed a cow	
T26	Livestock attack	16-Feb-16	Dhayla, Raoji ka bariya, Bhagal (Kelwa)	Nathdwara, Bhim & Rajsamand	Night (Dhayla, RKB), Dawn (Kelwa)	Village; Town	Not given		Attacked and tried to kill a cow's calf but spotted (Dhayla), killed 4 goats in raoji ka bariya, killed a cow in kelwa	
T27	Dead Leopard	18-Feb-16	Sukh naka, Jojawar forest range (Bhim)	Girwa (Udaipur) & Bhim (Rajsamand)	Night (Jojawar)	Cropfield; Forest	Female cub (Both cases)		**Female leopard cub (1.5 years old)** found dead in a well in a farm house in sukha naka; **female leopard cub (2 years old)** got hit by a vehicle in jojawar forest range near bhim and died	
T28	Captured	20-Feb-16	Sabla	Aspur (Dungarpur)	Not given	Village	Male	Livestock attack	Captured by FD, was killing livestock in the area	
T29	Human attack	21-Feb-16	Jhabra	Shergarh (Jodhpur)	Not given	Cropfield	Not given		Attacked on a female and 3 others in cropfields and forest, capture ops are failing	Female; Not given
T30	Rescued	22-Feb-16	Jaisinghpura khor	Jaipur urban	Dawn	Village	Female		Found trapped ina poachers iron trap near jogiyo ki dhani, spotted by villagers and rescued by FD	

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
T31	Leopard sighting	23-Feb-16	Ramgarh	Raipur (Pali)	Day	Open field	Not given		Leopard spotted by villagers which later vanished away, very poor FD resources in the area	
T32	Dead Leopard	23-Feb-16	Amartiya	Kumbhalgarh (Rajsamand)	Not given	Village	Female		Leopard killed in a road accident	
T34	Rescued	26-Feb-16	Banrol	Rajsamand	Dawn	Cropfield	Cub		**Leopard cub (3 months old)** found alone near cropfields by villagers and rescued by them, later they informed FD about the incident and will be released in the same forest later, separated from his mother the previous night.	
T35	Dead Leopard	26-Feb-16	Jhadoli	Dhariyawad (Pratapgarh)	Dawn	Forest	Female		Leopard killed in a road accident	
T36	Livestock attack; Rescued	29-Feb-16	Kodwadiya nayaghar, Mawli road, Rajsamand/ Viyal (Badgaon)	Nathdwara (Rajsamand) & Bargaon (Udaipur)	Dawn (Rajsamand), Night (Udaipur)	Cropfield; Village	Not given		Leopard trapped in an iron trap installed by poachers near a cropfield in kodwadiya, Nathdwara, Rescued by FD on time and taken to udaipur for medical care; Leopard entered a goshala in Vviyal village and attackedand killed 2 **cows and a calf,** escaped later on without the kill.	
T37	Leopard sighting	Feb-16	Rajaliya	Nawa (Nagaur)	Dusk	Forest	Not given			
T38	Livestock attack	Feb-16	Degana	Degana (Nagaur)	Dusk	Forest	Not given		Many sheep and goats killed by leopard in theforest , owner was not there, happened nearby degana	
T39	Dead Leopard	02-Mar-16	Salawali	Neem ka thana (Sikar)	Not given	Open field	Not given		5-7 years old leopard found dead, reason of death is inconclusive	
T40	Human attack	04-Mar-16	Mandak ka gurha	Khamnor (Rajsamand)	Night	Village	Not given		Attacked on a male and a female inside the house and escaped	Male; Adult; Female; Adult
T41	Leopard sighting; Dead Leopard	04-Mar-16	Asan (Garhi range); Saredi	Garhi (Banswara)	Not given	Cropfield	Female cub (Asan), Female with cubs (Saredi)		**Female leopard cub** found dead in an iron trap in a cropfield, wires slither throat, FD not sure yet whether trap was installedfor a leopard (Asan) ; **FD spotted a female leopard with her cubs in Saredi just a few days back.**	
T42	Human attack; Dead Leopard	05-Mar-16	Bujhra	Deogarh (Rajsamand)	Day	Cropfield	Not given		In afternoon, **Leopard attacked on a girl in the cropfield, she cried and family came started beating the leopard with sugarcane sticks till death, victim girl lived.**	Male; Adult; Female; Young
T43	Human attack	05-Mar-16	Umri	Mandal (Bhilwara)	Day	Cropfield	Not given		**Leopard attacked on a female when she was working in the cropfield in the afternoon and then attacked on another male who came in defense, both victims lived.**	Male; Adult; Female; Adult
T44	Human attack	05-Mar-16	Bansiya	Simalwara (Dungarpur)	Day	Village	Not given		**Leopard attacked a wardpanch in afternoon when he went for bathroom in the open** behind atal sewa kendra, bansiya, Later the leopard hid in the nearby wooden block and **continuously got pelted by stones from villagers**, FD arrived late and big ruckus went on, scared leopard attacked on a FD worker too, details of capture not given	Male; Adult

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
T45	Leopard sighting	06-Mar-16	Gudla ; Barar	Nathdwara & Bhim (Rajsamand)	Night & Dawn (Gudla), Night (Barar)	Cropfield; Village	Not given		Leopard spottedin a **wheat cropfield** in midnight at gudla who was found in an abandoned house next morning, villagers got curious to see by themselves causing risk of attack; Leopard spotted by aa male outside his house when he went for a bathroom in the midnight , nothing else happened.	
T46	Leopard sighting	07-Mar-16	Maldeta	Baytoo (Barmer)	Day	Village	Not given		Leopard entered in an under construction home and spotted in the afternoon by the workers, **FD informed but arrived late and arranged a rescue operation till evening, leopard vanished from the home.**	
T47	Human attack	08-Mar-16	Seengatwara	Sarada (Udaipur)	Day	Cropfield	Not given		**Leopard attacked 3 males in the afternoon in a wheat cropfield,** victims lived, FD informed, came late and rescue operation was too loose, Leopard vanished away.	Male; Adult
T48	Rescued	09-Mar-16	Ghat ke balaji, Galata	Jaipur urban	Dawn	Forest	Cub		**Leopard cub** spotted by two civilians at ghat ke balaji who got separated from his mother, Rescued by FD and taken to Jaipur zoo instead of searching for the mother.	
T49	Leopard sighting	09-Mar-16	Seengatwara	Sarada (Udaipur)	Dawn	Cropfield	Not given		Probably the same leopard which attacked 3 males earlier here	
T50	Livestock attack	11-Mar-16	Samod	Chomu (Jaipur)	Night	Village	Not given		Multiple livestock kill by Leopard, Killed **dog** too, Pugmarks found near Police station.	
T51	Livestock attack	12-Mar-16	Ramoravrali		Night	Cropfield	Not given		Leopard attacked and killed livestock and pet **dog** too in the night, **FD informed but totally unreliable, None arrangements were made.**	
T52	Human attack	15-Mar-16	Tejafala (Salumbar)	Salumbar (Udaipur)	Day	Cropfield	Not given		**Leopard attacked 4 villagers who were working in the cropfields in the afternoon, Later attacked FD guard too, all victims lived.**	Male; Adult
T53	Human attack	16-Mar-16	Nithaua	Aspur (Dungarpur)	Day	Village	Not given		Leopard came into the village in the afternoon and attacked few people in the ruckus, escaped away.	Not given; Not given
T54	Captured	16-Mar-16	Shrimadhopur	Sri madhopur (Sikar)	Not given	Town	Not given	Human attack	found inside a house in shrimadhopur	
T55	Livestock attack	19-Mar-16	Padakhora	Pratapgarh	Night	Village	Not given		Killed a goat and cow	
T56	Rescued	22-Mar-16	Raiyana (Babakua forest)	Garhi (Banswara)	Dawn	Cropfield	Cub		**Leopard cub (weeks old) found in a corn cropfield** in the morning by the villagers who got seaparated from his mother previous night, babakua forest is just nearby, FD informed who waited for mother to come and rescue her cub.	
T57	Human attack	Mar-16	Goma ka bariya	Mandal (Bhilwara)	Dusk	Village	Not given		Leopard entered in the village in the evening and attacked on few people, ruckus created, later escaped into the forest	Male; Adult
T58	Leopard sighting	Mar-16	Gyangarh	Mandal (Bhilwara)	Not given	Village	Not given		Leopard spotted by a male and then he instantly ran away inside a room, leopard was just standing there and went back into the forest.	

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
T59	Livestock attack	Mar-16	Mandal	Mandal (Bhilwara)	Not given	Town	Not given		Killed a cow's calf	
T60	Leopard sighting	03-Apr-16	Nareli	Mandal (Bhilwara)	Day	Mines	Two cubs			
T61	Leopard sighting	04-Apr-16	Thurpal pahadi, Palthur- dhendlawa	Aspur (Dungarpur)	Not given	Open field	Female with two cubs		**Female leopard with her 2 cubs** was spotted by few people on thurpal pahadi, they went near to scare her away and mother attacked in defense.	
T62	Leopard sighting; Livestock attack	05-Apr-16	Naka bazar bridge, Seenghatwara; Maruwas	Sarada & Mavli (Udaipur)	Night (Maruwas)	Village	Not given		Leopard spotted by people in naka bazaar bridge at singhatwara for two consecutive days who killed a stray **cow** over there, **stones pelted by the people to scare it away; Leopard killed a cow's calf in a livestock shed in the night**	
T63	Leopard sighting	07-Apr-16	Malka khera	Asind (Bhilwara)	Dawn	Village	Not given		Leopard entered in the village, ruckus happened whereby many **people pelted sticks and stones towards the leopard and locked it inside a bathroom and called FD.**	
T64	Human attack	09-Apr-16	Khamnor	Khamnor (Rajsamand)	Night	Cropfield	Not given		Leopard sneaked in midnight in a **sugarcane cropfield** and **took a boy who was sleeping their with his parents in the midnight, killed him**, family woke up and spotted leopard nearby the deadbody who immediately escaped away.	Male; Infant
T65	Livestock attack	10-Apr-16	Badnor	Asind (Bhilwara)	Night	Cropfield; Village	Not given		Two cases whereby leopard killed a **cow** in a livestock shed and in another one killed a **goat** in a cropfield in the night.	
T66	Leopard sighting	10-Apr-16	Khamnor	Khamnor (Rajsamand)	Dusk	Cropfield	Not given		Leopard again spotted inside the **sugarcane cropfields, killed a boy a few days a back.**	
T67	Livestock attack	10-Apr-16	Anandsagar forest area	Banswara	Night	Forest	Not given		Killed a goat	
T68	Human attack	13-Apr-16	Magrawali thori	Sarada (Udaipur)	Dusk	Open field	Not given		Leopard entered in a livestock shed but got noticed so villagers chased it to the mountains to beat and got attackd by the leopard , none killed, past killings of livestocks happened.	Male; Adult; Male; Young
T69	Dead Leopard	15-Apr-16	Bokarsel	Aspur (Dungarpur)	Not given	Open field	Not given		Dead body found in a very poor state, sex could not be identified	
T70	Human attack	16-Apr-16	Harnawada shahji	Chhipabarod (Baran)	Dawn	Cropfield	Not given		**Leopard attacked on a female inside a eggplant cropfield while she was working, attacked few others and FD after ruckus and escaped, none killed, FD failing to capture.**	Female; Adult
T71	Leopard sighting	18-Apr-16	Rathodo ka guda (Shishoda)	Khamnor (Rajsamand)	Dawn	Open field	Not given		Leopard spotted by the villagers on nearby mountain in the morning, **they tried to chase it and beat it with sticks and stones, leopard escaped away.**	
T72	Livestock attack	19-Apr-16	Chat sardarpura	Nasirabad (Ajmer)	Dawn	Village	Not given		Killed a cow's calf	
T73	Leopard sighting; Livestock attack	28-Apr-16	Bagatpura	Railmagra (Rajsamand)	Day	Cropfield	Not given		Leopard spotted by a villager who was working in his **fodder cropfield** in the afternoon, other one claimed that leopard eaten his **two dogs and two cow's calves**	

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
T74	Livestock attack	28-Apr-16	Parda sakani	Aspur (Dungarpur)	Night	Village	Not given		Killed a goat	
T75	Leopard sighting	Apr-16	Ganoda	Ghatol (Banswara)	Dusk	Village	Not given		Villagers scared away the leopard which then escaped away	
T76	Human attack	Apr-16	Tetiyadev forest area, Kushalgarh	Kushalgarh (Banswara)	Day	Forest	Not given		**Leopard attacked on an old shepherdwho was in the forest for herding activity, victim lived**	Male; Adult
T77	Livestock attack	Apr-16	Biliyawas	Bhim (Rajsamand)	Not given	Forest	Not given		Killed a goat, Owner was not there	
T78	Dead Leopard	Apr-16	Shripura forest chowki, Chittorgarh road		Night	Forest	Female		Killed in a road accident	
T79	Livestock attack	Apr-16	Bherukheda	Deogarh (Rajsamand)	Day	Cropfield	Female		**Female leopard attacked on a goat in a cropfield and hid in a nearby canal for whole day, FD arrived very late and while rescuing in the night, leopard ran away in to the forest**	
T80	Human attack	Apr-16	Navaghara	Garhi (Banswara)	Day	Cropfield	Not given		**Leopard attacked 2 males in a sugarcane cropfield** and hid in a tree, **FD failing to capture and later on leopard escaped into the forest.**	Male; Adult; Male; Young
T81	Leopard sighting; Rescued	04-May-16	Deoriya (Kunwariya)/ Hindustan zinc road (Sakroda)	Deogarh (Rajsamand), Girwa (Udaipur)	Not given	Village; Forest	Cub (Deoriya)		**Leopard cub (1 year old) fallen in a well and later rescued by FD, will be released in the forests (not mentioned) (Deoriya)/ Two leopards been spotted at Hindustan zinc road near sakroda**	
T82	Rescued	06-May-16	Kankroli town	Rajsamand	Day	Town	Cub		**4 months old leopard cub came at JK KANKROLI ROAD in the afternoon , got separated from the mother, FD could not resuce the cub for hours, very unreliable.**	
T83	Leopard sighting	09-May-16	Taragarh- Happy valley	Ajmer	Not given	Forest	Not given		Leopard spotted at the mentione area by two males with a goat catch, escaped away after getting noticed.	
T84	Livestock attack	14-May-16	Teori	Viratnagar (Jaipur)	Night	Village	Not given		**Attacked a cow's calf but got spotted by villagers , they pelted stones and leopard ran away without the calf**	
T85	Dead Leopard	17-May-16	Kachabali	Bhim (Rajsamand)	Not given	Village	Not given		**Two males killed a leopard (1.5 years old) in huge retaliation , All theothers enjoyed it , clicked selfies with the dead leopard, FD being questioned.**	
T86	Rescued	29-May-16	Lakarwas	Girwa (Udaipur)	Dawn	Cropfield	Female		**Female leopard (2 years old)** found by the villagers in a deep injured state, informed FD and rescued, taken to udaipur biological park for medical care, Leopard was highly injured and famished.	
T87	Human attack	04-Jun-16	Indali	Jhunjhunu	Dawn	Cropfield	Not given		**Attacked a male in millet cropfield**	Male; Adult
T88	Human attack; Captured	06-Jun-16	Keharpura kalan	Chirawa (Jhunjhunu)	Not given	Cropfield	Not given	Human attack	FD teams from Jaipur and sariska capture the same leopard from keharpura kalan in a **millet cropfield**, reported to have attacked another male on second day	Male; Not given
T89	Human attack	07-Jun-16	Dholiya	Lasadiya (Udaipur)	Night	Cropfield	Not given		**Leopard sneaked in a house and took a 7 year old girl while she was sleeping at midnight, girl died**	Female; Young

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T90	Livestock attack	28-Jun-16	Akodara	Vallabhnagar (Udaipur)	Dawn	Village	Not given		Killed 3 cows	
T91	Rescued	29-Jun-16	Tonk	Tonk	Not given	Not given	Not given		**Leopard beaten badly by the people till almost died,** FD rescued and took it to jaipur zoo for medical care	
T92	Human attack	Jun-16	Lauwa	Salumbar (Udaipur)	Dawn	Village	Not given		**Leopard attacked on a 8 year old boy and his uncle came for defense, leopard escaped away.**	Male; Adult; Male; Young
T93	Dead Leopard	Jun-16	Jhali ka gurha	Girwa (Udaipur)	Night	Village	Not given		Leopard entered inside the village in night, villagers instantly started pelting stones deeply injuring the leopard and ultimately killed and torched it, **FD totally unreliable, did nothing**	
T94	Dead Leopard	Jun-16	Khole ke Hanumanji temple	Jaipur urban	Not given	City	Cub		**Leopard cub** found dead in the parking of mentioned area, no injuries or disease found , probably died due to hunger and thirst, Jhalana is nearby	
T95	Dead Leopard	Jun-16	Aamkha jhahira, Masalpur	Karauli	Not given	Not given	Not given		Leopards found dead atboth the respective places, FD being questioned as they did not have any information regarding this, do not even have idea of cause of deaths	
T96	Human attack	Jun-16	Jhanjhar mines, Kelwa	Rajsamand	Not given	Town	Not given		Leopard attacked on an old male and escaped away, victim lived	Male; Adult
T97	Human attack	Jun-16	Chitar ki nal (Kumbhalgarh)	Kumbhalgarh (Rajsamand)	Night	Village	Not given		Attacked and killed a girl	Female; Young
T98	Rescued	12-Jul-16	Bahadurpura	Abu road (Sirohi)	Dawn	Cropfield	Female		**Female leopard cub (1.5 years old) fallen in a well in a cropfield, Rescued by FD team from udaipurand taken to Mount abu for medical care, will be released in Abu forest.**	
T99	Dead Leopard	18-Jul-16	Sundarcha	Rajsamand	Not given	Open field	Male		**Male leopard (5years old)** found dead in a bad condition, **All nails were gone so probably poached.**	
T100	Livestock attack	25-Jul-16	Thola ghata		Night	Village	Adult with a cub		Killed 16 goats	
T101	Leopard sighting	Jul-16	Hareli (Karanpur)	Garhi (Banswara)	Dusk	Village	Not given		Leopard spotted by villagers in the evening, nothing happened, FD informed but no reply from their side	
T102	Rescued	Jul-16	Leelera (Delwara)	Girwa (Udaipur)	Dawn	Village	Not given		Leopard hit by a vehicle on highway, rescued and taken to sajjangarh biological park for medical care	
T103	Human attack; Captured	21-Oct-16	Bhadach, Doomroli	Thanagazi and Behror (Alwar)	Dusk (Bhadach)	Cropfield	Not given	Human attack	**Leopard attacked and killed a female working in a cropfield in the evening in Bhadach; earlier a leopard also killed a male in Doomroli again in a cropfield, that leopard was captured by FD**	Male; Adult; Female; Adult
T104	Human attack	31-Oct-16	Aamka	Thanagazi (Alwar)	Dawn	Open field	Not given		**Leopard attacked a female while she was defecating in the morning, victim lived**	Female; Adult
T105	Livestock attack	07-Nov-16	Sherawatwara, (Debari)	Girwa (Udaipur)	Night	Town	Leopard couple with two cubs		Killed goats and cow's calf	

Unique ID	Type of incident	Date published	Village name	Tehsil/District	Time of incident	Habitat/Area	Sex of leopard	Reason for capture	Comments	Description of human attacks
T106	Captured	06-Nov-16	Narsingh basni	Riyan badi (Nagaur)	Dawn	Cropfield	Not given	Leopard sight	Leopardspotted by a male in cropfield in the morning, rescue team came from jaipur and captured it, will be released in Todgarh wildlife sanctuary	
T107	Rescued	11-Nov-16	Aamka	Thanagazi (Alwar)	Not given	Village	Not given		Highly injured leopard found in aamka, rescued and taken to jaipur for medical care, **probably beaten by sticks and stones from villagers, head was totally injured**	
T108	Leopard sighting	26-Nov-16	Cement factory	Sawai madhopur	Night	Power plant	Leopard couple with two cubs			
T109	Captured	26-Nov-16	Jatav basti bharatpur	Bharatpur	Dawn	City	Male	Leopard sight	**Male leopard spotted by a male in the morning while and leopard attacked in reflex, ruckus created and after so much time rescued by FD and transferred to sariska tiger reserve.**	
T110	Leopard sighting	Nov-16	Duwawa	Chiitorgarh	Dusk	Cropfield	Not given		Leopard spotted by male in a cropfield, leopard then hid in a tree and stayed there for hours, FD keeping a check of any bad happening, nothing happened	
T111	Dead Leopard	01-Dec-16	Khadki bridge, Sendra	Raipur (Pali)	Dawn	Forest	Not given		**Leopard (5 years old) found dead with injuries over the body and lost nails, a goat dead body was also lying nearby but not injured at all, probably killed by poachers/villagers.**	
T112	Rescued	22-Dec-16	Dasaliya forest range, Dabi	Bundi	Day	Forest	Male		**Male leopard (7 years old)** found trapped in an iron trap installed by poachers/hunters, rescued by FD and taken to kota zoo for medical care.	
T113	Leopard sighting	23-Dec-16	Rajasthan university	Jaipur urban	Dawn	City	Cub		**Rescued by FD**	
T114	Leopard sighting	23-Dec-16	Purani ghati, Shahabad	Shahabad (Baran)	Not given	Forest	Not given		**Multiple sights of leopard at purani ghati of shahabad, good news for wildlife lovers and others, people seems to be happy.**	
T115	Leopard sighting	30-Dec-16	Ajitgarh	Sri madhopur (Sikar)	Night	Town	Not given		Leopard spotted in CCTV camera in the midnight at ajitgarh	
T116	Leopard sighting	Dec-16	Sarangpura	Vallabhnagar (Udaipur)	Day	Cropfield	Not given		Leopard spotted by villagers in **mustard cropfield**, FD arrived and keeping a check, Leopard escaped away	
T117	Dead Leopard	Dec-16	Hameerpur (Bansur)	Bansur (Alwar)	Dusk	Village	Not given		Leopard found dead, no injuries on the body, **villagers informed FD of leopard spotting few days back but was not captured**	
T118	Leopard sighting	Dec-16	Sports complex, Rajasthan University	Dawn	Residential area	City				

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COMMUNICATION

Bat diversity in the Banpale forest, Pokhara, Nepal during spring season

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Abstract: Bat research in Nepal is limited and most areas remain to be explored. Sparse research has been conducted in the Banpale forest and to improve the understanding of bat diversity, an updated species checklist was prepared. Trapping surveys using mist nets were conducted at four different locations in the forest from March to May 2018. This survey identified 55 individuals belonging to eight species within eight genera and four families. Trapping locations near less disturbed forest edges and water resources were found to have higher bat diversity compared to highly disturbed areas (e.g., landslides and logging areas). With information from survey and secondary source, we conclude that Banpale forest harbours 10 of the 53 bat species found in Nepal. We recommend adopting practices to conserve the forest from landslides and minimizing illegal logging to conserve bat forest habitats.

Keywords: Checklist, Chiroptera, edge, habitat, logging, trapping.

Nepali: नेपालमा चमेरा अनुसन्धान केहि अध्ययनमा मात्र सीमित छन् र अधिकांश क्षेत्रहरु अन्वेषण गर्नै बाँकी छन् । वनपाले जंगलमा पनि अनुसन्धानका कार्यहरु अत्यन्तै न्यून हुने गरेकाले हामीले यहाँको चमेरा विविधता बुझ्न चमेरा प्रजातिको सूची अद्यावधिक गरेकाछौं । २०१८ मार्च देखि मे महिनामा वनपाले जंगलको चार विभिन्न स्थानमा मिस्टनेट प्रयोग गरेर गरिएको सर्वेक्षणमा हामीले चार परिवार, आठ जेनेरा तथा आठ प्रजातिका जम्मा ५५ वटा चमेराहरू पकड्यौं । यस अनुसन्धानमा पहिरो तथा वनफँडानी भएका क्षेत्रको तुलनामा मानव हस्तक्षेप न्यून भएका वनको किनारा/छेउ र पानीका मुहान नजिक चमेराका प्रजाति बढी भेटिए । प्राथमिक र द्वितीय श्रोत अध्ययन परिणाम अनुसार नेपालमा पाइने कुल ५३ प्रजाति मध्ये वनपालेमा १० वटा चमेरा प्रजाति पाइने पुष्टि भएको छ । यस अध्ययन अनुसार चमेराको वासस्थान बचाउन वनपाले जंगलमा पहिरो विरुद्ध संरक्षणका अभ्यासहरु अपनाउनुपर्ने तथा अवैध वन विनास नियन्त्रण गर्नुपर्ने देखिन्छ ।

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INTRODUCTION

Bats (Chiroptera) are highly diverse (Hutson et al. 2001; Voigt & Kingston 2016) and found throughout the globe, except in the Antarctic and a few oceanic Islands (Mickleburgh et al. 2002). They provide many ecological and economic services such as pollination, seed dispersal, agricultural pest suppression, and material & nutrient distribution (Fujita & Tuttle 1991; Kunz et al. 2011). Of the >1400 species of bats found worldwide (Simmons & Cirranello 2021), 148 are reported from southern Asia (Srinivasulu et al. 2021).

Research and conservation efforts in Nepal's mammals are focused on large flagship vertebrates like tigers, rhinoceros, elephants, and snow leopards, and comparatively limited research has been conducted on small mammals such as bats (Acharya et al. 2010; Khanal & Baniya 2018). Thus, there has been limited evaluation of bat species diversity and status in Nepal (Csorba et al. 1999; Hutson et al. 2001; Molur et al. 2002; Acharya & Ruedas 2007; Baral & Shah 2008; Adhikari 2009; Acharya et al. 2010; Jnawali et al. 2011; Pearch 2011; Thapa 2014). Although the latest checklists enumerated 53 bat species from Nepal (Acharya et al. 2010; Thapa 2010), a few identifications were questioned, e.g., *Sphaerias blanfordi* (Thomas, 1891), *Myotis siligorensis* (Horsfield, 1855), and *Rhinolophus subbadius* Blyth, 1844 (Pearch 2011; Thapa 2014). Similarly, species previously identified as *Philetor brachypterus* (Temminck, 1840) from southern Asia was also revised to be *Mirostrellus joffrei* (Thomas, 1915) (Görföl et al. 2020). While many parts of the country are largely unexplored for bat research, recently a few expedition surveys have documented new species, e.g. , Thapa et al. (2012a) recorded *Scotozous dormeri* Dobson, 1875 from Koshi Tappu Wildlife Reserve; Sharma et al. (2019) recorded *Tylonycteris fulvida* (Blyth, 1859) from Kushma, Parbat and Sharma et al. (2021) recorded *Tadarida teniotis* Rafinesque, 1814 from Kali Gandaki canyon. Incorporating species revisions and recent findings, we ensure a current count of 53 valid bat species in Nepal.

Due to favourable climatic and topographical features, Pokhara has several caves, lakes, gorges, forests, and agricultural farms which provide suitable habitats for diverse bat species (Koju & Chalise 2012). A few exploration attempts were made in Pokhara valley in the late 20th century (Abe 1971; Bates & Harrison 1997; Csorba et al. 1999). Since then, other studies were conducted (Acharya 2006; Phuyal & Dhoubhadel 2006; Rajchal 2007; Adhikari 2008; Giri 2009; Bista 2011; Koju & Chalise 2012; Pokhrel & Budha 2014; Sharma 2016, 2019; Baniya 2018; Sharma et al. 2018a,b; Baniya et al. 2019) but most remain unpublished (e.g., in student theses). Adhikari (2008) and Giri (2009) reported 18 bat species, 16 caves, and two roosting sites of *Pteropus giganteus* (Brünnich, 1782) from the Pokhara valley. Pokhrel & Budha (2014) studied food habit of insectivore species from Mahendra cave. Sharma (2016) conducted diet analysis of *Pteropus giganteus* from Chinnedanda and later Sharma et al. (2018b) reported colony shift to new location, Shantiban Batika. Recently, two bat species—*Eonycteris spelaea* (Dobson, 1871) and *Rhinolophus luctus* Temminck, 1834—were recorded for the first time in western Nepal from the Banpale forest (Sharma et al. 2018a; Baniya et al. 2019). Further, colony monitoring and effects of visitor disturbances on *Hipposideros armiger* (Hodgson, 1835) have been studied in a bat cave, Pokhara (Baniya 2018; Sharma 2019). Although research and conservation attempts were made for bats of the Pokhara valley, actual species richness is still unknown and requires enumeration.

As Banpale forest lies within the boundary of the Institute of Forestry, Pokhara, it has been a hub for wildlife research and training programs. A few camera trapping, butterfly, and bird surveys have been conducted in the forest (Lama et al. 2013; Panthee et al. 2018, 2019); however, extensive research predominantly focusing on chiropterans is limited. Few occasional trapping and acoustic surveys were conducted in the forest (e.g., Daniel 2007a,b; Adhikari 2008; Giri 2009; Lama et al. 2013; Bhattarai 2019). These studies documented a few bat species: *Cynopterus sphinx* (Vahl, 1797), *Pteropus giganteus*, *Rhinolophus affinis* Horsfield, 1823, *Rhinolophus subbadius*, *Kerivoula picta* (Pallas, 1767), *Pipistrellus pipistrellus* (Schreber, 1774), *Pipistrellus coromandra* (Gray, 1838), *Miniopterus pussilus* (Dobson, 1876). This study was carried out to assess bat species diversity and update the valid bat checklist in the Banpale forest.

MATERIALS AND METHODS

Study area

The study was conducted in Banpale forest, Institute of Forestry, Pokhara, Tribhuvan University (28.18°N, 83.99°E), south-west of Pokhara metropolitan city-15. The institution covers 15ha of campus premises and 31.85ha of forest patches. The study site ranges from 750–915 m (Figure 1). Banpale forest is pristine subtropical mixed forest dominated by *Schima wallichii* and *Castanopsis indica*. Other species include, *Madhuca*

indica, *Diospyrus melabaricum, Dalbergia sisso*, *Michelia champaca*, *Bambusa* sp., and *Albizia* sp. A total of 112 florae species have been reported from the area (Bhatta 2011). It is surrounded by the agricultural and grazing lands, shrubs & human settlements in the north, south & east, and gorges, crevices, rocky slopes, river & landslide areas in the west. Average daily temperature in the valley ranges 25–33 °C in summer and -2–15 °C in winter (Kansakar et al. 2004) and receives mean annual precipitation of <3,000mm (Khanal 1995).

Methods

Trapping survey

The forest was divided into four different trapping sites; site A (28.188^{0}N, 83.988^{0}E), site B (28.186^{0}N, 83.990^{0}E), site C (28.186^{0}N, 83.989^{0}E), and site D (28.192^{0}N, 83.984^{0}E), and surveyed randomly once in 15 days from 15 March to 15 May 2018. In each site, two sizes of mist-nets (height 2.6m, length 4m and 6m, and 38mm mesh) were deployed >30cm from the ground level. Mist-nets were left open from 18.00 to 22.00 h with continuous inspection at 10-minute intervals to avoid serious entanglement of captured bats.

Morphometric measurement of bats

Vernier calipers (0.01mm accuracy) were used to record external morphometric measurements. The measurements taken include the head and body length (HBL), forearm length (FA), ear length (EL), tail length (TL), hind foot length (HF), and tibia length (TIB) (Bates & Harrison 1997). The body weight (BW) was measured using a pesola spring balance (1g accuracy). Bats were released after identifying their sex and age (Kunz & Parsons 2009) and capturing a few close up photographs with minimal disturbance. Aggressive and difficult to handle bats were released as soon as possible after identification. No voucher specimens were collected and no genetic analysis was performed during the study.

Identification of bats

Captured individuals were observed for key morphological characteristics. Identification was based on the morphological measurements (Table 1) and comparing photographs using available reference guides

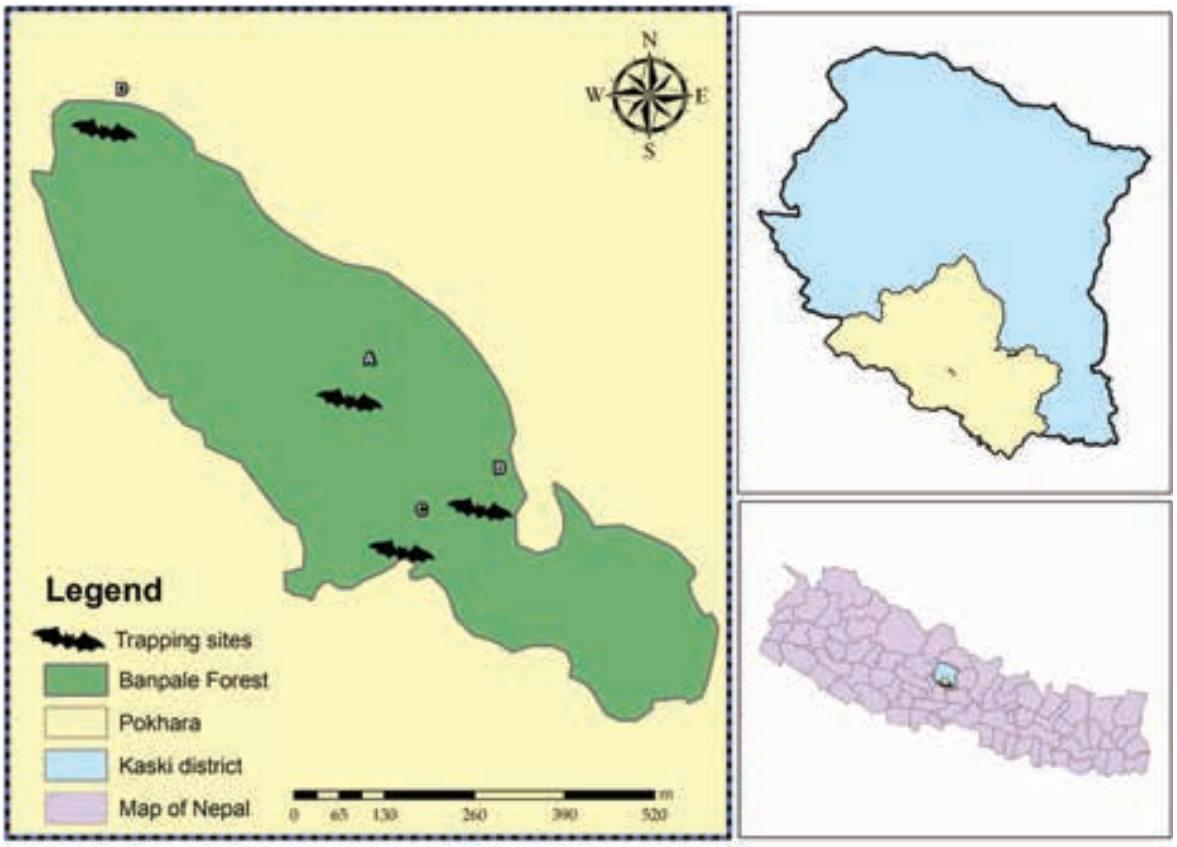

Figure 1. Map of study area showing four different sites at Banpale forest, Pokhara, Nepal. Note: A, B, C, D indicates different trapping sites inside Banpale forest where "A" is near the water resource in the middle of the forest; "B" is forest trail near the edge between forest, college quarter, and nursery; "C" is edge between forest and human settlements and "D" is near a landslide area.

and morphological keys (Bates & Harrison 1997; Acharya et al. 2010; Srinivasulu et al. 2010; Menon 2014).

Secondary data collection

Several published and unpublished reports, journal articles, newsletters, student thesis, and websites were reviewed to update the valid bat checklist in the Banpale forest.

Data analysis

Shannon diversity index (*H*) (Shannon & Wiener 1949) was calculated to understand species diversity in different trapping sites.

Shannon index (*H*) $= -\sum p_i Inp_i$

Where $p_i = \frac{S}{N}$

S = Number of individuals of one species
N = Total number of individuals captured
In = Logarithm to base e

Pielou's evenness (*J*) was calculated to compare the actual diversity value (the Shannon index, *H*) to the maximum possible diversity value (when all species are equally common, $H_{max} = InS$).

$$J = \frac{H}{H_{max}} \text{ Or } \frac{H}{InS}$$

Where *H* = Shannon index value
H_{max} = Maximum possible diversity value
S = Total number of species

RESULTS

Altogether 55 individuals were captured from four family and eight genera. Among them, eight bat species were identified while 10 individuals of *Pipistrellus* sp. remained unidentified to species level (Table 1, 2). Most of the captured species belonged to family Pteropodidae (3) and Vespertilionidae (3), followed by Rhinolophidae (2); only one species of Hipposideridae was recorded (Table 1). *Cynopterus sphinx* was the most captured (42%) followed by *Pipistrellus* sp. (18%), *Rousettus leschenaultii* (13%), *Hipposideros armiger* (9%), *Rhinolophus affinis* (9%), and *Nyctalus noctula* (3.6%); *Eonycteris spelaea*, *Rhinolophus luctus*, and *Myotis sicarius* were each captured once (Table 2). Although *Pteropus giganteus* was uncaptured, it was observed travelling to fruiting sites through the edge of Banpale forest around 18.45h hours during the study period.

Most of the bats were captured from site A (49%) followed by site B (36%), whereas only 9% of bats were captured from site C, and lowest 5.5% from site D (Table 2). Although site B was the second most captured site, bat diversity and evenness were highest among other sites (*H*= 0.37, J= 0.17) followed by site A (*H*= 0.35, J= 0.16), site C (*H*= 0.22, J= 0.10), and lowest in site D (*H*= 0.16, J= 0.07) (Table 2). The overall bat diversity of the forest was 1.1 and evenness was 0.5 (Table 2).

Based on the survey and literature review, the study confirmed and updated checklist of 10 bat species from the Banpale forest (Table 3). Out of these, four species are Pteropodidae belonging to four genera (*Cynopterus*, *Eonycteris*, *Pteropus* and *Rousettus*), three are Vespertilionidae with three genera (*Pipistrellus*, *Myotis* and *Nyctalus*), two are Rhinolophidae with genera *Rhinolophus*, and one Hipposideridae with genera Hipposideros (Table 3).

DISCUSSIONS

Of 10 bat species identified in this study, all (4) fruit bat species of Nepal were documented from the Banpale forest. At least one fruit bat was captured from each trapping site, reflecting their high activity in the forest. *Cynopterus sphinx* was captured the most, whereas *Eonycteris spelaea* was captured only once. Apart from forest vegetation, Banpale is also surrounded by several varieties of fruits inside the Institute of Forestry premises, e.g., *Diploknema butyracea, Diospyros malabarica, Psidium guajava, Magnifera indica, Bombax ceiba, Elaeocarpus sphaericus, Litchi chinensis, Musa* sp., *Oroxylum indicum* and *Neolamarckia cadamba.* These fruit plants are the most preferable diet for fruit bats in Nepal (Sharma 2016), whereas species like *Musa* sp., and *Schima wallichii*, abundant in the forest, are preferred roosts for the tent making bat, *Cynopterus sphinx* (Acharya et al. 2010). As *Pteropus giganteus*, whose nearby colony is 3.1km away, was observed travelling through the edge of the forest for foraging, perhaps cave dwelling bat species; *Rousettus leschenaultii* and *Eonycteris spelaea* also use Banpale forest as foraging route, as there is no cave in the forest (Sharma et al. 2018a). Similarly, the foliage roosting bat *Cynopterus sphinx* may use the forest as roosting site, since it has smaller foraging range (Marimuthu 1998; Nair et al. 1999) and was previously recorded roosting in *Schima wallichii* in the forest (Giri 2009). The forest vegetation is likely to host suitable roosting sites for this species. Hence, the varieties of food resources around

Table 1. Morphometric measurements of captured bats from the Banpale forest, Pokhara, Nepal. Range value (r), mean value (m) and standard deviation (sd) value of each morphometric measurements (in mm); forearm length (FA), head-body length (HBL), hindfoot length (HF), ear length (EL), tail length (TL), tibia length (TIB), and body weight (BW) (in gm) of each species is provided in brief. "n" indicates total number of individuals measured and remarks includes key identifying feature of the species.

	Pteropodidae			Rhinolophidae		Hipposideridae	Vespertilionidae		
Species **Measurements**	*Cynopterus sphinx* (n= 23)	*Eonycteris Spelaea* (n= 1)	*Rousettus leschenaultii* (n= 7)	*Rhinolophus affinis* (n= 5)	*Rhinolophus luctus* (n= 1)	*Hipposideros armiger* (n= 5)	*Nyctalus noctula* (n= 2)	*Myotis sicarius* (n= 1)	*Pipistrellus* sp. (n= 10)
FA	r= 59.3–69.3 m= 64.9 sd= 3.6	71.3	r= 75.1–84.2 m= 79.1 sd= 4.0	r= 52.3–53.8 m= 52.9 sd= 0.7	70.5	r= 83.7–86.5 m= 84.8 sd= 1.3	r= 53.5–55.3 m= 54.4 sd=1.3	46.4	r=2 7.8–28.8 m= 28.3 sd= 0.4
HBL	r= 83.1–99.6 m= 91.7 sd= 5.4	99.5	r= 95.5–114.2 m= 104.4 sd= 8.1	r= 60.7–62.9 m= 61.6 sd= 1.0	81.7	r= 91.5–94.6 m= 92.5 sd= 1.4	r= 72.5–73.2 m= 72.9 sd= 0.5	57.0	r= 40.2–44.9 m= 42.9 sd= 2.0
HF	r= 10.5–14.1 m= 11.9 sd= 1.2	17.9	r= 15.1–17.3 m= 16.1 sd= 0.8	r= 7.9–9.3 m= 8.4 sd= 0.8	16.3	r= 13.1–15.1 m= 13.9 sd= 0.9	r= 10.1–10.5 m= 10.3 sd= 0.3	15.8	r= 5.1–5.8 m= 5.4 sd= 0.3
EL	r= 18.3–24.1 m= 21.3 sd= 2.1	19.9	r= 14.5–18.8 m= 17.1 sd= 1.6	r= 13.9–15.5 m= 14.6 sd= 0.8	34.2	r= 24.1–29.7 m= 26.3 sd= 2.5	r= 14.1–14.8 m= 14.5 sd= 0.5	15.0	r= 8.1–9.5 m= 8.8 sd= 0.6
TL	r= 7.7–18.1 m= 12.0 sd= 3.4	10.6	r= 9.8–14.3 m= 12.5 sd= 1.9	r= 22.1–24.5 m= 23.1 sd= 1.1	40.2	r= 52.8–56.8 m= 54.2 sd= 1.8	r= 42.9–45.1 m= 44.0 sd= 1.6	56.5	r= 27.5–30.1 m= 28.7 sd= 1.0
TIB	r= 25.1–28.5 m= 27.3 sd= 1.2	29.5	r= 35.1–41.6 m= 38.7 sd= 2.5	r= 22.8–24.1 m= 23.3 sd= 0.6	36.8	r= 36.6–40.8 m= 38.3 sd= 2.0	r= 19.3–19.7 m= 19.5 sd= 0.3	17.4	r= 10.6–11.5 m= 11.0 sd= 0.4
BW	r= 38.3–78.1 m= 61.7 sd= 13.1	68.0	r= 85.5–98.1 m= 90.9 sd= 4.4	r= 15.4–16.3 m= 15.8 sd= 0.4	31.4	r= 52.5–55.6 m= 53.9 sd= 1.4	r= 23.5-24.3 m= 23.9 sd= 0.6	11.2	r= 9.6–11.6 m= 10.4 sd= 0.8
Remarks	presence of white ear margin on both sides of ear.	presence of anal glands; absence of claw on second digit.	presence of claw on second digit; pinnae margins less marked than *C sphinx.*	ear is short, horseshoe is broad.	presence of circular basal lappets; long, dark and woolly pelage.	presence of four supplementary leaflets in noseleaf with outer leaflet distinctively smaller.	larger than other species of *Nyctalus*, ear is short and tragus is club shape.	hair tips at the belly are ginger in colour.	naked muzzle, ear is short and broad, antitragus is obsolete.

Table 2. Comparison of species abundances and bat diversity in four different trapping sites at Banpale forest; A, B, C and D. "m" represents total number of male captured, "f" as female captured and "j" as juvenile. "0" indicates no capture.

Sites **Species**	**A**	**B**	**C**	**D**	**Total**	**Relative abundance (%)**
Cynopterus sphinx	11	8	2	2	23 (m= 8, f= 12, j= 3)	41.81
Eonycteris spelaea	0	1	0	0	1 (m= 1)	1.82
Rousettus leschenaultii	4	2	1	0	7 (m= 3, f= 3, j= 1)	12.73
Rhinolophus affinis	2	2	0	1	5 (m= 3, f=2)	9.09
Rhinolophus luctus	1	0	0	0	1 (m= 1)	1.82
Hipposideros armiger	3	2	0	0	5 (m= 3, f= 2)	9.09
Nyctalus noctula	1	1	0	0	2 (f= 2)	3.64
Myotis sicarius	0	1	0	0	1 (f= 1)	1.82
Pipistrellus sp.	5	3	2	0	10 (m= 4, f= 5, j= 1)	18.18
Total	27	20	5	3	55	100
Capture percent (%)	49.09	36.36	9.09	5.45		
Diversity (*H*)	0.35	0.37	0.22	0.16		
Evenness (*J*)	0.16	0.17	0.10	0.07		

Table 3. Updated bat checklist of Banpale forest, Institute of Forestry, Pokhara, Nepal. "LC" indicate least concern, "DD" as data deficient, and "VU" as vulnerable.

	Species name	Common name	Nepali name	Family	IUCN status	National status	Sources
1	*Cynopterus sphinx*	Greater Short-nosed Fruit Bat	नेप्टे चमेरो	Pteropodidae	LC	LC	this study; Giri 2009; Bhattarai 2019
2	*Eonycteris spelaea*	Dawn Bat	मिर्मिरे चमेरो	Pteropodidae	LC	DD	this study; Sharma et al. 2018a
3	*Pteropus giganteus*	Indian Flying Fox	वदुरा, राज चमेरो	Pteropodidae	LC	LC	this study
4	*Rousettus leschenaultii*	Leschenault's Rousette	सानो वदुरा	Pteropodidae	LC	LC	this study
5	*Rhinolophus affinis*	Intermediate Horse-shoe Bat	मझौला घोड्नाले चमेरो	Rhinolophidae	LC	LC	this study; Giri 2009
6	*Rhinolophus luctus*	Great Woolly Horse-shoe Bat	मखमली घोड्नाले चमेरो	Rhinolophidae	LC	LC	this study; Baniya et al. 2019
7	*Hipposideros armiger*	Great Himalayan Leaf-nosed Bat	ठुलो गोलोपत्रे चमेरो	Hipposideridae	LC	LC	this study; Adhikari 2008
8	*Nyctalus noctula*	Common Noctule	गन्धे चमेरो	Vespertilionidae	LC	DD	this study
9	*Myotis sicarius*	Mandelli's Mouse-eared Bat	मंडेलिको मुसाकाने चमेरो	Vespertilionidae	VU	VU	this study
10	*Pipistrellus coromandra*	Coromandel Pipistrelle	बुच्चे चमेरो	Vespertilionidae	LC	LC	Daniel 2007a,b

Banpale could be the key reason for high species capture from family Pteropodidae and availability of roosting vegetation for most capture of *Cynopterus sphinx.* The only record of *Eonycteris spelaea* could be due to rarity; it is 'Data Deficient' in the National Red List (Jnawali et al. 2011) and occasionally reported from Nepal (Sharma et al. 2018a).

Of the six insectivorous bat species, three belong to the Vespertilionidae family, two to Rhinolophidae, and one to Hipposideridae. Although *Pipistrellus* sp. has remained unidentified, we can extrapolate the unidentified species to be *Pipistrellus coromandra*, previously recorded in the forest by Daniel (2007a,b); however, its morphological measurements, distribution ranges, and echolocation parameters overlap with *Pipistrellus javanicus* (Srinivasulu et al. 2017). Further genetic analysis or cranio-dental characteristics is required for confirmation. It is also the most captured insectivore. High capture from the forest could be due to its diverse roosting and feeding habits; as it is found to roost in a wide variety of roost sites such as tree cavities, buildings, rock cervices, cracks in walls, beneath slates, and within cavity walls (Avery 1991; Jenkins et al. 1998), which are prominent in and around the forest and provide varied habitats (Russo & Jones 2003). Other two vesper bat species were *Nyctalus noctula* and *Myotis sicarius. Nyctalus noctula* is a high elevation bat (Acharya et al. 2010) and little is known about its distribution, hence it is considered 'Data Deficient' in the National Red List (Jnawali et al 2011). Seasonal migration is common to some high elevation bats, especially to the female population to escape from seasonally harsh weather conditions, scarcity of foods, and to find suitable roosts in milder climate (Fleming & Eby 2003). Female *Nyctalus noctula* also undergo seasonal migration in the lower elevational regions during winter (Furmankiewicz & Kucharska 2009). Here both captured females during March suggest they could be migratory individuals. Likewise, *Myotis sicarius* is 'Vulnerable' globally (Srinivasulu & Srinivasulu 2019) as well as nationally (Jnawali et al. 2011) and endemic to southern Asia (Bates & Harrison 1997). It is generally found in hilly forests and faces massive threats due to habitat alterations and deforestation, and hence is only known to be present in protected areas and forests (Molur et al. 2002). Low capture of these two species could be due to their rarity. Even though *Hipposideros armiger* and *Rhinolophus affinis* are mainly cave dwellers, a few individuals were captured from the forest. Both of these species are widespread throughout Nepal, roost on a wide variety of sites (caves, tunnels, old houses, and temples; Acharya et al. 2010), and feed on a diverse array of insects (Zubaid 1988). As there is no cave in the forest, they might use tree cavity or rock cervices as a roosting site or use the forest as a foraging ground. Only one individual of *Rhinolophus luctus* was captured throughout our study period. It is solitary and roosts in several roost types; old houses, tree cavities, tunnel, mines, holes, and caves (Csorba et al. 2003; Baniya et al. 2019). Perhaps due to its lone roosting behavior and variety of preferred habitats, it was captured only once from the forest. Further, the availability of roost sites

and high insect abundance (Racey & Swift 1985; De Jong & Ahle´n 1991; Jenkins 1998) could be the main reason for the presence of these insectivorous bats in the forest.

Bat species diversity and richness were unevenly distributed within the Banpale forest. Site B was the most diverse with eight species recorded, followed by Site A with seven, while sites C and D had three and two species, respectively. Site B is located in the forest trail near the edge between forest, college quarter, and nursery site, and is relatively less disturbed compared to sites C and D. Likewise, site A was near the water resource in the middle of the forest, which may account for high bat density. Anthropogenic disturbances such as illegal logging were prominent in site C (edge between forest and human settlements), and site D was located near a landslide area which may account for low bat diversity. In consonance with these findings, bat diversity was also found to decrease due to logging activities (Danielsen & Heegaard 1995; Brosset et al. 1996; Clarke et al. 2005; Meyer et al. 2016; Sharma et al. 2018b), and landslides (Vanlalnghaka 2013). Bat species diversity and composition in forests have been studied from different parts of the world (Korad et al. 2007; Loayza & Loiselle 2009; Shafie et al. 2011; Thapa et al. 2012b; Deshpande 2012; Korad 2014, 2018; Tshering et al. 2020).

Revision of bat species from the Banpale forest

A few species have previously been reported from the Banpale forest. Daniel (2007a,b) reported *Pipistrellus coromandra,* and later Adhikari (2008) supported this finding. Giri (2009) reported *Cynopterus sphinx*, *Rhinolophus affinis*, and *Pipistrellus pipistrellus;* however, the existence of *Pipistrellus pipistrellus* has not been documented from Nepal (Acharya et al. 2010; Thapa 2014); moreover, occasionally reported from southern Asia (Hutson et al. 2008). This report lacks photographic evidence, and we suggest the species identified could have been *Pipistrellus coromandra*, reported earlier by Daniel (2007a,b). *Cynopterus sphinx* was reported earlier by Bhattarai (2019) as well as Baniya et al. (2019) and this study also supports the record of both *Cynopterus sphinx* and *Rhinolophus affinis* from the forest. Lama et al. (2013) reported *Rhinolophus subbadius*, *Kerivoula picta* and *Miniopterus pussilus* based on unpublished secondary data. An occurrence of *Rhinolophus subbadius* is doubtful from Nepal (Csorba et al. 2003; Thapa 2014). *Kerivoula picta* has been recorded only from two locations, Chitwan and Shuklaphanta national parks (Myers et al 2000; Poudyal et al. 2019), and most probably distributed in lower elevated areas of Nepal, i.e., Terai regions. *Miniopterus pussilus* is 'Data Deficient' nationally (Jnawali et al. 2011) but recorded from Pokhara valley (Bates & Harrison 1997). Due to unpublished sources, lack of photographic evidence, and taxonomic details, we also doubt the record of these species from the forest. *Pteropus giganteus* was observed flying through the edge of the forest; foraging in the forest, and an electrocuted individual was also sighted inside the campus premises. Further, *Rousettus leschenaultii* was recorded by Acharya, P.R. (as personal communication), *Eonycteris spelaea* by Sharma et al. (2018a) (part of this study), and *Rhinolophus luctus* by Baniya et al. (2019). Both *Rousettus leschenaultii* and *Rhinolophus luctus* were also recorded during our study period. Here, we represent the first record of *Eonycteris spelaea* from the Banpale forest and western Nepal as well as fourth record for the country (Sharma et al. 2018a); the first record of *Nyctalus noctula* and *Myotis sicarius* from the Banpale forest and second record from the Pokhara valley; previously recorded at Sudame by Csorba et al. (1999); the first record of *Hipposideros armiger*; second record of *Rousettus leschenaultii* and *Rhinolophus luctus* from Banpale forest. The record of these species from the forest indicates that they might have been overlooked during previous mammal researches or sparse and inconsistent bat surveys in the forest. All of these findings sum up a total of 10 bat species from the Banpale forest.

CONCLUSION

Comprehending our study and data, we can generalize the Banpale forest to be rich in bat diversity harbouring either roosting habitat or foraging grounds for both fruit dependent as well as insect dependent bats. Availability of fruits, good insect abundance, and the presence of edges, water resources, crevices, and cavities might be a vital reason for high bat diversity in the forest. Based on survey efforts and literature, we confirmed the record of 10 species of bats in the forest, indicating relatively high density in terms of its geographic extent. Bat diversity in the forest was noted to vary among sites, with maximum diversity near the forest edge, water resources and less disturbed areas, and lower diversity in the landslide and logged areas. Hence, this study recommends the campus committee adopt practices to conserve the forest from landslides and minimize illegal logging. This study did not capture bats from high tree canopies nor record echolocation calls, and was limited to only two months. Surveying of bats throughout the year with the

Image 1. *Eonycteris spelaea*

Image 2. *Rousettus leschenaultii*

Image 3. *Cynopterus sphinx*

Image 4. *Pteropus giganteus*

Image 5. *Rhinolophus luctus*

Image 6. *Rhinolophus affinis*

Image 7. *Hipposideros armiger*

Image 8. *Myotis sicarius*

Image 9. *Nyctalus noctula*

Image 10. *Pipistrellus* sp.

use of trapping as well as acoustic devices will provide a better understanding of seasonal species composition in the forest, and can lead to new information and findings to guide conservation efforts.

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A patho-microbiological study of tissue samples of the Greater Adjutant *Leptoptilos dubius* (Aves: Ciconiiformes: Ciconiidae) that died in Deeporbeel Wildlife Sanctuary, Assam, India

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Abstract: The Greater Adjutant is an IUCN Red List 'Endangered' scavenging stork. This study reports the findings of post-mortem, histopathology, and a series of microbiological tests conducted on the Greater Adjutant that died in Deeporbeel Wildlife Sanctuary, Assam. A post-mortem examination revealed extensive nodule forming parasitic (*Balfouria monogama*) infestations in the stomach and intestine. Generalised congestion and haemorrhages in multiple organs were also revealed by the histopathological findings. Bacteriological culture detected the presence of *Escherichia coli, Enterococcus* sp., and *Clostridium perfringens* (*C. perfringens* was confirmed by *cpa* gene PCR). Virus detection tests like HA and HI test for NDV and rapid antigen detection test for Avian Influenza virus were found to be negative; however, PCR of tissue samples from two Greater Adjutants for Flavivirus was found to be positive. Greater Adjutants may carry the above bacteria as commensals in their GI tract and may possibly act as a reservoir of Flavivirus. The actual cause of deaths, however, were confirmed by the forensic report to be due to organophosphorus toxicity.

Keywords: *Balfouria monogama*, *Clostridium perfringens*, Flavivirus, northeastern India, organophosphorus toxicity, stork.

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INTRODUCTION

The Greater Adjutant *Leptoptilos dubius* is a member of the stork family Ciconiidae. The world population was estimated at less than 1,000 individuals in 2008 and led to the Greater Adjutant being upgraded as 'Endangered' on the IUCN Red List of Threatened Species (BirdLife International 2016, 2019). The bird, has now been confined only to Cambodia and in Assam and Bihar in India. Kamrup District in Assam is known to be a stronghold of the species, with almost 75% of its population in Assam found in this district (BirdLife International 2016).

Greater Adjutants being massive in their stance, have sparse natural predators and the only recorded causes of premature mortality are due to the direct or indirect actions like nest falls, malicious man-made acts like poisoning, shooting, and rarely electrocution when the birds accidentally fly into overhead electricity wires (Singha et al. 2003; Birdlife International 2016). The Greater Adjutant feeds partly on carrion, especially at refuse dumps and also hunts small live animals in typical stork fashion, by walking slowly in marshes and shallow waters, lakes, and agricultural land (Grimmett et al. 2016).

There was an unprecedented death of about 30 numbers of Greater Adjutants in the Deeporbeel Wildlife Sanctuary, Assam, mainly confined to a garbage dumping site from 22 January to 3 February, 2017. A forensic report by the Directorate of Forensic Sciences, Govt. of Assam confirmed the cause of deaths to be due to organophosphorus (OP) toxicity (Report No. DFS.1192/164/Tox-61/17). Here, a patho-microbiological study of tissue samples of the Greater Adjutant was done for the screening of a possible association of bacteria and viruses to the cause of death of the Greater Adjutant, besides OP toxicity. Screening for the possibility of the presence of zoonotic viruses, especially Flavivirus in the Greater Adjutants was also carried out in this study.

MATERIAL AND METHODS

Post-mortem examination and sample collection: A post-mortem (PM) was done on six Greater Adjutants, and samples like heart, blood, and tissue samples from all the vital organs were collected aseptically for both bacteriological and virological screening. Tissue samples were preserved in 10% formalin for the histopathological studies. Appropriate tissue samples like intestinal loop, pieces of liver, pieces of brain, and body fats were collected in saturated salt solution and sent to the Directorate of Forensic Sciences, Govt. of Assam for examination.

Histopathology: Histopathological examination of the tissue samples were carried out with routine hematoxylin and eosin (H&E) stain as per the standard procedure (Culling 1974).

Microbial screening tests: For the bacteriological screening, PM samples from all the birds were subjected to aerobic (in brain heart infusion agar and eosin methylene blue agar) and anaerobic bacterial isolation (in blood agar), at 37˚C for 24 hours and observed for cultural characteristics and gram staining was done for differentiation of gram positive and negative bacteria. For the virological screening, homogenised tissue samples were inoculated in nine days old embryonated chicken eggs for isolation of probable viral etiology. Viral haemagglutination (HA) and haemagglutination inhibition (HI) test was carried out using known serum and 4HA unit of the antigen. Procedure for HA and HI test was done according to standard protocol (OIE terrestrial manual 2015a,b). Screening for avian influenza virus was done using rapid antigen detection technique from lung, spleen, and cloacal swabs (OIE terrestrial manual 2015a).

Molecular diagnosis

Polymerase chain reaction (PCR) for *Clostridium perfringens* targeting *cpa* gene**:** PCR was done for confirmation of the anaerobic bacterial culture using specific primers *cpa* (Titball et al. 1999) targeting alpha toxin of *Clostridium perfringens.* The sequence of the primers are Forward: 5'-GCTAATGTTACTGCCGTTGA-3', and Reverse: 5'- CCTCTGATACATCGTGTAAG-3'. PCR cycling conditions were: 95˚C for 5 min for 1 cycle, 94˚C for 30 sec, 53˚C for 1.30 min, 72˚C for 1.30 min for 40 cycles and final extension of 72˚C for 7 min, with 25µl of total PCR reaction volume comprising 12.5µl of PCR mastermix, 1µl (10 pmol) forward primer, 1µl (10 pmol) of reverse primer, 2µl of DNA template and 8.5 ul of nuclease free water (NFW). Bacterial colony DNA was extracted by using heat and cold lysis method.

PCR for screening of Flavivirus: Screening for flavivirus was done by PCR using universal primer targeting flavivirus genus. The flavivirus universal primer sequences are: DJS (+) : 5' –GACATGGGGTATTGGAT-3' and DJA (-) : 5'-TCCATCCCATACCTGCA-3' (Meiyu et al. 1997) with positive band size at 413bp. The PCR conditions were run according to Meiyu et al. (1997). RNA extraction from the suspected tissue samples (Table

no. 1) were done using Qiagen RNA extraction kit. cDNA was prepared by PCR in two steps, first step by using 11µl RNA sample, 1µl random hexamer primer and incubated at 65˚C for 7 minutes, then the second step by adding RT buffer (5x) 4µl, dNTP mix (10mM) 2µl, RT enzyme (200 units/ul) 1µl, RT inhibitor (40 units/ul) 0.5µl, NFW 0.5µl and incubated in PCR for one cycle each at 25˚C for 5 min, 42˚C for 1 hr and 72˚C for 10 minutes. The cDNA obtained was finally subjected to PCR using Flavivirus universal primer set. A 25µl reaction volume was made adding 6 ul cDNA, 12.5µl master mix (Thermoscientific), 1µl each of forward and reverse primer (25 pmol), 4.5µl NFW and then subjected to PCR conditions as following: one cycle of initial denaturation at 94˚C for 5 min, 30 cycles of subsequent denaturation, annealing and extension at 93˚C for 40 sec, 55˚C for 45 sec, 72˚C for 60 sec, respectively and a final extension step at 72˚C for 10 min.

RESULTS

None of the affected birds survived, despite the supportive treatment. Post-mortem findings of most of the dead Greater Adjutants (n= 6) showed congested brain (Image 1), mild hepatomegaly (Image 2), and splenomegaly, congestion, & haemorrhage of lungs (Image 3) & intestine (Image 4). There were presence of nodule forming trematode parasites (*Balfouria monogama*) inside the nodules under mucosal and sub-mucosal layer of proventriculus, gizzard, and intestine (Image 5, 6). The stomach also contained partially digested food materials.

Microscopically in the brain, there were purkinje cell degeneration, heterophilic infiltration in the parenchyma, severe congestion, haemorrhages and perivascular oedema (Image 7). In the liver, there was degeneration and necrosis of hepatocytes with congestion, focal haemorrhages, and hemosiderosis. The vascular walls were thickened with perivascular infiltration of lymphocytes and macrophages with lymphoid nodules formation at some places, and fibrous tissue proliferation were also observed (Image 8). In the lung, there was severe congestion and haemorrhages throughout the lung parenchyma (Image 9). In the intestine, necrotic desquamated epithelial debris of intestinal epithelium were seen. The mucosal and submucosal layer showed lymphoid proliferation. Some of the follicles showed lymphoid depletion. In some areas depleted follicles were replaced by reticular fibre. In the kidney, the renal tubular epithelial cells were severely necrotic with focal haemorrhage and atrophy of glomerulus were seen. Cystic dilation of some of the tubules in the medullary part were also observed (Image 10).

Bacterial culture in specific media showed bacterial growth in both aerobic and anaerobic bacterial cultures from different organs at 37˚C for 24 hours. Results from gram staining of the isolates from different organs has been given in Table 1; however, no bacterial growth was observed from heart blood. Bacterial cultures from stomach and intestinal contents were found to be positive for *C. perfringens* in PCR targeting *cpa* gene, giving a band size of 324bp (Image 11). Cultures of *E. coli* isolated from different organs showing characteristic metallic sheen in the EMB agar, also characteristic gram-

Image 1–6. Gross Lesion: 1—Congestion in brain (→) | 2—Enlarged liver (→rounded edge) | 3—Congestion and haemorrhage in lung (→) | 4—Congestion and haemorrhage in intestine (→) | 5 & 6—Parasitic infestation in gizzard (→). © B. Dutta. P. Kakati & D. Brahma

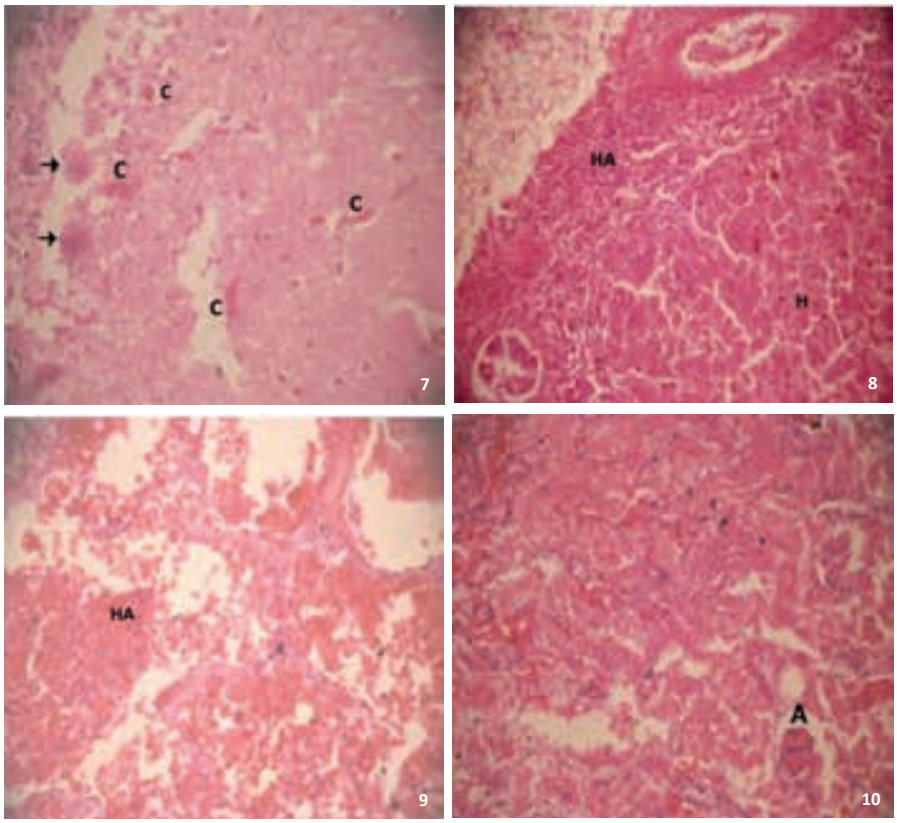

Image 7–10. Histopathological lesions (under 400x magnification): 7—Congestion (C) and degeneration of purkinje cells (→) in brain | 8—Degeneration and necrosis of hepatocytes with congestion, focal haemorrhages (HA) and hemosiderosis (H) in liver | 9—Congestion and haemorrhage (HA) in lung | 10—Atrophy of glomerulus (A), necrotic renal tubular epithelial cells with focal haemorrhage in kidney. © B. Dutta

Table 1. Results of organ-wise bacterial and viral detection tests.

Tests/Organisms		Samples (n= 6)							
		Brain	Lung	Spleen	Liver	Heart blood	Kidney	Intestine	Stomach content
Bacterial Culture	*Clostridium perfringens*	-ve	-ve	-ve	-ve	-ve	-ve	**2**	**2**
	Escherichia coli	-ve	**4**	**3**	**3**	-ve	-ve	6	6
	Enterococcus sp.	-ve	**2**	-ve	-ve	-ve	-ve	6	6
	Other unidentified bacteria	-ve	-ve	-ve	-ve	-ve	**2**	6	6
Virus detection tests	Egg inoculation	-ve	-ve	-ve	-ve	-ve	Not done	Not done	Not done
	HA/HI for NDV								
	Rapid antigen test for Avian influenza								
	PCR for Flavivirus	1	2	2	Not done	Not done	Not done	Not done	Not done

positive diplococci, i.e., *Enterococcus* spp. were detected in gram staining. Besides these, some other bacteria were also present which were unidentified.

Out of the tests for detection of virus, the samples from the two Greater Adjutants were found positive for genus *Flavivirus* by PCR using Flavivirus universal primer giving a band size at 413bp (Image 12). All the samples were found to be negative for avian influenza virus by rapid antigen detection test. Samples were also negative for New Castle Disease Virus (NDV) in Hemagglutinin (HA) and Hemagglutinin inhibition (HI) tests. Details of bacteria and virus detected from different organs are given in Table 1.

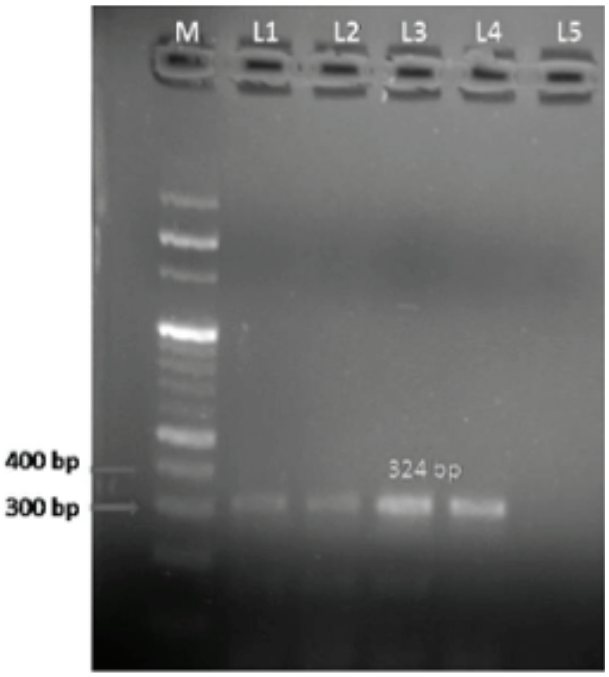

Image 11. PCR for *Cl. perfringens* (*cpa* gene) from tissue samples of Greater Adjutant Stork. M= Marker (1kb), L1–L4= bacterial culture from intestine and stomach content, L5= negative control

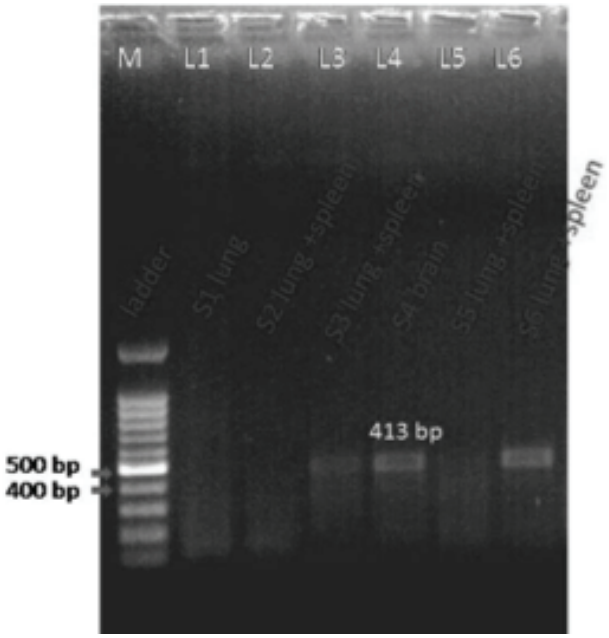

Image 12. RT-PCR for Flavivirus from tissue samples of Greater Adjutant Stork. M= marker (1kb), L1–L6= tissue samples.

DISCUSSION

Poisoning is a malicious act which causes toxicity and death of both domestic as well as wild animals. Accidental poisoning or toxicity cases may also occur due to consumption of contaminated food waste from garbage dumping sites. This study reports the case of OP toxicity in the Greater Adjutants, found dead in the Deeporbeel area, Guwahati, Assam. The histopathological findings of the multiple internal organs like the brain, lung, liver, kidney in our study, showing overall congestion and haemorrhages similar to the histopathological lesions of OP toxicity reported by other studies (Harith 2009) and in the literature (Smith et al. 1972). The storks that died of OP toxicity might have consumed some food waste from the garbage dumping site, contaminated by OP. Poisoning of small wetlands to catch fish in the dry forests of northern and eastern Cambodia potentially poses a significant threat, and in Guwahati, pesticide use at open rubbish dumps where storks flocked to feed led to several mortalities in 2005 (BirdLife International 2016).

The Greater Adjutants being natural scavengers, survive on the dead and decaying matters besides their feeding habits on amphibians and fishes in shallow water bodies and paddy fields (Grimmett et al. 2016). They have chances of exposure and infestation to intestinal parasites besides many pathogenic microorganisms. Similar to our case, Islam et al. (2009) reported *Balfouria monogama* as a highly pathogenic nodule forming parasite and caused extensive nodules on the wall of small intestine of a juvenile male Greater Adjutant, grossly visible from serosal surface, with presence of 1–2 adult parasites and necrotic masses in each nodule. Besides, some bacteria were also isolated and identified in our case study. The bacteria *C. perfringens*, a gram-positive, spore-forming, non-motile anaerobe ubiquitous in the environment, being found in the soil, in decaying organic matter and as a member of the normal gut flora of many animals that causes a variety of diseases in humans, including gas gangrene (*Clostridial myonecrosis*), enteritis necroticans (Pigbel), acute food poisoning, and antibiotic associated diarrhoea (Titball et al. 1999; O'Brien & Melville 2004). As detected in this case, *C. perfringens* may be found as commensal in these scavenging birds; however, the presence of the bacteria *C. perfringens* may have aggravated the condition of necrotic enteritis in the storks. Besides, *E. coli*, gram-negative bacteria and *Enterococcus* sp., gram-positive bacteria are also found as commensal in the GI tract of most animals and birds. These bacteria are also found in the environment as saprophytes/ coliforms, and may cause infection or food poisoning due to contamination of food and water with faecal materials (Farnleitner et al. 2010). These bacteria are

also associated with GI tract or secondary infections in immunocompromised conditions. The scavenger birds may be resistant to infections due to these bacteria and they may be found as commensals. Immune suppressed or diseased condition, however, may make the birds susceptible to infections. In fact, the bacteria like *E. Coli* and *Enterococcus* may have spread from the GI tract to other organs due to tissue damage due to the toxicity. Wild animals, especially wild birds are indirectly involved in the global transmission of antimicrobial resistant genes of the bacteria like *E.coli, K. pneumoniae* and *Enterobacter* spp. by acting as reservoirs and vectors, and are responsible for the interspecies transmission between humans, domestic animals, the environment, and wildlife (Wang et al. 2017). Thus, the bacteria like *C. perfringens, E. coli,* and *Enterococcus* sp., are capable of causing enteric infection in animals and birds (companion/domestic/wild) as well as humans indicating their zoonotic importance (Benskin et al. 2009; Kiu & Hall 2018; Ramos et al. 2019).

Many water and migratory birds are also important reservoirs of viruses like avian influenza, newcastle disease virus, and most of the important poultry viruses (Vandegrift et al. 2010; Snoeck et al. 2013; OIE 2018a,b). The flaviviruses (genus *Flavivirus*) are important pathogens of wild birds, domestic poultry and humans, and several members are zoonotically important (OIE 2018a). The viruses in the Japanese encephalitis group are related to birds and mostly transmitted by Culex mosquitoes. These viruses are distributed worldwide and cause widely diverse diseases varying from mild viral symptoms to severe and fatal hemorrhagic and neurological diseases (Meiyu et al. 1997; Davidson 2015). West Nile fever, caused by West Nile virus under the genus *Flavivirus*, is also a mosquito-borne viral disease that can affect birds, humans, and horses causing inapparent infection, mild febrile illness, meningitis, encephalitis, or death (OIE 2018b). Migratory birds could spread into densely populated urban areas (in places like urban parks) allowing introduction of a Flavivirus that could infect local Culex mosquitoes and produce disease after feeding on humans (Lopes et al. 2015). The Greater Adjutants living near the water bodies may get infected by Flavivirus from the bites of infected mosquitoes and, thus, there is a possibility of them serving as reservoirs of Flavivirus.

CONCLUSION

From this study of Greater Adjutants, we come to the conclusion that, the birds may carry bacteria like *E. coli*, *Enterococcus* sp., and *C. perfringens* and some other bacteria as commensals in their GI tract. Greater Adjutant Storks may also act as the reservoirs of Flavivirus; however, the forensic report confirmed the cause of their deaths to be due to organophosphate toxicity, which is also obviously suggestive from the post-mortem and histopathological findings. The presence of the bacteria and virus may have aggravated the condition of the Greater Adjutants during the acute phase of the toxicity.

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COMMUNICATION

Vaduvur and Sitheri lakes, Tamil Nadu, India: conservation and management perspective

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Abstract: Wetlands are declining globally. Hence, it is reasonable to assume that most existing wetlands are impacted to some degree by human land-use that in turn caused population declines in many wetland-dependent taxa. The National Wetland Atlas has classified Tamil Nadu as a wetland-rich state as they occupy 6.92% of geographic area. However, studies on wetlands are limited in Tamil Nadu. Hence, an attempt was made to identify the threats to the Vaduvur and Sitheri lakes and their associated fauna. In total, 118 species of birds belonging to 87 genera, 48 families and 18 orders in Vaduvur Lake and 87 species of birds belonging to 71 genera, 48 families and 16 orders in Sitheri Lake were recorded. A total of 28 zooplankton species were recorded in both the lakes comprising 14 species of rotifers, six species of cladocerans, five species of copepods, two species of ostracods, and one species of protozoa. A total of 15 species of fishes were identified from the sellers who catch fishes from the Sitheri Lake. The physico-chemical parameters of water varied according to the seasonal fluctuations in rainfall pattern. In general, wetland management for waterbirds of these two lakes should focus on providing suitable nesting habitats and available food resources for dependant avifauna. Management of invertebrates, amphibians, and fishes in these two lakes is one technique that can be used to provide foraging opportunities for waterbirds. An integrated approach and increased co-operation would result in the rational use of this freshwater resource leading to improved standards of living around this lake.

Keywords: Illegal trade, poaching, threats.

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INTRODUCTION

Wetlands are declining globally. Between 1993 and 2007, the global acreage of wetlands decreased by 6% (Prigent et al. 2012). Hence, it is reasonable to assume that most existing wetlands are impacted to some degree by human land-use that in turn caused population declines in many wetland-dependent taxa. Wetlands have many successional stages and hydroperiods, represented in close proximity, thus, managing wetlands effectively requires an understanding of basic ecosystem processes besides using appropriate management techniques that depend on target species, coastal versus interior wetlands, available infrastructure, resources, and management objectives.

The National Wetland Atlas, prepared by the Ahmedabad (Gujarat) Space Application Centre (SAC), Indian Space Research Organization (ISRO), has classified Tamil Nadu as a wetland-rich state as they occupy 6.92% of the geographic area. One-hundred-and-twenty-five species of birds including both migratory and resident that depend on wetlands fully or partly and 28 other species found in the vicinity of wetlands are known from Tamil Nadu. Although Tamil Nadu State has several wetlands, studies are limited to very few: Point Calimere (Sugathan 1982), Kaliveli (Pieter 1987), Singanallur Lake (Reginald et al. 2007), Pallikaranai (Raj et al. 2010), Karaivetti (Gokula 2010), Vaduvoor (Gokula & Raj 2011), and Sitheri (Gokula & Raj 2015). The majority of research work on wetland management in Tamil Nadu relates to the limnological and ornithological aspects. Nevertheless, the land-use changes and socio-economic activities leading to changes in limnological and biodiversity aspects of these wetlands have not been explored substantially. Moreover, the national water sector agenda pays little attention to wetland management resulting in over exploitation of wetland's resources. Hence, an attempt was made to identify the threats to the Vaduvur and Sitheri lakes and their associated fauna.

STUDY AREA

The Vaduvur Lake, situated between 10.698–10.706 ^{0}N & 79.309–79.322 ^{0}E, spread over c. 128ha and Sitheri Lake, situated between 10.712–10.728 ^{0}N & 79.323–79.342 ^{0}E, spread over c. 87ha, are located at a distance of 20km from Mannargudi, a town, situated between 10.636–10.677 ^{0}N & 79.432-79.450 ^{0}E in Tiruvarur District in Tamil Nadu. The Vaduvoor Lake was declared a bird sanctuary by the forest department in July 1999. The bunds help in holding the water up to an average depth of c. 2.5m. Vegetation of the lake consists of *Prosopis chilensis*, *Azadirachta indica*, *Tamarindus indica*, and *Acacia nilotica* including planting of *A. nilotica* by the forest department under the Sanctuary Management Program. The Sitheri Lake is currently being maintained by the public works department, Tamil Nadu, however, the forest department of Tamil Nadu has a plan to bring this wetland and its components under the protected areas network. The Vennaru River is the main source of water in addition to the monsoon (largely from the north-east) for both the lakes.

METHODS

Birds were counted using direct count method from selected vantage points following Bibby et al. (1992) and Sutherland (1997). Counts were made four times in a month during which birds were observed from 06.00 –10.00 hr and 16.00–18.00 hr, being their most active periods of the day from September 2010 to February 2012. No count was done during extreme weather conditions. The water quality of the lakes was assessed using the standard methods described by APHA (1996). Identification of zooplankton was done by following Alfred et al. (1973) and Adoni et al. (1985). Zooplankton samples were collected from the two lakes by towing a plankton net, made up of bolten silk with a mesh size of 100µm, from surface water to 1m depth. One-hundred litre of water from the lakes was filtered through the zooplankton net and collected planktons were preserved in 5% formalin. Planktons were identified up to species level. Planktons were enumerated using SedgwickRafter chamber and species richness and diversity were calculated. Fish collected by the local people were inspected and identified up to the species level, based on which, a list of fish species for each lake was prepared. Jayaram (1999) was followed to identify the fish fauna. Several visits were made around the lakes and villages nearby for collecting information on threats to avifauna and two lakes. Formal and informal interviews were conducted with local people to prepare a list of threats to these two lakes and dependant avifauna. During the fieldwork, anthropogenic activities, viz., hunting, illegal fishing, and woodcutting (if any) were monitored and quantified (if possible) following Joshua & Johnsingh (1994). Only fishing and illegal hunting of birds were identified as threats to the wetlands. People who are directly or indirectly involved in the above said two

threats were approached for additional quantitative (if possible) and qualitative information. Fish markets were periodically visited for collecting information on illegal bird trade. Informal interviews were conducted with those traders for further details. Wherever permission was granted, quantification were made on the number of individuals and species of birds involved in the trade. The methodology was based on the principles and procedures of the Australian/New Zealand Standard for Risk Management ISO 31000:2009 (Standards Australia 2009; AZ/NZS 4360:1999) and HB 203: 2000 Environmental Risk Management – Principles and Process (Standards Australia 2009).

RESULTS AND DISCUSSION

In total, 118 species of birds belonging to 87 genera, 48 families, & 18 orders in Vaduvur Lake and 87 species of birds belonging to 71 genera, 48 families, & 16 orders in Sitheri Lake were recorded and the details are given elsewhere (Gokula & Raj 2011, 2015). The numerical differences may be attributed to the combination of any of the factors, viz., size and location of wetlands, proximity to other wetlands, water level, foraging opportunity, food availability, availability of nest-sites, inter and intra specific competition, human pressure, site fidelity of bird species, and site history. Besides regular common migrants, both the lakes harbour Near Threatened bird species, viz.: Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, and Oriental White Ibis *Threskiornis melanocephalus*. Among the bird species recorded, the most numerous were Garganey *Anas querquedula* and Northern Shoveller *Anas clypeata*, however, individuals of a majority of the species were poor in numbers. Little Grebe *Tachybaptus ruficollis*, Little Cormorant *Phalacrocorax niger*, Little Egret *Egretta garzetta*, Cattle Egret *Bubulcus ibis*, Indian Pond Heron *Ardeola grayii*, and Pheasant-tailed Jacana *Hydrophasianus chirurgus* nest in Sitheri; while, Little Grebe, Asian Openbill *Aanastomus oscitans*, Cattle Egret, Black-crowned Night Heron *Nycticorax nyctiorx*, Grey Heron *Ardea cinerea*, Little Egret, Little Cormorant *Microcarbo niger*, Pheasant-tailed Jacana nest in Vaduvur Lake. In both the wetlands, birds breed largely during and after the north-east monsoon as reported by Subramanya (2005) for majority of the heronries of Tamil Nadu.

A total of 28 zooplankton species were recorded in both the lakes comprising 14 species of rotifers, six species of cladocerans, five species of copepods, two species of ostracods, and one species of protozoa (Table 1). A greater number of species of zooplanktons was recorded during November to June followed by May to July (Table 2). The diversity of planktons was more during the monsoon rather than in the summer in both the lakes, which is in contrast to other such studies carried out in Tamil Nadu. Manikam et al. (2014, 2017) reported high diversity of planktons in summer and attributed it to favourable temperature and availability of food in the form of bacteria, phytoplankton, and suspended detritus during the season. Hence, a detailed long-term study is needed to confirm it further.

The Sitheri Lake is a very good fishery resource. A total of 15 species of fishes were identified from the sellers who catch fishes from the Sitheri Lake and the Vennaru River, a prime source for the two lakes (Table 3). Thiyagesan & Nagarajan (1995) reported the negative impacts of the over exploitation of aquaculture and fisheries resources in inland and coastal wetlands of the eastern coast of India on their bird life.

With respect to water quality the changes in water chemistry has been considered to exert influence in the distribution of many aquatic plant species (Catling et al. 1986; Shay & Shay 1986; Chee & Vitt 1989; Engelhardt & Ritchie 2001; Lentz-Cipollini & Dunson 2006). As waterbirds and wetland dependant birds depend directly or indirectly on aquatic fauna and flora which in turn depend on water chemistry, birds' distribution is expected to change with changes in water chemistry. As anticipated the physico-chemical parameters of water varied according to the seasonal fluctuations (Table 4). The limnological variables showed two distinct clusters: July to December with high rainfall and January to April with less/no rainfall (Figure 1). The rainfall (both from north-west and south-east monsoons between June to December) and lack of rainfall (between January to May) showed greater influences in the values of water quality parameters in both the lakes.

Three major villages are situated around these two lakes: Vaduvur Vadpathi (2,289 individuals belonging to 575 families of which 1,154 are males while 1,135 are females), Vaduvur Melpathi (3,010 individuals belonging to 817 families of which 1,478 are males while 1,532 are females), and Vaduvur Thenpathi (3,412 individuals belonging to 896 families of which 1,673 are males while 1,739 are females). The socio-economic status of the people of these villages revealed that both the lakes play a vital role in the livelihood of many people. Agriculture is the main occupation of the people of these villages and they greatly depend on the lake for irrigation and other domestic purposes. Paddy is the main crop cultivated

Table 1. Species of planktons recorded in Vaduvur and Sitheri lakes during the study period.

	Vaduvur Lake	Sitheri Lake
Group	**Species**	**Species**
Protozoa	*Vorticella* sp.	*Vorticella* sp.
Rotifera	*Brachionus calyciflorus*	*Brachionus calyciflorus*
Rotifera	*B. quadridentatus*	*B. quadridentatus*
Rotifera	*B. forticula*	*B. forticula*
Rotifera	*Euchlanis* sp.	
Rotifera	*Horella brehmi*	*Horella brehmi*
Rotifera	*Lepadella* sp.	
Rotifera	*Mytilina* sp.	*Mytilina* sp.
Rotifera	*Notholca* sp.	*Notholca* sp.
Rotifera	*Trichotria* sp.	*Trichotria* sp.
Rotifera	*Trichocera rattus*	*Trichocera rattus*
Rotifera	*Testudinella patina*	*Testudinella patina*
Rotifera	*Asplanchna brightwelli*	
Rotifera	*Lecane lunaris*	*Lecane lunaris*
Rotifera	*L. bulla*	*L. bulla*
Cladocera	*Alonella* sp.	*Alonella* sp.
Cladocera	*Bosmina longirostris*	*Bosmina longirostris*
Cladocera	*Daphnia carinata*	*Daphnia carinata*
Cladocera	*Diaphanosoma* sp.	
Cladocera	*Diaphanosoma* sp.	*Diaphanosoma* sp.
Cladocera	*Moina daphnia*	*Moina daphnia*
Copepoda	*Calonoid copepod*	*Calonoid copepod*
Copepoda	*Heleodiaptomus viduus*	*Heleodiaptomus viduus*
Copepoda	*Mesocyclops hyalinus*	*Mesocyclops hyalinus*
Copepoda	*Thermocyclops sp.*	*Thermocyclops sp.*
Copepoda	*T. crassus*	*T. crassus*
Ostracoda	*Cypris* sp.	*Cypris* sp.
Ostracoda	*Stenocypris malcolmsoni*	*Stenocypris malcolmsoni*

Table 2. Species richness and diversity of planktons recorded during various months of the study area.

	Vaduvur	Sitheri	Vaduvur	Sitheri
months	Taxa_S	Taxa_S	Shannon_H	Shannon_H
Sep-10	19	16	2.795	2.642
Oct-10	23	19	2.963	2.784
Nov-10	28	24	3.132	3.009
Dec-10	28	24	3.127	3.007
Jan-11	21	17	2.841	2.636
Feb-11	17	16	2.614	2.566
Mar-11	13	12	2.336	2.272
Apr-11	8	8	1.895	1.895
May-11	9	9	2.062	2.062
Jun-11	8	8	1.934	1.934
Jul-11	8	8	1.992	1.992
Aug-11	11	11	2.322	2.322
Sep-11	18	16	2.768	2.655
Oct-11	23	19	2.9	2.729
Nov-11	28	24	3.09	2.961
Dec-11	27	24	3.018	2.934
Jan-12	20	17	2.73	2.596
Feb-12	17	15	2.566	2.487

around these two wetlands and it is grown three times in a year. The first crop is known as 'Kuruvai' (the short-term crop) with a duration of three and a half to four months from June–July to October–November. The second crop called the 'Thaladi' has a duration of five to six months from October–November to February–March. The third is the 'Samba' (the long term) crop and has a duration of almost six months from August to January. During the cultivation periods, in particular, between the months of October and January, the agriculture fields are water-logged with aquatic invertebrates. Thus, the agriculture fields surrounding these two wetlands and in nearby villages not only act as a unique foraging ground but also provide various foraging opportunities to the waterbirds and wetland dependant birds during their stay at in these two lakes. The water-logging of agricultural fields often attracts waterbirds, especially when they are close to other wetlands (Nagarajan & Thiyagesan 1996; Kahlert et al. 2007). Moreover, paddy fields support the highest bird diversity when they are water logged with abundant aquatic insects, worms, snails, and tadpoles (Deep 2008). Moreover, when they are flooded in winter they often provide a good feeding habitat for large numbers of birds (Chan et al. 2007). Croplands that are flooded to a shallow depth act as temporary foraging grounds for waders. Some species appear to need very large rice-fields while others prefer smaller ones and edge habitats (Burton et al. 2002). Hence, lakes with sufficient water and surrounded by agriculture fields with agricultural activities are more crucial to sustain the population of waterbirds and wetland dependent birds that traditionally inhabit any wetland. Due to unusual drought and fall in rainfall due to climate change, lack of interest in agricultural practices, and conversion of agricultural land into human habitation, agricultural activities in agriculture fields have drastically been declining not only around these lakes but also in the entire district. Recently, the Federation of Tamil Nadu Agricultural Associations reported that

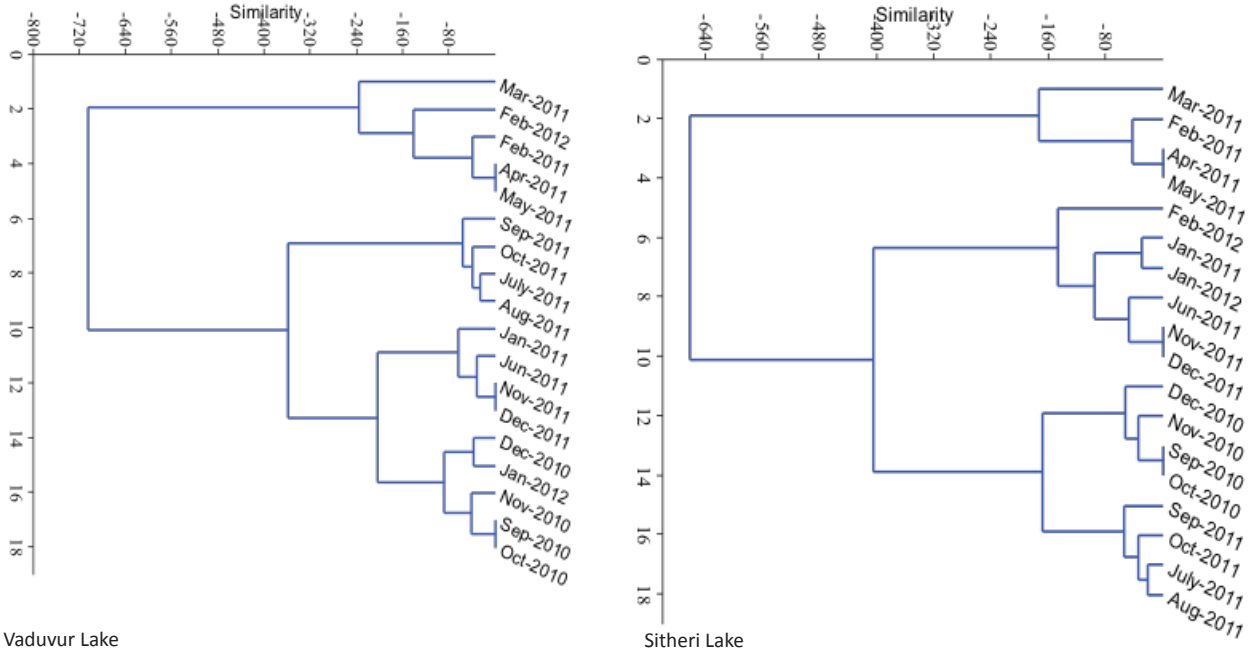

Figure 1. Dendrogram showing seasonal clusters for water quality parameters recorded in Vaduvur and Sitheri lakes.

from 2001 to 2011, nearly 8,67,582 farmers have stopped agriculture due to various reasons, including huge losses. Interestingly, there was an increase in the number of agricultural labourers during the period, as the farmers sell their land for real estate and prefer to work on daily wages. They attributed the reason for the plight of the farmers to wrong import policies of the government, unremunerative prices for farmers' produce, industrialization and urbanization, coupled with the failure to divert the rain and other waters going to sea to the farmers' fields, by linking rivers.

As majority of the lakes in Tamil Nadu go dry in summer, it is presumed that waterbirds move from places lacking adequate water to places with adequate water ignoring site fidelity. Although, both these lakes go 90% dry in the month of May, they still attract a significant number of waterbirds from other parts. The Spot-billed Pelican *Pelecanus philippensis* being a late arrival (largely during late November) particularly in the southern districts of Tamil Nadu performs its breeding activity until the month of April (February to April being crucial months to raise the young ones) while all other species complete their breeding activities largely by January. As majority of the lakes go dry from the month of February onwards in Tamil Nadu, the movement of pelicans from their traditional sites to new lakes with sufficient water is common (Gokula 2011). The Vaduvur Lake is one such wetland that supports pelicans during the above said crucial months. Hence, in order to support Spot-billed Pelican, a near threatened bird, proper steps have to be taken to sustain the water level during April and May.

Various kinds of threats such as excessive fishing, poaching of birds, cattle grazing, fuel-wood collection, siltation, weed invasion, and pollution were identified particularly for the lakes during the study period. Earlier Wolstencroft et al. (1989) reported that these were the major threats in Asia in various wetlands. Thiyagesan & Nagarajan (1995) listed similar threats to the coastal wetlands of Tamil Nadu, southern India. Divakaran (2000) also noticed a majority of these threats in different islands of the Gulf of Mannar, southern India, causing great havoc for bird life there. The forest department of Tamil Nadu has protected the Vaduvur Lake under the bird sanctuary category thus the lake is comparatively free from above said illegal activities such as fishing and poaching of birds. All such activities have been prevailing in the Sitheri Lake.

Waterbird harvest is widespread, long-standing, and an important activity for local communities around the world. In many countries, the harvest takes place as a primary food source, but sport or recreational hunting is also popular; however, waterbird harvest has not been a popular activity in India since time immemorial and it may either be due to the availability of food resources in plenty or due to the culture. Sport or recreational hunting of waterbirds, however, was a part of the recreational activities of kings/maharajas

Table 3. List fish species recorded in the Sitheri Lake, Tamil Nadu, India.

	Fish	Vernacular name	National status, Global status (in parenthesis)
	Cyprinidae		
1	*Barilius bendelisis*	Vannathikendai	LRnt/N (LC)
2	*Puntius sophore*	Kullakendai, Mochakendai	LRnt/N (LC)
3	*labeo calbasu*	Karupan sel, Selukendai	LRnt/N (LC)
4	*Cirrhinus reba*	reba	VU (LC)
5	*Puntius conchonius*	Vallikendia	VU (LC)
6	*Rasbora daniconius*	Bhavanikendia	NE (LC)
	Cobitidae		
7	*Lepidocephalus thermalis*	Ayirai	NE (LC)
	Bagridae		
8	*Mystus cavasius*	Naikeluthi	LRnt/N (LC)
9	*Mystus vittatus*	Vazhppu	VU (LC)
10	*Mystus bleekeri*	Keluthi	VU (LC)
	Cichlidae		
11	*Etroplus suratensis*	Sella kasu, Puradi, Salladai meen	NE (LC)
12	*Etroplus maculatus*	Sethakendai, Bommi	NE (LC)
	Gobiidae		
13	*Awaous gutum*	Ulluvai,Kalulluvai	VU (LC)
	Clariidae		
14	*Clarias batrachus*	Thalmeen, Thal Kendia	VU (LC)
	Mastacembelidae		
15	*Mastcembelus armatus*	Aarrah	VU (LC)

EN —Endangered | VU—Vulnerable | LRnt—Lower Risk near threatened | NE—Not Evaluated | LC –Least concern (IUCN status).
Status nationally as per CAMP assessment (Molur & Walker 1998).

and it continued until the British colonial period. Later, the Indian Wildlife (Protection) Act 1972 prevented this activity to be practiced anywhere in India. Still a nomadic community called 'Narikurava' in Tamil Nadu hunts birds for food as well as commercial purposes. In the interview, some admitted they supply birds dead or alive, specific or common to customers depending on their needs. Some suggested they should be given controlled hunting permits enabling them to make a sustainable living while protecting wildlife. Due to their small population size and the insignificant demand for wild birds among the public comparing others (fish, mutton, domestic chicken) in the market, however, it is generally assumed that hunting is well below the sustainable utilization, a level commonly regarded as a cornerstone in the conservation of nature.

In the present study, frequent visits were made to fish markets of Vaduvur and Mannargudi (a town situated 12km away from the study area) to assess the wild bird trade from 2009 to 2015 (Table 5 & Image 1). In total 68 visits were made of which wild bird trade was found on 26 occasions. On all the occasions, (except three), no same person was found trading in wild birds. Two (belonging to Narikurava) persons involved in wild bird trade were sighted on three occasions. When approached for informal interviews we found many illegal wild bird traders made good their escape, while a very few stayed and engaged in conversation. People belonging to Narikurava though afraid to be photographed with birds, revealed facts like where and how they caught the birds. In total, 974 birds belonging to 21 species, 11 families and eight orders were recorded in the wild bird trade. It even included the Spot-billed Pelican, a Near Threatened bird. Among the orders, Coconiiformes dominated with seven species of birds followed by Gruiformes with five species of birds. Among the bird species, White-breasted Waterhen (89), Little Egret (87), Common Coot (76), and Water Cock (73) were sold in more numbers. Although wild bird trade was found in all the months of the year, it was more frequent during November to January. All the species of birds were largely bought for the purpose of meat. On one occasion, a crow was found sold to a customer and the enquiry with the trader revealed that it was for the purpose of black magic. He also revealed that they do supply crow on request occasionally for the above said purpose. The traders also revealed that all the birds were caught from the paddy fields surrounding the wetlands during early morning and late evening hours using indigenious traps (such as clap trap, mesh nets, and nooses). Although the forest officials frequently intercept, and arrest those involved in the hunting of wild birds in and around Vaduvur area, patrolling larger areas surrounding these two wetlands is not possible and feasible with the existing work force in the forest department. Often, arrested people are booked under the provisions of the Indian Wildlife (Protection) Act 1972. In the early 1970s and 1980s, over 150 families of different communities from Nagapattinam, Thanjavur, and Thiruvarur districts were involved in trapping migratory shorebirds and ducks that used to frequent the coastal wetlands, in several lakhs, during the migratory season (October to April). Now, many bird trappers have shifted to fishing as they were looked down upon for carrying on this illegal profession. Cattle egrets and pond herons are often bought by roadside restaurants and wine shops to serve and sell as

Table 4. Descriptive statistics of water quality parameters recorded during various months of the study area.

	Descriptive Statistics: Vaduvur Lake							Descriptive Statistics: Sitheri Lake				
Water Quality Parameters	Min	Max	Mean	SE	V	SD	Min	Max	Mean	SE	V	SD
Turbidity (NTU)	8.00	32.00	18.56	1.72	53.08	7.29	8.00	30.00	17.39	1.61	46.60	6.83
Total Dissolved Solids	270.00	595.00	394.89	20.80	7785.75	88.24	265.00	560.00	385.67	20.37	7472.12	86.44
Electrical Conductivity MicS/cm	415.00	912.00	605.56	31.88	18292.73	135.25	415.00	897.00	595.67	29.25	15404.40	124.11
pH	6.74	8.00	7.38	0.06	0.08	0.28	6.40	7.90	7.33	0.08	0.10	0.32
Alcalinity pH as CaCO3 (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity Total as CaCO3(mg/l)	105.00	222.00	146.17	6.87	848.97	29.14	108.00	223.00	143.89	6.89	855.28	29.25
Total Hardness as CaCO3(mg/l)	81.00	238.00	126.06	8.94	1437.59	37.92	78.00	237.00	123.22	8.71	1366.89	36.97
Calcium as Ca(mg/l)	24.00	61.00	33.33	2.11	79.88	8.94	24.00	56.00	31.44	1.81	58.97	7.68
Magnesium as Mg (mg/l)	4.00	20.00	10.56	0.93	15.44	3.93	5.00	19.00	10.00	0.82	12.00	3.46
Iron Total as Fe (mg/l)	0.00	2.50	0.72	0.16	0.44	0.66	0.00	2.20	0.67	0.14	0.36	0.60
Manganese as Mn (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Free Ammonia as NH3 (mg/l)	0.00	1.13	0.48	0.08	0.11	0.33	0.00	1.10	0.43	0.07	0.08	0.28
Nitrite as NO2 (mg/l)	0.00	0.45	0.14	0.04	0.03	0.16	0.00	0.45	0.13	0.04	0.02	0.15
Nitrate as NO3 (mg/l)	0.00	5.00	0.67	0.38	2.59	1.61	0.00	4.00	0.56	0.30	1.67	1.29
Chloride as Cl (mg/l)	48.00	127.00	91.06	5.71	585.94	24.21	43.00	120.00	88.83	5.17	480.50	21.92
Fluoride as F (mg/l)	0.00	0.40	0.19	0.02	0.01	0.08	0.00	0.40	0.14	0.02	0.01	0.08
Sulphate as SO4 (mg/l)	2.00	36.00	23.44	2.67	128.26	11.33	6.00	34.00	23.00	2.30	94.94	9.74
Phosphate as PO4 (mg/l)	0.08	1.64	0.60	0.11	0.20	0.45	0.07	1.54	0.59	0.10	0.19	0.43
Tidy's as O	0.40	1.84	0.94	0.11	0.20	0.45	0.40	1.70	0.93	0.10	0.19	0.43

Table 5. Various species of birds recorded in the illegal trade.

					Used in trade as/for						
	Common name	Aviculture/pet use	Meat	Sport	Medicinal use	Black magic	Available months	Availability rating	Frequency of occurrence	Number of visits	Total number birds found
1	Little Grebe *Tachybaptus ruficollis*	*	*				Nov–Feb	Frequent	18	26	67
2	Spot-billed Pelican *Pelecanus philippensis*		*				Nov–Jan	Rare	1	26	1
3	Little Cormorant *Phalacrocorax niger*	*	*				Nov–Jan	Less Frequent	4	26	12
4	Little Egret *Egretta garzetta*		*				Nov–Jan	Frequent	22	26	87
5	Grey Heron *Ardea cinerea*		*				Nov–Jan	Less frequent	4	26	5
6	Large Egret *Casmerodius albus*		*				Nov–Jan	Less frequent	5	26	8
7	Cattle Egret *Bubulcus ibis*		*				All the months	Very frequent	26	26	67
8	Indian Pond-Heron *Ardeola grayii*		*				All the months	Very frequent	26	26	56
9	Black-crowned Night Heron *Nycticorax nycticorax*		*				All the months	Very frequent	26	26	69
10	Asian Openbill-Stork *Anastomus oscitans*		*				Nov–Jan	Rare	2	26	2
11	White-breasted Waterhen *Amaurornis phoenicurus*		*				Nov–Jan	Frequent	16	26	89
12	Water Cock *Gallicrex cinerea*		*				Nov–Jan	Frequent	14	26	73
13	Purple Moorhen *Porphyrio porphyrio*		*				Nov–Jan	Frequent	15	26	67
14	Common Moorhen *Gallinula chloropus*		*				Nov–Jan	Frequent	16	26	68
15	Common Coot *Fulica atra*		*				Nov–Jan	Frequent	18	26	76
16	Pheasant-tailed Jacana *Hydrophasianus chirurgus*		*				Nov–Jan	Frequent	14	26	56
17	Gull-billed Tern *Gelochelidon nilotica*		*				Nov–Jan	Frequent	14	26	45
18	Common Tern *Sterna hirundo*		*				Nov–Jan	Frequent	14	26	46
19	Little Brown Dove *Streptopelia senegalensis*	*	*	*	*		All the months	Frequent	19	26	45
20	Asian Koel *Eudynamys scolopacea*		*				All the months	Frequent	15	26	34
21	House Crow *Corvus splendens*					*		Based on order	1	26	1
	Total										974

chicken. Regardless of months, Cattle Egrets and Pond Herons are trapped every day for this purpose. Hence, proper awareness programmes to other communities and alternate sources of livelihood for Narikurava are essential to wean them away from their traditional but destructive profession. All these birds involved in the illegal trade play a very significant role in the agro-ecosystem as they feed on various insect species and thereby control the pest population.

Anand (1999) reported desiltation was not only useful in terms of improvement of irrigation and fisheries potential, but also to the increase of wildlife diversity and use. During the rainy season the eroded soil from their catchments, gets dumped into these lakes, which in turn reduces the water holding capacity of the lake. Siltation, a serious problem, results in low water depth thereby facilitating the invasion of weed patches. Vallenweider (1968) reported that water bodies with less water depths would be more affected by eutrophication problems. The *Ipomoea aquatic* (weed) invasion was very extensive in these lakes. Anand (1999) observed that the *Ipomoea* invasion changed the water quality and reduced the primary production and nutrient cycle. As a result the weeds should be cleared either manually or by application of weedicide. Such a step will increase the irrigation potential of the lake and improve the condition for the wildlife, especially waterbirds.

The lake area is used by surrounding villagers for grazing their domestic livestock especially during summer. This intensive cattle grazing could result in

Image 1. Various species of waterbirds found in the local market. © V. Gokula

breaking the nutrient cycle of the lake. Further, the trampling cattle might harden the soil surface and reduce the aeration of the lake. Earlier Meganathan (2002) also expressed similar apprehensions for the freshwater lakes of Tamil Nadu. The local people must be educated in this aspect. The surrounding village people are using the lake for washing their livestock. The livestock are allowed to freely drink and bathe in this lake. This cattle washing pollutes the water and acts as a deterrent for waterbirds. Hence, cattle washing should be prohibited in the lake.

Another threat is wood collection for fuel by the local villagers from the lakes and its immediate surroundings. *Acacia*, *Zizypus*, and *Prosophis* were the plants cut for fuel wood. They are the roosting and nesting places for birds like openbill storks and night herons. Dickson et al. (1995) stated that protection of vegetation along the sides of the wetlands is important to retain water quality and accommodate wildlife including breeding birds. Hence, this vegetation, especially at the northern region of the Vaduvoor Lake and the entire Sitheri Lake must be given full attention and protection to prevent human disturbances to nesting activities through wood removal. In 2015, *Prosopis chilensis*—then roosting and nesting sites for several species of birds, were completely removed by the people, which in turn affected the avifauna

Although many of the heronries in Tamil Nadu, despite the stench emanating from the nesting activities of the birds, are zealously protected by villagers (e.g., Kanjirankulam, Udayamarthandapuram, Vettangudi, Vedanthangal, and Koonthakulam), villagers in and around the Vaduvoor Lake lack such interest towards protection of birds. Usage of crackers and musical instruments by villagers are very common during festival times in Vaduvoor Lake area. A prominent Kothandaramar Temple and a community temple are situated around the Vaduvoor Lake. Although, festivals of Kothandaramar Temple largely come between June and August, disturbance to birds by the devotees are considerably less as birds are less during these months. Frequent family functions held at the community temple

situated at the edge of the lake, however, cause a major threat to the breeding birds particularly during the migration and breeding seasons. It has been suggested that the greatest and most depressing problem in conservation is not habitat loss or overexploitation but the human indifference to such problems (Balmford 1999). Overcoming such indifference is likely to depend on providing both the opportunities to appreciate areas and species, and education to highlight the ecological, aesthetic, cultural, spiritual, recreational, and economic importance. Education is one of the major techniques available to conservationists through which change in behaviour or compliance with new legislation can be achieved. Moreover, maintaining protected areas is easier if there is public support, which often leads to political and financial support and greater adherence to rules and regulations (Shepard & McNeely 1998). Hence, a proper public awareness program has to be initiated about the conservation of birds and lakes among the public.

As the lake is situated on one side of the Trichy-Mannargudi main road, vehicular sound is a great threat to the breeding birds. High decibel noise often disturbs the breeding activities of the birds, and frail chicks. Hence, usage of horns by vehicles should be banned from start to end of the lake at least during the peak breeding season of birds.

Pesticides, manures, and fertilizers are being increasingly used to ensure greater production of food in the nearby paddy fields around the lake. Some of these chemicals find their way into soils, water and other parts of the environment as a result of direct application or by indirect means. Hence, it is also necessary to monitor the water for possible pesticide contaminants since the lake is also the main source of water supply for agricultural consumption. In addition to awareness, volunteers should be trained to monitor the breeding population of birds and other threats to birds and wetlands.

CONCLUSION

In general, wetland management for waterbirds of these two lakes should focus on providing suitable nesting habitats and available food resources for dependant avifauna. Management of invertebrates, amphibians, and fishes in these two lakes is one technique that can be used to provide foraging opportunities for waterbirds. Most species often rely much on nearby aquaculture fields thus a straightforward 'farm crisis' may badly affect the avifauna of these two lakes. Hence, agricultural activities around the two lakes should be encouraged. The water level and water quality of the lake should be properly maintained to cater to the needs of both irrigation and wildlife. Periodic desilting should be initiated with proper care and planning to provide a variety of depth levels. Cattle grazing and cattle washing in the lake should be totally prohibited. The weed *Ipomoea* should be removed totally. Poaching of waterbirds should be stopped by effective steps, such as better vigil and weaning of nomadic life from wildlife hunting by educating them and providing alternative livelihood. An awareness campaign must be conducted so that the local public realizes the significance of the lake in terms of their wildlife values and need to utilize them judiciously and sustainably for mutual benefit. There is an excellent potential for developing these lakes as very good tourist attractions since these lakes are situated near other famous tourist areas such as Point Calimere Wildlife Sanctuary, Karaivetti Lake, and other cultural heritage sites (such as Tharangambadi, Thanjavur, and Velankanni). Ecotourism would increase the income of the local people. Hence, an integrated approach and increased co-operation would result in the rational use of this freshwater resource leading to improved standards of living around this lake.

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COMMUNICATION

A new species of shieldtail snake (Squamata: Uropeltidae: *Uropeltis*) from the Bengaluru uplands, India

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Abstract: A new species of shieldtail snake, *Uropeltis jerdoni*, is here described based on eight specimens from Devarayana Durga and Nandi Durga that are under-researched hills near Bengaluru in southern India. The new species is a member of the *Uropeltis ceylanica* group that can be distinguished from related taxa as follows: a truncate and flattened caudal shield with a circumscribed concave disc; part of rostral visible from above subequal to its distance from frontal; rostral partially separating nasal scales; 17: 17: 17 dorsal scale rows; 140–148 ventral scales; 7–9 pairs of subcaudals; dark blackish-grey above, powdered with minute yellow specks, yellow lateral stripes on neck and tail; ventrolateral region with yellow mottling; venter black. This new species is currently known only from two ranges Devarayana Durga and Nandi Durga but judging by the presence of similar, adjacent massifs, is hypothesized to be present in nearby hillocks surrounding Bengaluru City.

Keywords: Allopatry, colouration, Devarayana Durga, Nandi Durga, peninsular India, scalation, *Uropeltis jerdoni* sp. nov.

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Author contributions: SRG led the diagnosis of the new species against the comparative materials that he had examined and wrote the manuscript with inputs from NSA and ODA. KGP led the field work and gathered data from the live uncollected specimen and photo-documented the subjects. ODA examined and scored morphological details of historical paratypes and cross-checked data from the recent type specimens, while registering them with the museum. NSA conducted the field surveys and roadkill specimen collections, examined the type specimens and scored morphological details. All authors equally contributed in fine tuning and refining the draft and approved the final version.

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INTRODUCTION

Snakes of the family Uropeltidae Müller, 1832 are an under-researched group of small and unassuming fossorial snakes from the Indian subcontinent (Beddome 1886; Smith 1943; Rajendran 1985; Whitaker & Captain 2004; Wallach et al. 2014). The genus *Uropeltis* Cuvier, 1829 currently consists of 25 species occurring in the hills of peninsular India (Pyron et al. 2016; Jins et al. 2018; Ganesh & Achyuthan 2020). The first species in this genus that was described was *Uropeltis ceylanica* Cuvier, 1829, a species that is currently considered to be a complex (Gower et al. 2008; Ganesh et al. 2014) and with an erroneous type locality 'Ceylon' that is outside the known distribution of the species (see Pyron et al. 2016). Of late, two species *U. bicatenata* (Günther, 1864) and *U. shorttii* (Beddome, 1863) previously considered invalid were resurrected and one species *U. madurensis* (Beddome, 1878) that was previously considered a subspecies, was elevated to a full species rank (see Gower et al. 2008; Ganesh et al. 2014). In recent times, two new species *Uropeltis bhupathyi* Jins, Sampaio, Gower, 2018 and *Uropeltis rajendrani* Ganesh & Achyuthan, 2020 were described from the Western Ghats and the Eastern Ghats, respectively (Jins et al. 2018; Ganesh & Achyuthan 2020).

These snakes, owing to their naturally-patchy distribution and high beta diversity, that is a diversified multi-species assemblage of fauna constituted by each having a small, typically non-overlapping distribution range, resulting in turn-over among hill ranges (sensu Socolar et al. 2016), were hypothesized to be potential model organisms for evolutionary studies in the Indian peninsula (Cadle et al. 1990; Bossuyt et al. 2004; Ganesh 2015; Pyron et al. 2016). Molecular phylogenetic studies reveal that this genus of snakes radiated rapidly and recently during early Miocene, some 20 million years ago (Cyriac & Kothandaramiah 2017). Despite these works, the fact is that our current understanding of the diversity and distribution of the genus *Uropeltis* remains incomplete. Here, we describe a new species of *Uropeltis* representing an innominate population from a locality that is previously-unsampled for shieldtail snakes, a hill-dominated region situated around Bengaluru City that is recently recognised as an important area for herpetological diversity and endemism (see Agarwal et al. 2019).

MATERIALS & METHODS

The current work is based on our examination of 39 preserved specimens (representing 16 congeners) and the type specimens as well as live uncollected specimens of the new species that is described herein. During our expeditions in the uplands of Bengaluru, we came across three specimens (two dead, one alive) that we could assign to the genus *Uropeltis* sensu Pyron et al. (2016) in lacking mental grove, supraocular, postocular or temporal scales and having a dorso-ventrally depressed tail with a scaly caudal disc. The road kill specimens were noticed having apparent breakage of certain scales in the ventral aspect and indentations in parts of their trunk suggesting a run over by a small vehicle. During our perusal of uropeltid collections in the Bombay Natural History Society Museum, we came across six historical specimens that fully match with the new species. We photographed the subjects using high resolution digital cameras. We scored morphological details like scalation, measurements and colour patterns with the help of magnifying hand lenses (5 X optical zoom). We measured the preserved specimens using vernier calipers (LC 0.1 mm) except for snout-vent length that was measured with a standard measuring tape (LC 1 mm). We followed Smith (1943) for definition and terminology of morphological characters, except for ventral scales for which Gower & Ablett (2006) counting method was followed. Symmetrical head scalation values were given in left / right order. Dentition characters were scored by counting one half (lateral side) of both the upper jaw (maxillary) and the lower jaw (mandibular/ dentary). Teeth were counted by manually opening the preserved specimen's mouth and inserting a cotton plug. Counts were done viewing through a Celestron 20–200 X zoom magnification illuminated microscope. A linear incision in the subcaudal was done on the preserved specimens to check for genitalia. Comparisons and differential diagnosis are provided based on the series of preserved voucher specimens in collections that we examined (see Appendix 1) and also on our perusal of original description papers and subsequent taxonomic treatises (see literature cited). The new species belongs to Smith's (1943) Group II, in having an obliquely truncate tail, terminating in a thickened, circumscribed, concave caudal disc covered with multicarinate scales (see Smith 1943). Comparisons are presented as differential diagnosis, following the pattern in works on the genus *Uropeltis* by Ganesh et al. (2014) and Ganesh & Achyuthan (2020). Museum abbreviations are as follows: CSPT—Chennai Snake Park Trust, Chennai, India;

CESS—Centre for Ecological Sciences / Snakes, Indian Institute of Sciences, Bengaluru, India; BNHS—Bombay Natural History Society, Mumbai, India; MAD—Madras Government Museum, Chennai, India.

TAXONOMY

***Uropeltis jerdoni* sp. nov.**
Jerdon's Shieldtail Snake
(Image 1A–G, 3A–B)
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Holotype: BNHS 3562, adult female, a rather intact roadkill near village, coll. KGP and NSA in January 2020.

Type locality: Devarayana Durga (13.371˚N, 77.210˚E; 1,060 m) in Tumkur District, Karnataka, India.

Paratypes (n= 7): BNHS 3563, adult female, animal in early ecdysis, same data as holotype; BNHS 216 a–b, BNHS 217 a–b, BNHS 218 a–b, coll. Frank Wall from Nandi Durga (13.370^{0}N, 77.681^{0}E; 1,470 m) in Chikballapur District, Karnataka, India; coll. date unknown.

Referred specimen (n= 1). One live uncollected adult, sex unknown, same data as holotype.

Etymology: Patronym named in genitive singular case, honouring Thomas Caverhill Jerdon (1811–1872), a pioneering English naturalist who described some of the earliest reptiles from the Bengaluru uplands.

Diagnosis: A species of *Uropeltis* known from the Bengaluru uplands, characterized by the following combination of characters: caudal shield truncate, with a distinct thickened circumscribed concave disc; part of rostral visible from above subequal to its distance from frontal; rostral scale partially separating nasal scales; snout fairly pointed, subovoid; eye diameter 3/4th that of ocular shield; supralabials 4; infralabials 3–4; dorsal scale rows 17:17:17; ventral scales 140–148; subcaudal scales 7–9 pairs; dorsum dark blackish-grey overall with minute yellow speckling; an yellow stripe on either sides on neck and tail; ventrolateral region distinctly mottled with yellow; venter uniform dark blackish-grey, rarely with a few yellow dots.

Description of holotype

Habitus: A fairly small but thick-set and robust shieldtail snake; forebody mildly thicker than the rest of trunk; head not evident, narrower than neck; snout fairly pointed in profile, subovoid; eyes large, ¾ the size of ocular scale; tail with a distinctive flat, thickened, circumscribed disc.

Measurements in mm: snout to vent length 186.2; tail length 11.1; maximum body width 7.1; head length 7.7; head width 4.6; head depth 3.8; internarial distance 1.26; interorbital distance 2.81 at the front of the ocular and 3.41 at the rear of the ocular; eye to snout tip distance 3.67; eye to lip distance 1.12; snout-parietal distance 3.0; posterior end of rostral to posterior end of parietal distance 5.14; tail shield length 9.91; tail shield width 6.12; tail shield depth 3.67; parietal scale length 3.32; parietal scale width 2.71; frontal scale length 1.45; frontal scale width 1.78; ocular scale length 1.41; prefrontal scale length 1.17; midbody ventral scale width 1.33; midbody basal coastal scale width 2.31.

Scalation: Rostral visible from above, partly dividing nasals, anteriorly, but posteriorly in contact with one another, behind rostal; part of rostral visible from above subequal to its distance from frontal; nostril piercing nasal, pointed towards rostrum and first supralabial; nasals slightly smaller than prefrontal; ocular scale slightly smaller than nasal and/ or prefrontal; frontal hexagonal, longer than broad; broader anteriorly, posteriorly produced towards a tapering point, wedged deeper within the midline contact of parietals; parietals large, as large as distance between snout tip and anterior end of frontal; ocular scale separating contact between prefrontal and parietal; ocular, in contact with frontal; supralabials 4/4, first supralabial the smallest of all head scales, rectangular; second supralabial subequal to rostral, higher than broad; third supralabial broader than high, higher anteriorly, shorter posteriorly; fourth supralabial the largest, subequal to frontal, smaller than parietal; infralabials 3/4, first infralabial large, second the largest, third/ fourth ones small and elongate; scales overall smooth and glossy, imbricate, cycloid; dorsal scale rows: 17: 17: 17; ventrals 146, 1.5 times as wide as adjacent scale rows; anal scale paired, subequal to ventral scale but larger than subcaudal scale; subcaudals 9, paired; caudal scales across length of tail shield 8; caudal scales across width of tail shield 4; caudals scales with 2–5 keels per scale; tail shield ending with two projecting spurs.

Colouration: Dorsum lustrous dark blackish grey overall; anterior end (head, neck) with a brownish tinge, while the posterior end (tail shield) steely bluish-black; dorsum with very fine, scarce yellow powdering all along the trunk from head to near pre-cloacal region; tail and tail shield devoid of yellow patterning above; a distinct pair of yellow ventrolateral stripes from snout tip till tail shield; the yellow stripes rather evident from infralabials till neck, from where onwards the yellow colouration becomes restricted only to scale borders of the last rows of coastal scales; the central part of coastal scales and

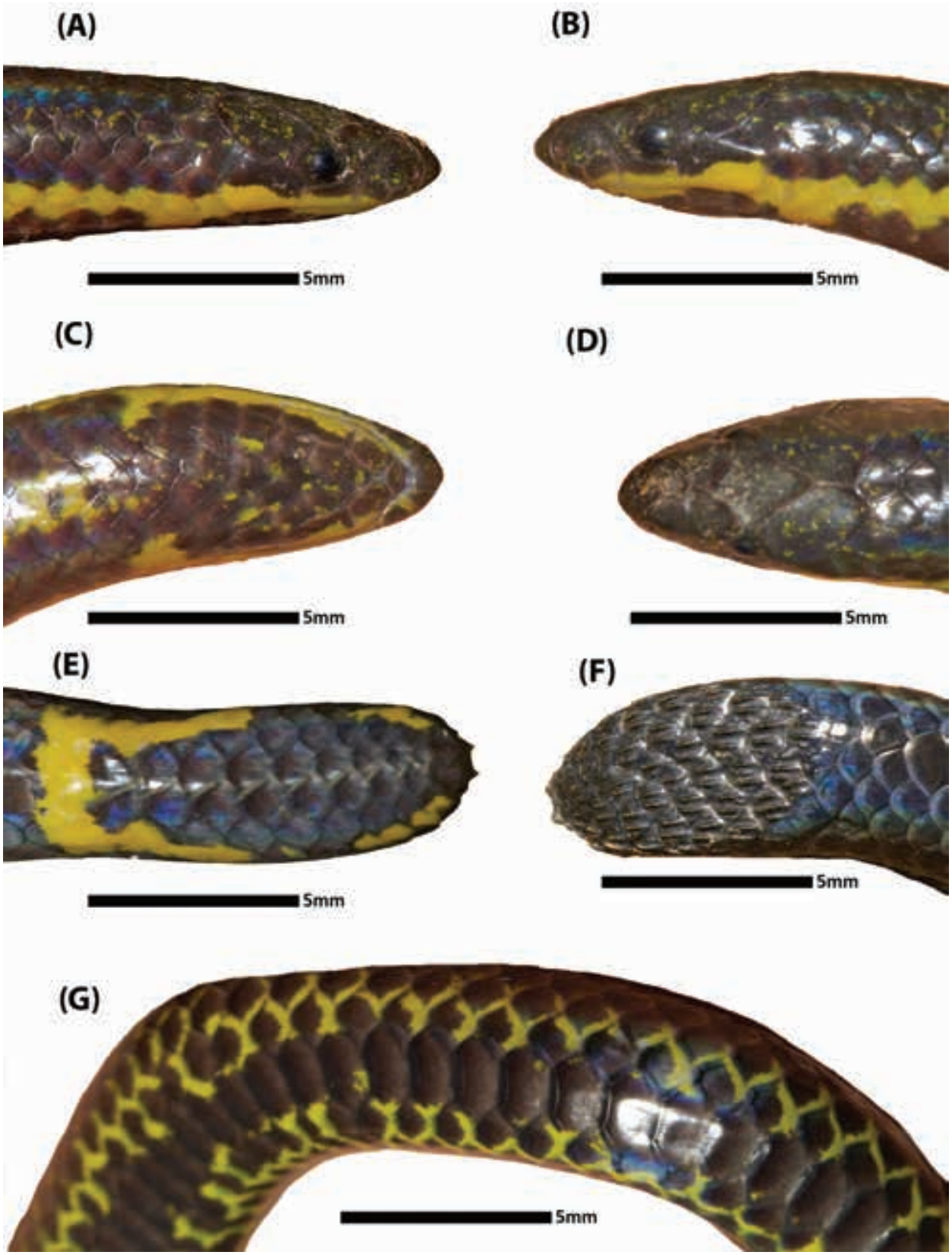

Image 1. Profiles of Holotype BNHS 3562 of *Uropeltis jerdoni* sp. nov.: A—head left view | B—head right view | C—head ventral view | D—head dorsal view | E—tail ventral view | F—tail dorsal view | G—close up of ventral scales. © N.S. Achyuthan.

almost whole of the ventral scales totally black, rarely with any yellow intrusions; thick yellow stripes along subcaudals that widen and meet across the anal shield; tongue dark reddish-brown, darker at the tips; iris black.

Dentition: On each side of the jaw, eight maxillary (upper jaw) teeth and five mandibular or dentary (lower jaw) teeth present; teeth conical, visibly curved inwards, uniform in size throughout, except for the two front-most teeth that are slightly smaller; diastema absent.

Variation shown by paratypes: Agreeing well with the holotype in general and showing the following intraspecific variations: dorsal scale rows 17:17:17; supralabials 4; infralabials 3/4; ventrals 143–148; subcaudals 7–9; snout to vent length 147–201 mm; tail length 8–13 mm; maximum body width 5.2–7.0 mm; head length 7.0–8.8 mm; head width 3.0–4.3 mm; head depth 3.1–4.1 mm; internarial distance 1.2–1.9 mm; interorbital distance 2.9–3.4 mm front, 3.2–3.7 mm back; eye to snout tip distance 3.0–3.9 mm; eye to lip distance 1.0–1.1 mm; snout-parietal distance 2.8–4.9 mm; posterior end of rostral to posterior end of parietal distance 4.1–5.8 mm; tail shield length 7.3–9.3 mm; tail shield width 4.8–5.9 mm; tail shield depth 3.4–5.1 mm; parietal scale length 2.0–3.5 mm; parietal scale width 1.4–2.8 mm; frontal scale length 1.5–3.7 mm; frontal scale width 1.6–2.9 mm; ocular scale length 1.0–2.1 mm; prefrontal scale length 1.2–1.5 mm; midbody ventral scale width 2.1–3.9 mm; midbody basal coastal scale width 1.1–1.8 mm. Because the paratype from Devarayana Durga was still in ecdysis, its colouration differed to a more brownish than dark blackish colouration overall. The paratypes from Nandi Durga were understandably paler and less intense in colouration, due to long years of preservation. They had overall dull brown body colour with straw yellow side stripes and ventral patches. One historical paratype, BNHS 216a has left lower jaw and right temporal damaged and torn off. All the historical paratypes had posterior parts of underside incised.

Distribution and Natural History: *Uropeltis jerdoni* sp. nov. is a poorly-known snake, as this is a so-far unsampled population about which published literature has not dealt with (see Pyron et al. 2016 and references therein). Though Wall had collected this species from "Nandydug" (=Nandi Durga), historical literature during or after Wall's time (e.g., Smith 1943), never stated the occurrence of any uropeltids near about Bengaluru, except *U. ellioti* that belongs a different species group. The holotype and one paratype were roadkills recently collected from the Ghat road of a hill fort temple – Devarayana Durga. These snakes would have probably been killed the previous night by vehicle plying on the ghat road. A live uncollected adult of unknown sex, measuring about 250 mm total length was sighted in an earthworm farm at the type locality. The snake was dug out from underneath the soil surface by the

Image 2. Profiles of Paratype BNHS 3563 of *Uropeltis jerdoni* sp. nov.: A—head left view | B—head right view | C—head ventral view | D—head dorsal view | E—tail dorsal view | F—tail ventral view. © O.D. Adhikari.

Image 3. *Uropeltis jerdoni* sp. nov. Profiles of Holotype BNHS 3562: A—entire dorsal view | B—entire ventral view; Profiles of Paratype BNHS 3563: C—entire dorsal view | D—entire ventral view. © O.D. Adhikari.

Image 4. Entire view of a live uncollected topotypical adult *Uropeltis jerdoni* sp. nov. showing life colouration and general appearance.

workmen when we authors (PKG and NSA) were present to document biodiversity. The snake was inoffensive and tried to dig underground when exposed and during photography. It had blue-black dorsum; ventrolateral yellow reticulations; black venter; concave, circumscribed tail disc; scale rows 17:17:17; 143 ventrals; paired anal scale; nine pairs of subcaudals, thereby matching in morphology with the preserved specimens. To the best of our knowledge, the only other uropeltid snake sympatric with the new species is *Uropeltis* cf. *ellioti* (Gray, 1858), a distinctly reddish-brown coloured species with evident, convexly-rounded tail shield (Group I of Smith 1943) having a large yellow spot on tail tip (also see Whitaker & Captain 2004; Pyron et al. 2016). The distribution range of *Uropeltis jerdoni* sp. nov. is a mix of deciduous vegetation distributed within a sprawl of predominantly rocky boulder-dominated hilly terrain (Boraiah & Fathima 1970; Bhaskar & Kushalappa 1995), currently known from two peaks north of Bengaluru – Devarayana Durga and Nandi Durga that are 40 airline km apart. *Uropeltis jerdoni* sp. nov. is hypothesized to be a primarily nocturnal, worm-eating, viviparous, fossorial snake that is particularly active during rain, like most members of its family (Rajendran 1985).

Comparisons and differential diagnosis: The new species is here compared with the 25 recognized species of *Uropeltis* from India (see Pyron et al. 2016; Jins et al. 2018; Ganesh & Achyuthan 2020). By having an obliquely truncate tail terminating in a thickened, circumscribed, concave caudal disc covered with multicarinate scales, *Uropeltis jerdoni* sp. nov. differs from the following 14 species: *U. bhupathyi, U. ellioti, U. nitida, U. ocellata, U. dindigalensis, U. beddomei, U. macroryncha, U. woodmasoni* (Group-I tail shield of Smith 1943)*, U. grandis, U. maculata, U. petersi, U. liura, U. pulneyensis* (Group-III tail shield of Smith 1943). Further, *Uropeltis jerdoni* sp. nov. also differs from the remaining congeners (after Gower et al. 2008; Ganesh et al. 2014; Ganesh & Achyuthan 2020) with a thickened, circumscribed, caudal shield categorized under Smith's (1943) Group II A & B as follows (only opposing suite of character states listed): *U. arcticeps* (southern Western Ghats): dorsal scales lacking a clearly defined yellow scale border; ventral scale counts much lower (127–128); *U. bicatenata* (northern Western Ghats): yellowish scalloping chain-like pattern across both sides of the body; ventral scale count 130–141; *U. broughami* (southern Western Ghats): 19 midbody scalerows; rostral scale much produced and ridged with a dorsal keel; dorsum brown with distinct small, yellow-black-edged transverse ocelli; ventral scale counts much higher (181–230); *U. ceylanica* s. auct. (Western Ghats): anterior dorsum without distinct yellow spots; venter lacking a clearly defined brownish scale border; ventral scale counts much lower (119–146; 130 in holotype – Gower et al. 2008); *U. macrolepis* complex

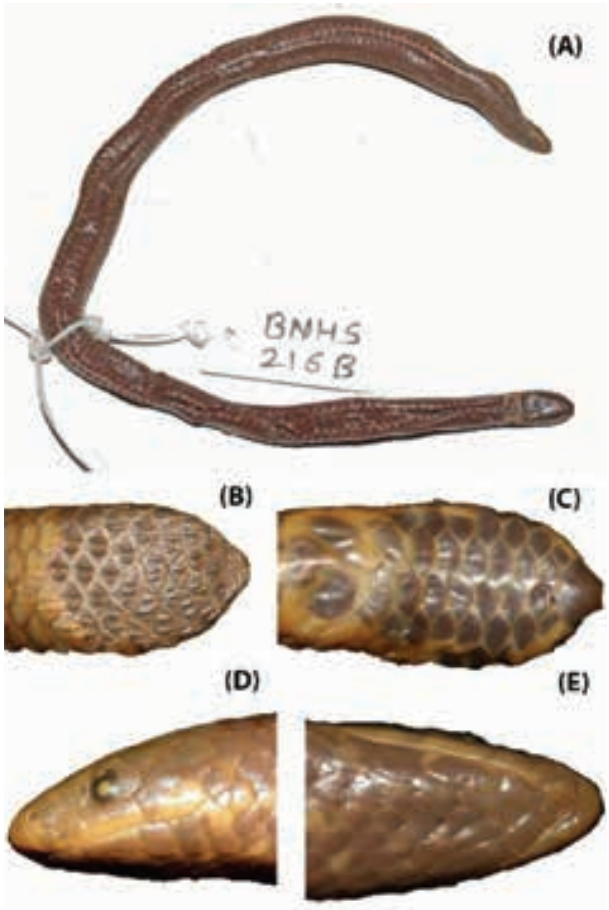

Image 5. Historical paratypes of *Uropeltis jerdoni* sp. nov.: A—BNHS 216b entire view | B—BNHS 217b tail dorsal | C— BNHS 217b ventral views | D—BNHS 218b head lateral | E— BNHS 218b head ventral. © O.D. Adhikari.

Image 6. Devarayana Durga, the type locality of *Uropeltis jerdoni* sp. nov. showing the rocky hillocks, the vegetation type and the presence of buildings, roads, and tourism. © K.G. Punith.

Image 7. Nandi Durga, another locality of *Uropeltis jerdoni* sp. nov. showing the general view of landscape and contemporaneous habitats. © Raghunath R. Belur & Sugandhi Gadadhar.

(northern Western Ghats): 15 midbody scalerows; lower ventral scale counts (120–140); dorsum blackish-brown with yellow broken spots forming zig-zag crossbars or annuli or a pair of distinct, thick, yellowish-orange paravertebral stripes extending across most of the body except near neck, where there are two large orange spots; *U. madurensis* (southern Western Ghats): snout much more rounded in profile; body colour rich brown, dorsal scales with a clearly defined yellow scale border throughout the back, giving a yellow-reticulated appearance; no ventrolateral yellow reticulations, but ventrals with large alternating yellow blotches; ventral scale count 144–157; *U. myhendrae* (southern Western Ghats): dorsum with brownish-black body, each scale with yellowish posterior border forming more or less complete band or annuli; part of rostral visible from above distinctly longer than its distance from frontal; ventral scales 139–156; *U. phipsoni* (northern Western Ghats): a pair of yellowish lateral streaks along both sides of the body; part of rostral visible from above distinctly longer than its distance from the frontal; ventral scales 138–157; *U. rajendrani* (southern Eastern Ghats): ventrals 146–158; rounded snout profile; body deep ochre brown; presence of yellow colouration in the ventral scales; part of rostral visible from above, not much longer than its distance from frontal; *U. rubromaculata* (southern Western Ghats): presence of two large red caudal spots; much lower ventral counts (127–136); *U. rubrolineata* (southern Western Ghats): presence of two ventrolateral red stripes; much higher ventral counts (165–172); *U. shorttii* (southern Eastern Ghats, allopatric): dorsal body brownish or bluish-black, with distinct yellowish annuli or crossbars; ventral scales 137–156.

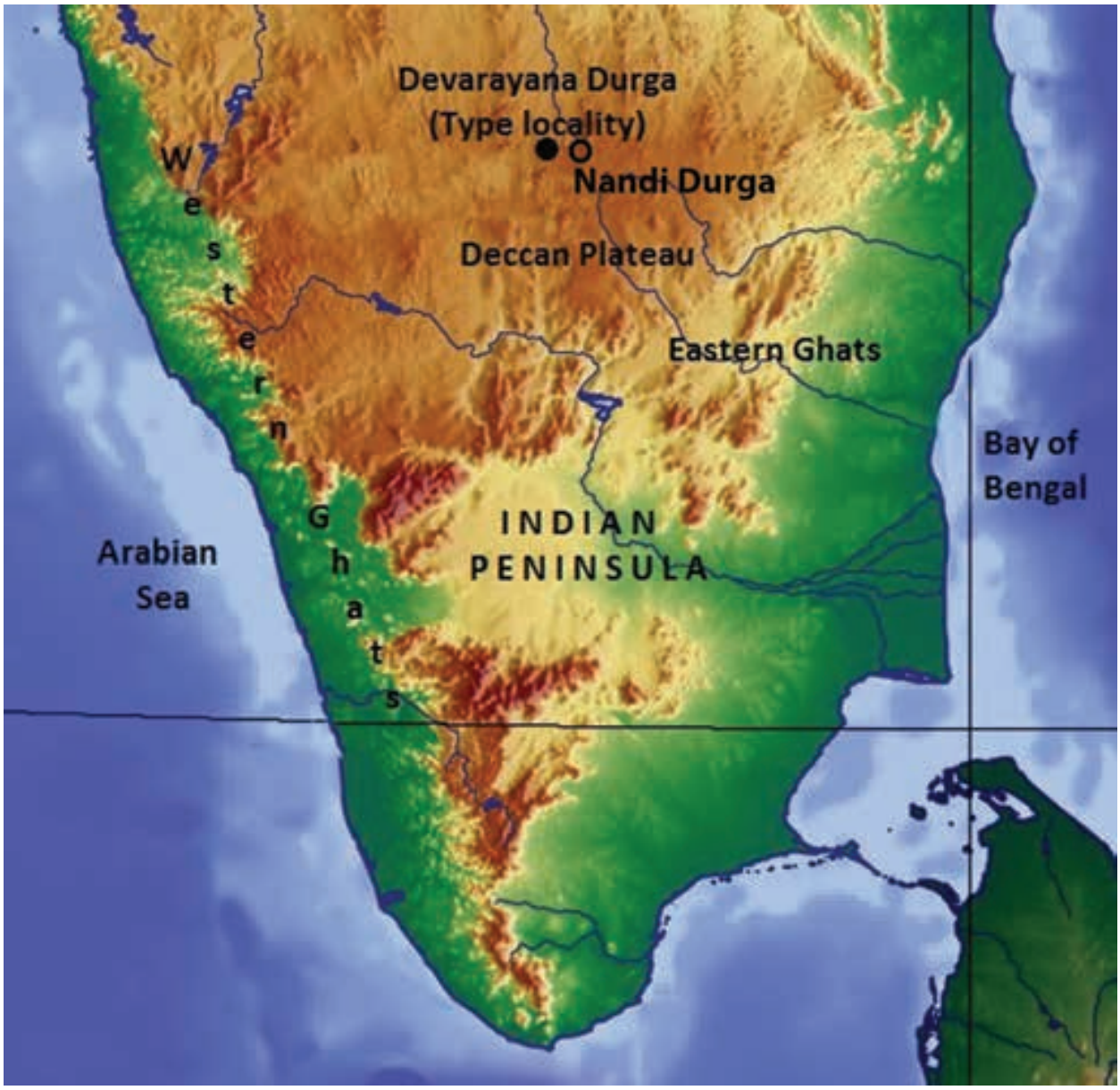

Image 8. Physical map of southern India, depicting the distribution of *Uropeltis jerdoni* sp. nov.: Devarayana Durga (type locality)—filled circle | Nandi Durga—open circle.

DISCUSSION

Uropeltis jerdoni sp. nov. is the 26th species of *Uropetlis* to be described. Recent descriptions of *Uropeltis* were either from the Western Ghats (Jins et al. 2018) or the Eastern Ghats (Ganesh & Achyuthan 2020). But in the present case, *Uropeltis jerdoni* sp. nov. is described from the intervening region – the Bengaluru uplands, that is flanked by both the Western and the Eastern Ghats on either sides. In fact, the only species of shieldtail snake known from regions in India apart from the Western Ghats and the Eastern Ghats, is the apparently 'widespread' *U. ellioti* (Gray, 1858) reported from most of the hilly areas across the Indian peninsula (Smith 1943; Whitaker & Captain 2004). Thus, *Uropeltis jerdoni* sp. nov. is a previously unsampled new species of shieldtail snake that has not been reported in literature under any incorrect names. This is in contrast to *U. bhupathyi* that was long-thought to be and misreported in literature as *U. ellioti* (see Jins et al. 2018).

Uropeltis jerdoni sp. nov. is described based on two, recently preserved, female road-kills (holotype and paratopotype), six historically-collected specimens and one uncollected, unsexed, live individual (referred

material). These materials originate from two, nearby (40 airline km apart) hill ranges – Devarayana Durga (type locality) and Nandi Durga. Shieldtail snakes, especially the diverse genus *Uropeltis* is a radiation of cryptic species (Cyriac & Kodandaramiah 2017), with each of the constituent species displaying very subtle morphological variations (Gower et al. 2008; Ganesh et al. 2014; Jins et al. 2018; Ganesh & Achyuthan 2020) and occupying small, allopatric geographic ranges (Pyron et al. 2013; Ganesh 2015). In the case of *U. jerdoni* sp. nov. its nearest related congeners are *U. shorttii* of Shevaroys that is 200 airline km south off Devarayana Durga-Nandi Durga and *U. ceylanica* s. lat. of the equally-distant Malnad part of the Western Ghats.

The localities where *Uropeltis jerdoni* sp. nov. has been recorded, the Bengaluru uplands, is poorly inventoried for biodiversity, especially herpetofauna. T.C. Jerdon was perhaps the foremost naturalist to explore the area in and around Bengaluru, when he described a new gecko *Cnemaspis mysoriensis* (Jerdon, 1853), over 165 years ago. *Uropeltis jerdoni* sp. nov. is a humble tribute to his pioneering efforts to inventory and describe the reptiles of Bengaluru. In recent times, five more new reptiles were described from places near Bengaluru—*Hemidactylus graniticolus* from Harohalli (Agarwal et al. 2011), *Hemidactylus whitakeri* from Kodalagurki (Mirza et al. 2018), *Cyrtodactylus srilekhae* from Thathaguni (Agarwal 2016), *Hemiphyllodactylus jnana* from Kodigehalli (Agarwal et al. 2019), and a snake *Lycodon deccanensis* from the same Devarayana Durga (Ganesh et al. 2020). These works well indicate that further explorations around Bengaluru would reveal further reptile diversity, endemism and novelties. As for the genus *Uropeltis*, the recent taxonomic research and increase in diversity hints that more studies in this and other genera of uropeltid snakes will add to the growing body of literature on their increased taxonomic diversity.

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Appendix 1. List of preserved voucher specimens studied.

Uropeltis ceylanica: MAD no number from Perambikulam; another unnumbered specimen from Cochin; MAD 1938 from Attikan (Mysore) E. Barne's collection, from ca. 5000 feet, in June 1938; more unnumbered specimens, from Nilgiris, Cochin and Travancore; CESS 092 from Pakshipathalam, Bramgiri, Kannur District, Kerala; CESS 281, from Coorg, Madikeri District, Karnataka.
Uropeltis dindigalensis: MAD no number from Sirumalai, Madura District.
Uropeltis ellioti: CESS 079, from Chemmunji, Peppara WLS, Trivandrum District, Kerala; CSPT/S-81 from Shevaroys, Salem District, Tamil Nadu.
Uropeltis grandis: MAD no number from Anamalai, Coimbatore District, Tamil Nadu.
Uropeltis liura: CSPT/S-3, n= 2, from Madurai hills, Madurai District, Tamil Nadu.
Uropeltis maculata: CESS 186 from Anaimudi Shola NP, Idukki District, Kerala; MAD no number from Anamalai, Coimbatore District, Tamil Nadu.
Uropeltis madurensis: CSPT/S-6, from High Wavys, Theni District, Tamil Nadu.
Uropeltis myhendrae: CSPT/S-5, from Vannathipparai, Kanyakumari District, Tamil Nadu.
Uropeltis nitida: CESS 408 from Nelliampathy RF, Palghat District, Kerala.
Uropeltis* cf. *ocellata: MAD no number from Perambikulam; more unnumbered specimens from Cochin (Kerala) and Kodaikanal, Palni hills (Tamil Nadu).
Uropeltis petersi: CSPT/S-7a from Kodaikanal, Dindigul District, Tamil Nadu.
Uropeltis pulneyensis: MAD 1929, n=6 collected by E. Barnes, during April-May, from 6000–6800 feet, Kodaikanal, Palni hills; CSPT/S-4a, from Kodaikanal, Dindigul District, Tamil Nadu.
Uropeltis rajendrani: BNHS 3559 (holotype), BNHS 3560, 3561 (paratypes), n=3, from Bodhamalai hills, Salem-Namakkal Districts, Tamil Nadu.
Uropeltis rubromaculata: MAD no number from Anamalai, Coimbatore District; CSPT/S-7 from Anaimalai, Coimbatore District, Tamil Nadu; CESS 322, from Anaimalai WS, Tirupur District, Tamil Nadu.
Uropeltis shorttii: CSPT/S-80, n= 2 from Shevaroy Hills, Salem District, Tamil Nadu.
Uropeltis woodmasoni: CSPT/S-4, from Anaimalai, Coimbatore District, Tamil Nadu.

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COMMUNICATION

A looming exotic reptile pet trade in India: patterns and knowledge gaps

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Abstract: Commercial trade of exotic reptiles through CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) in India is relatively recent (<2 decades). Social media platforms and web portals are known to be used for pet trade. Exotic pet trade is not legally regulated within India. Therefore, little is known on the scale at which this trade is carried out in India. We conducted a two-year study between 2018 and 2020 gathering information of exotic reptile pet trade online and summarized CITES documentation of the yearly import export records from 1976 to 2018 by CITES secretariat. This manuscript provides a baseline for the extent of the trade, invasive species and the species traded in mainland India. We found that there is an extensive trade of exotic reptiles in the country, comprising 84 species including the highly venomous species such as *Bitis gabonica*. According to CITES records of 1976–2018, 98.6% of the reptile imports into India have not been reported to the CITES management authorities in India. We also found some evidence of trade in protected native species through the exotic pet trade network. Furthermore, some highly threatened reptile species including many listed in Appendix I of CITES are traded in India.

Keywords: CITES, disease, exotic reptiles, IUCN, social media, trade.

Abbreviations: CITES—The Convention on International Trade in Endangered Species of Wild Fauna and Flora | IUCN—International Union for Conservation of Nature.

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INTRODUCTION

Globally, the exotic pet trade has increased over the years and human induced translocation of species has substantially increased during the last few decades (Pimentel et al. 2008; Seebens et al. 2017). Live trade in exotic reptiles is no exception to this increasing trend (Auliya et al. 2016; Hierink et al. 2020). Trade of live animals and plants is identified as a major pathway of biological invasions (Mooney & Cleland 2001; Krishnakumar et al. 2009; Engeman et al. 2011; Lockwood et al. 2019; Mohanty & Measey 2019) and in some cases it also leads to the spread of infectious diseases to other native flora and fauna including humans (Karesh et al. 2005; van Borm et al. 2005; Pavlin et al. 2009; Falcón et al. 2013; Mendoza-Roldan et al. 2020). Invasive species have wreaked havoc on native ecosystems in different parts of the world and have led to the extinction of several native species (Savidge 1987; Mooney & Cleland 2001; Jones et al. 2008; Gurevitch & Padilla 2004; Shine 2010; Simberloff & Rejmanek 2010; Willson et al. 2011; Dorcas et al. 2012).

The international trade in wildlife is estimated to be worth hundreds of billions of dollars annually and has steadily increased in value (Engler 2008; Roe 2008). A virtual display of exotic animals on the internet attracts customers and it is a major outlet for trade in wildlife (Lavorgna 2014). This medium (internet and social media) has also been identified as a useful source to document the scale at which the trade is carried out (Vaglica et al. 2017; Jensen et al. 2019).

Approximately, 5,800 species of animals and 30,000 species of plants are covered by CITES in order to protect them from over-exploitation by trade. India has been a party to CITES since 1976. Currently, 897 species & subspecies and populations of reptiles are included in Appendices I (87 species), II (749), and III (61), which is ~8% of the 11,050 reptile species in the world (http://www.cites.org; Uetz et al. 2020). Reptiles are one of the extensively traded groups of vertebrates in the exotic pet trade. Approximately, 8% of the reptile species traded in the world are regulated by CITES (Auliya et al. 2016; http://www.cites.org). India is high in reptilian diversity (~619 species in mainland India) (Uetz et al. 2020) and there is a serious threat to native fauna due to exotic pets as trade increases the likelihood of invasion and spread of diseases. Furthermore, information on the extent of globally threatened species in exotic pets traded in India is not available. Thus, there is an urgent need to document what proportion of the reptiles traded into India are CITES listed and their International Union for Conservation of Nature (IUCN) Red List status. The aim of the present study is to assess the exotic reptile pet trade in India to determine: i) the extent, in terms of traded species and trade volume, ii) associated discrepancies in the CITES records, iii) potential invasive species, and iv) discuss key challenges and provide recommendations for monitoring.

MATERIALS AND METHODS

Online sale data

To understand the scale of trade (legal and illegal) of exotic reptiles in India, information was gathered from the internet including four social networking applications (Facebook, Instagram, Telegram, and WhatsApp) and websites listing exotic animals for sale. During the course of two years (April 2018–March 2020), we monitored 75 WhatsApp groups, 26 pet networking groups on Facebook, 18 groups on Telegram, 11 groups on Instagram, and 20 websites selling exotic reptiles. The groups were selected based on their activity and posts related to buying and selling of various reptiles. Each selected group was monitored on a daily basis and websites listing exotic species for sale were surveyed weekly; additionally, photos and advertisements were collected as evidence of trade and for the purpose of species identification by subject experts. We followed the guidelines on ethical decision making and internet research (Markham & Buchanan 2012). All exotic species were identified to the species level. These species were categorized into four groups: lizards, snakes, turtles, and crocodiles. The IUCN Red List and CITES Appendix status of the listed species were considered to assess threat levels. During the monitoring of social networking platforms, efforts were made to access information about the original regions/states from which particular photos or advertisements were posted with the help of the open-source intelligence tools (OSINT). The number of traders recorded by us in the reptile pet trade ranged from 1 to 27 in each state. We categorized the online trading frequency as Low (1–9), Medium (10–18), and High (19–27). Bar plots and pie chart were prepared in R 3.2.0 (R Core Development Team 2017) using package ggplot2 (Wickham 2016) and a map was prepared using QGIS 3.10 (QGIS.org 2020).

Seizure data

To assess the illegal import of exotic reptiles through different customs entry and exit points, information related to the seizure of exotic animals was collected

from multiple media sources including news reports, seizure reports by enforcement agencies such as Customs, Directorate of Revenue Intelligence (DRI), and Wildlife Crime Control Bureau (WCCB) over a period of two years (March 2018–March 2020).

CITES trade data

To assess legal imports of exotic reptiles into India we accessed import data from 1976 to 2018 from the CITES Trade Database (https://trade.cites.org/ last accessed on 20.vi.2020). Only imports with the purpose codes B (breeding in captivity or artificially propagation) and T (commercial) were considered as only these two codes clearly indicate specimens which were imported for the purpose of trade. We cross-checked published CITES trade data with the Wildlife Crime Control Bureau, New Delhi annual report (http://wccb.gov.in/Content/CITES.aspx).

RESULTS

In total we recorded 84 species of reptiles in trade, many are categorized as threatened by the IUCN Red List, viz: five Critically Endangered (CR), nine Endangered (EN) species, and nine Vulnerable (VU) species (Appendix 1 and Appendix 3).

Online trade

There is an extensive virtual market for exotic reptiles in India through social media; our findings show WhatsApp, Facebook, Telegram, Instagram, and web portals are the key media (Figure 1a). Websites often advertised fewer species for sale than that of social media platforms (Figure 1a).

In total, 70 reptile species were identified to be traded via the various social media platforms, including 31 species of lizards, 12 species of snakes, and 27 species of turtles; no crocodile species were found in online trade (Figure 1b, Table 1, Appendix 1). Among lizards, varanids (Varanidae) were found to be the most frequently traded species followed by iguanids (Iguanidae), and agamids (Agamidae). Twelve species of exotic snakes (Appendix I) were found to be traded online. *Python regius* is the most commonly traded snake species. We also found highly venomous snakes such as *Bitis gabonica* and *Drysdalia coronoides*. We found 27 species of exotic turtles and tortoises in trade. Apart from *Trachemys scripta elegans* which are traded in large numbers (Appendix 2), we also found some rare and threatened species of turtles including *Astrochelys radiata* and *Malacochersus tornieri* in trade (Appendix 1). Among the three groups found in online trade, more species of lizards were traded compared to snakes and turtles (Table 1).

Table 1. Number of exotic reptile species in trade found by this study in mainland India. See Appendices 1–2 for complete list of species.

	Listed for sale by exotic pet traders	Seizures by enforcement authority	
	No. of Species	No. of Species	No. of Individuals
Crocodiles	0	1	21
Lizards	31	12	45
Snakes	12	6	22
Turtles	27	3	12417

We found five species listed in Appendix I of CITES in the Indian pet trade: *Cyclura lewisi*, *Cyclura cornuta*, *Shinisaurus crocodilurus*, *Astrochelys radiata*, and *Malacochersus tornieri* (Appendix 1). Additionally, 31 species in trade were found to be listed under Appendix II, and four species under Appendix III.

Furthermore, we found seven posts (5 species) related to live reptile species which are protected under the Indian Wildlife (Protection) Act 1972. These posts led to the seizure/rescue of *Geochelone elegans* (N= 11), *Geoclemys hamiltonii* (N= 7), *Pangshura tecta* (N= 71), *Varanus bengalensis* (N= 1), and *Python molurus* (N= 1) from pet traders by the enforcement authorities.

Our study shows that Tamil Nadu (10%), Maharashtra (9.7%), and West Bengal (9.3%) holds the major proportion of traders dealing with live exotic reptiles, followed by Kerala (8.5%), Delhi (7.3%), and Uttar Pradesh (7%) (Figure 2). Most traders are based in large metro cities (Chennai, Mumbai, Pune, Kolkata, Delhi, Lucknow, and Hyderabad).

Seizure data

Fifteen seizures of illegally imported reptiles were conducted by enforcement agencies, and a total of 12,505 individuals belonging to 22 species were confiscated (Appendix 2). The seized individuals belonged to species ranging across four reptile groups; including twelve species of lizards, six species of snakes, three testudines, and one crocodile species (Table 1, Appendix 2). Lizards were the most smuggled group; 12 species were seized by enforcement authorities in India.

During the two years period (2018–2020), enforcement authorities successfully seized individuals of five species listed in Appendix I of CITES: *Cyclura stejnegeri*, *C. pinguis*, *C. lewisi, Testudo kleinmanni*,

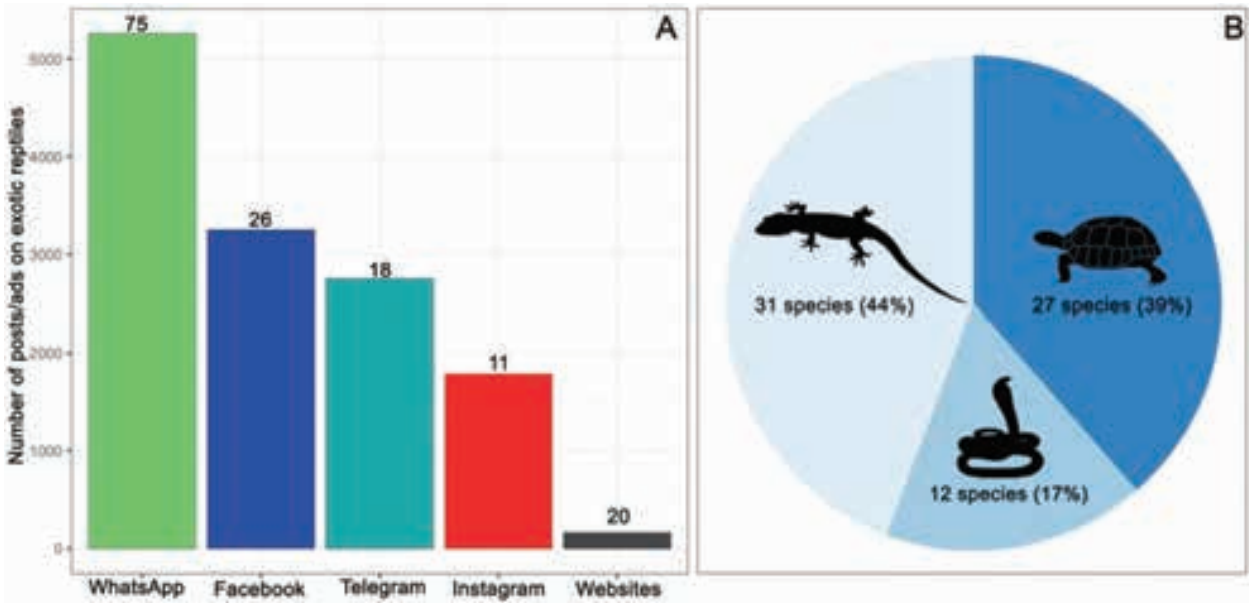

Figure 1. Summary of exotic reptile pet trade detected online, between 2018–2020: A—Number of posts/ads in various social media platforms and trade websites, number of groups monitored in each platform are labelled on top of each bar | B—Proportion of species in different groups (snakes, lizards & turtles) of reptiles recorded. Silhouettes are from PhyloPic.org contributed by Alex Slavenko (Lizard), V. Deepak (Snake) & Andrew A. Farke & Yan Wong (Tortoise).

Table 2. Summary of species recorded in online trade, seizures and import data listed in CITES website. Categorized by CITES Appendices (I–III); NA—Not available.

	No. of species found on sale by pet traders in India				No. of species seized by enforcement authority in India				No. of species imported to India via CITES from 1976 to 2018		
Appendix	**I**	**II**	**III**	**NA**	**I**	**II**	**III**	**NA**	**I**	**II**	**III**
Crocodiles	0	0	0	0	1	0	0	0	2	5	0
Lizards	3	18	0	10	3	7	0	2	1	2	0
Snakes	0	5	0	7	0	3	0	3	0	2	0
Turtles	2	8	4	13	1	1	0	1	0	4	1

Crocodylus siamensis and nine species listed under Appendix II including *Centrochelys sulcata* and *Varanus prasinus*.

CITES trade

We found that between 1976 and 2018 there were 25 different consignments of live import of reptiles into India from other countries for breeding in captivity (B) and commercial (T) purposes. This included 1,293 individuals belonging to 17 species including seven species of crocodiles (63 individuals), three species of lizards (208 individuals), two species of snakes (406 individuals), and five species of turtles (616 individuals) (Appendix 3). These imports comprised of three species from Appendix I, 13 species from Appendix II and one species from Appendix III (Table 2). The import data shows that between 1976 and 2018 only 18 individuals of four species of crocodiles were reported to the CITES Management Authority in India (Appendix 3). This information was reported only for the year 2000 and the remaining 1,275 individuals were never reported (Appendix 3).

CITES data revealed that between 2000 and 2017, seven *Mecistops cataphractus* and three *Cyclura cornuta* were imported into India for the purpose of breeding in captivity from Netherlands and Denmark. These are species listed in Appendix I; however, there are no captive breeding operations registered with the CITES Secretariat for these species.

Figure 2. State wise distribution of traders selling live exotic reptiles in different Indian states documented during this study. Online trading frequency: low (1–9), medium (10–18) and high (19–27). Cities with high trade records are labelled in italics.

DISCUSSION

This study reveals an extensive trade of exotic reptiles in India for the first time, which includes many threatened species. We recorded a total of 84 species of exotic reptiles in the pet trade many of which are highly likely to have entered India illegally. Twelve species were seized by Customs Authorities at different entry points (while attempting to smuggle into India) before it reached the market for sale (Appendix 1–3).

Cities like Bengaluru, Chennai, New Delhi, Hyderabad, Kolkata, Lucknow, Mumbai, Pune, Thiruvananthapuram, and Vadodara in 12 Indian states have been historically associated with illegal sale of Indian Star Tortoises and people who kept them as pets (Moll 1983; WWF 1994; Sekhar et al. 2004; Anand et al. 2005; D'Cruze et al. 2015). We found similar results with high levels of exotic reptiles being traded in most of these cities (Chennai, Hyderabad, Kolkata, Lucknow, Mumbai, New Delhi, and Pune) listed above (Figure 2). Extensive trade and export of endemic Indian fish species through exotic species traders was uncovered by Raghavan et al. (2013). Similarly, we found that traders who sell exotic reptiles are to some extent involved in illegal trade of Indian reptile species as pets. This mainly includes turtles (*Pangshura tecta, Geoclemys hamiltonii*, and *Geochelone elegans*) and sometimes other reptiles (*Varanus bengalensis* and *Python molurus*) which are protected species in India, listed on the Schedules of The Wildlife (Protection) Act, 1972. However, we did

not find any evidence of native species being exported during this study.

Social media platforms provide a safe medium for trading exotic animals by maintaining anonymity of the seller and forming closed networks controlled by group administrators. On Instagram, traders were found to display exotic reptiles by posting photographs, without specific mention of prices for sale. On the contrary, on open platforms like websites, very few exotic reptile species and individuals were on display. The displayed species (e.g., *Iguana* spp. or *Trachemys scripta*) were usually available in large quantities for low prices (between ₹120–160) and there were some species which were sold for a higher price range (between ₹4,500–40,000) per individual.

Among lizards, *Varanus* species were found to be the most smuggled species followed by iguanids, agamids, chamaeleonids, and scincids (Appendix 2). In March 2018, Guwahati police and forest authority conducted a seizure of four Gaboon Vipers *Bitis gabonica*, among several other wild animals. The consignment's suspected origin was Aizawl in Mizoram, reportedly, it was planned to be sold to a trader in New Delhi. In another case, the Chennai Customs Authority (CCA) detained a person at the Chennai International Airport and confiscated several exotic animals including a Horned Pit Viper *Cerastes cerastes*, which was allegedly smuggled into India from Thailand. Published reports on exotic reptile pet trade in India are sparse (Soundararajan et al 2015). While the trade of live reptiles in India has been recorded since 1983, extensive trade is only recorded in the last two decades (Appendix 2–3; Ramsay et al. 2007) and CITES import/export data shows an increase in the number of traded species and individuals in the past decade (Appendix 3). Undocumented import/export of species and individuals is much higher than the reported numbers.

Bush et al. (2014) reported globally a large number of Appendix I listed captive-bred mammals and birds and wild-caught birds and reptiles in legal international trade. Seven species of exotic reptiles listed in Appendix I (*Cyclura cornuta*, *C. lewisi*, *Shinisaurus crocodilurus*, *Astrochelys radiata*, *Malacochersus tornieri*, *Crocodylus siamensis*, and *Mecistop scataphractus*) and found to be in the pet trade, but were not reported to the CITES authorities in India. CITES trade data shows that until 2000 there were only eight species of reptiles imported into India (Appendix 3). Only more recently the trade has intensified in both number of species and individuals (Appendix 3). Discrepancies in the number of import and export in CITES data have been reported in the past (Blundell & Mascia 2005; Russo 2015; Robinson & Sinovas 2018) and we also found similar pattern in this study (Appendix 3). Species listed in Appendix I of CITES are threatened with extinction and in general no international commercial trade is allowed. International trade in species listed in Appendix II and Appendix III for commercial purposes is permitted, but only with the relevant permits required by the convention. The domestic online trade of CITES listed species in such large quantities raises concerns about illegal imports into the country especially given that 98.6% of the imports into India have not been reported to the CITES management authorities in India. Apart from the fact that these imports were not reported to Indian CITES Management Authority, they indicate a lack of compliance with CITES Resolution Conf. 12.10 (Rev. CoP15) by the parties involved.

Regulations for exotic species in India

In India, the import of exotic live reptiles is regulated by CITES and Customs Act 1962 with the "Policy Conditions". The importer has to apply for a license to import live animals (including their parts and products) to the director general of foreign trade along with the recommendation of the concerned chief wildlife warden of the state which is to be furnished at the time of custom clearance at "Exit" point. On June 2020, the Indian Government (Ministry of Environment forest & climate change (Wildlife Division) released an advisory for dealing with import of exotic live species in India and declaration of stock (http://environmentclearance.nic.in/writereaddata/om/30052020WildlifeAdvisorySpecies.pdf).

Threatened species in trade

Already threatened wild populations of species such as *Chelodina mccordi*, *Astrochelys radiata*, *Carettochelys insculpta*, and *Malacochersus tornieri* if over exploited for the pet trade, may be decimated in their native range. The former two tortoises were identified among the 25 most endangered turtles and tortoises in the world (Rhodin et al. 2011). India as a signatory to CITES should take serious preventive measures to avoid trade of threatened species. As per the CITES Article VII, Paragraph 4, specimens of an animal species included in Appendix I bred in captivity for commercial purposes, may be deemed to be specimens of species included in Appendix II. While some species imported in pet trade into India are reported to have been bred in captivity (Appendix 3) many other threatened species in trade do not have this information. This is another reason to have

a proper record for import and export of exotic species. Lyon & Natusch (2011) showed that 80% of *Morelia viridis* exported from Indonesia annually are illegally wild-caught. Population declines have been reported in some reptile species due to heavy exploitation for pet trade (Parusnath et al. 2017).

Invasive species in the exotic pet trade

The Red-eared Slider *Trachemys scripta elegans* is classified by the IUCN's Invasive Species Specialist Group as one of the 'World's Worst Invasive Alien Species' (Lowe et al. 2000; ISSG 2010). A species native to the Mississippi River in the United States, the Red-eared Slider is now an invasive species in 75 countries or overseas territories (Vyas 2019; Uetz et al. 2020). They are often sold as small hatchlings but upon reaching adulthood, these turtles are much larger and more aggressive (Cadi & Joly 2004). This is often the case for many other reptiles (Stringham & Lockwood 2018). Thus, they are often discarded into local waterways (Cadi & Joly 2004). Young Red-eared Slider turtles are carnivorous; they undergo a shift in diet as they mature to become omnivores (Ligon 2007; Boyer & Scott 2019) and predate on native species of turtles (Vyas 2020). They prey on local fish species and may compete for food and nesting space with the native turtle populations (Girondot et al. 2007).

In India, Red-eared Sliders were reported from 35 water bodies in the state of Gujarat which is also the natural habitat for one or more of the four native species of turtles (*Pangshura tecta*, *Nilssonia gangetica*, *Lissemys punctata*, and *Melanochelys trijuga*) (Vyas 2019). Apart from Gujarat, Red-eared Slider has also been reported from Karnataka, West Bengal, Punjab, Hyderabad, Rajasthan, and Goa (Jadhav et al. 2018; Chaudhuri et al. 2018; Vyas 2019). Until recently (2007), there were no records of Red-eared Slider from India (Ramsay et al. 2007) but now it is considered to be an invasive species in India which if not tackled may pose a serious threat to native turtles.

Red-eared Sliders are often traded in large quantities. In the two-year period, 12,385 individuals were seized by the custom authorities from Chennai and Trichy international airports. Our monitoring of online traders suggest that these turtles were sold at low prices (₹30 to ₹40 per individual) from exporting countries, due to high availability, better survival rate, and small size suitable for transporting in large quantities.

Zoonotic diseases and fatal snake bites associated with pet reptiles

Snake fungal diseases caused by *Ophidiomyces ophiodiicola* have been documented in the pet trade and are identified as responsible for the population decline of free ranging snakes in North America (Allender et al. 2015). Multiple disease outbreaks in chelonians due to ranavirus infections have been described in North America, Europe, and Asia (Duffus et al. 2015; Marschang et al. 2016). Global trade of reptiles and amphibians in combination with the wide host range of ranaviruses are suspected to have increased the emergence of these infections (Stöhr et al. 2013; Marschang et al. 2016).

Iguana iguana as pets have been identified as a source of Salmonella infections in humans (Sanyal et al. 1997; Warwick et al. 2001). Furthermore, several zoonotic diseases with high risk to humans such as neuroangiostrongyliasis, pentastomiasis, and sparganosis are transmitted from reptiles (Mendoza-Roldan et al. 2020). Annually, an estimated 50,000 people die of snake bites in India (Mohapatra et al. 2011). Importing venomous exotic pets and the danger of snake bites from these exotic species impose an unnecessary additional burden to the medical community.

Key challenges and recommendations

We identify six main challenges arising from exotic reptile pet trade in India: 1. introduction of invasive species, 2. spread of diseases from exotic pets to native reptiles, 3. spread of zoonotic disease from exotic reptile pets to humans, 4. trade of highly threatened species poses serious conservation challenges, 5. trade of protected species in India under the cover of exotic pet trade, and 6. trade of highly venomous reptiles. Thus, it is essential to introduce corrective measures to stop illegal trade and regulate legal trade of exotic reptiles. Systematic monitoring of the pet trade online will be crucial to understand the extent of trade. India currently lacks systematic information on even the relatively better-known invasive reptiles; for example, the Red-eared Slider turtles is not listed as invasive species in India by the Global Invasive Species Database and there is only one record of this species in India Biodiversity Portal (IBP; Vattakaven 2016). Global citizen science initiative iNaturalist have 395 observations of this species in Singapore since September 2016 but only 34 records from India during the same time period (accessed on 17 February 2021). We need better documentation of introduced species in India and citizen science initiative like IBP and iNaturalist can be a useful platform to record and map distribution of such species. The general public

also need to be made aware of the damage inflicted to the native fauna and environment by releasing exotic reptiles (e.g., turtles). International trade of threatened species listed in Appendix I of CITES needs to be eradicated in India with more cyber patrolling.

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Appendix 1. List of exotic reptiles found in online trade in mainland India during our surveys (2018–2020). Note out of the total 70, 12 species are listed as threatened and seven species are vulnerable by the IUCN Red List. NA= Not available, IUCN Red List: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Least Concerned (LC).

Group	Family	Common Name	Scientific name	Native Country/region	IUCN Redlist category	CITES
lizards	Agamidae	Frilled dragons	*Chlamydosaurus kingii*	Australia	LC	NA
lizards	Agamidae	Flying lizard	*Draco* sp.	Unknown	LC	NA
lizards	Agamidae	Bearded dragon	*Pogona vitticeps*	Australia	LC	NA
lizards	Agamidae	Egyptian spiny-tailed lizard	*Uromastyx aegyptia*	North Africa/Middle east	VU	Appendix II
lizards	Anguidae	Legless glass lizard	*Ophisaurus attenuatus*	United States	LC	NA
lizards	Chamaeleonidae	Chamaeleon	*Chamaeleo* sp.	Unknown	NA	Appendix II
lizards	Cordylidae	East African spiny-tailed lizard	*Cordylus tropidosternum*	East Africa	NA	Appendix II
lizards	Eublepharidae	Leopard gecko	*Eublepharis macularius*	Asia	NA	NA
lizards	Gekkonidae	Giant day gecko	*Phelsuma grandis*	Madagascar	LC	Appendix II
lizards	Iguanidae	Basilik lizard	*Basiliscus basiliscus*	Colombia	LC	NA
lizards	Iguanidae	Spiny tail iguana	*Ctenosaura oaxacana*	Mexico	VU	Appendix II
lizards	Iguanidae	Rhinoceros Iguana	*Cyclura cornuta*	Caribbean island of Hispaniola	EN	Appendix I
lizards	Iguanidae	Blue Iguana	*Cyclura lewisi*	Grand Cayman Island	EN	Appendix I
lizards	Iguanidae	Green Iguana	*Iguana Iguana*	America, Brazil	LC	Appendix II
lizards	Agamidae	Chinese water dragon	*Physignathus cocincinus*	SE Asia	NA	NA
lizards	Scincidae	Monkey tailed skink	*Corucia zebrata*	Solomon Islands	NA	Appendix II
lizards	Scincidae	Axanthic blue-toungued skink	*Tiliqua gigas*	New Guinea and surrounding islands	LC	NA
lizards	Scincidae	Red-eyed crocodile skink	*Tribolonotus gracilis*	Papua New Guinea	LC	NA
lizards	Shinisauridae	Chinese crocodile lizard	*Shinisaurus crocodilurus*	China	EN	Appendix I
lizards	Teiidae	Rainbow whiptail	*Cnemidophorus lemniscatus*	Central & south America, Caribbean islands	LC	NA
lizards	Teiidae	Caiman lizard	*Dracaena guianensis*	Central & south America	LC	Appendix II
lizards	Teiidae	Argentine black and white tegu	*Salvator merianae*	South America	LC	Appendix II
lizards	Teiidae	Red tegu lizard	*Tupinambis rufescens*	South America	LC	Appendix II
lizards	Varanidae	Ridgetail monitor	*Varanus acanthurus*	Australia	LC	Appendix II
lizards	Varanidae	Savanah monitor lizard	*Varanus exanthematicus*	Africa	LC	Appendix II
lizards	Varanidae	Finsch's monitor lizard	*Varanus finschi*	New Guinea and Australia	LC	Appendix II
lizards	Varanidae	Mangrove monitor lizard	*Varanus indicus*	Papua New Guinea, Indonesia and Australia	LC	Appendix II
lizards	Varanidae	Peach-throated monitor lizard	*Varanus jobiensis*	Papua New Guinea, New Guinea and Indonesia	LC	Appendix II
lizards	Varanidae	Quince monitor lizard	*Varanus melinus*	Indonesia	LC	Appendix II
lizards	Varanidae	Argus monitor lizard	*Varanus panoptes*	Papua New Guinea, Indonesia and Australia	LC	Appendix II
lizards	Varanidae	Dampier peninsula goanna	*Varanus sparnus*	Australia	LC	Appendix II
Snakes	Boidae	Red tailed boa	*Boa constrictor*	South America	LC	Appendix II
Snakes	Boidae	Emerald tree boa	*Corallus caninus*	South America	LC	NA

Group	Family	Common Name	Scientific name	Native Country/region	IUCN Redlist category	CITES
Snakes	Boidae	Kenyan sand boa	*Eryx colubrinus*	Horn of Africa & NE Africa	LC	NA
Snakes	Boidae	Yellow anaconda	*Eunectes notaeus*	South America	NA	Appendix II
Snakes	Colubridae	Indonesian paradise gliding snake	*Chrysopelea paradisi*	Southeastern Asia	LC	NA
Snakes	Colubridae	California kingsnake	*Lampropeltis getula californiae*	United States and Mexico	LC	NA
Snakes	Colubridae	Corn snake	*Pantherophis guttatus*	North American	NA	NA
Snakes	Elapidae	White lipped snake	*Drysdalia coronoides*	Australia and Tasmania	LC	NA
Snakes	Pythonidae	Bismarck ringed python	*Bothrochilus boa*	Papua New Guinea	LC	Appendix II
Snakes	Pythonidae	Blood python	*Python curtus*	Sumatra	LC	Appendix II
Snakes	Pythonidae	Ball Python	*Python regius*	West Sub Saharan Africa	LC	Appendix II
Snakes	Viperidae	Gaboon viper	*Bitis gabonica*	Central and West Sub Saharan Africa	LC	NA
Turtles	Carettochelyidae	Pig-nosed turtle	*Carettochelys insculpta*	Papua New Guinea	EN	Appendix II
Turtles	Chelidae	Swamp turtle	*Acanthochelys* sp.	South America	NA	NA
Turtles	Chelidae	Snake neck turtle	*Chelodina mccordi*	East Timor and Indonesia	CR	Appendix II
Turtles	Chelidae	Red matamata	*Chelus fimbriata*	South America	NA	NA
Turtles	Chelidae	Pink-bellied side-necked turtle	*Emydura subglobosa*	Australia and Papua New Guinea	LC	NA
Turtles	Chelydridae	Common snapping turtle	*Chelydra serpentina*	North America	LC	Appendix III
Turtles	Chelydridae	Alligator snapping turtle	*Macrochelys temminckii*	North America	VU	Appendix III
Turtles	Emydidae	Painted turtle	*Chrysemys picta*	North America	LC	NA
Turtles	Emydidae	Ornate wood turtle	*Glyptemys insculpta*	North America	EN	Appendix II
Turtles	Emydidae	Diamondback terrapin	*Malaclemys terrapin*	North America	VU	Appendix II
Turtles	Emydidae	Coastal plain cooter	*Pseudemys concinna floridana*	North America	NA	NA
Turtles	Emydidae	Eastern box turtle	*Terrapene carolina*	North America	VU	Appendix II
Turtles	Emydidae	Red eared slider	*Trachemys scripta elegans*	North America	LC	NA
Turtles	Emydidae	Yellow-bellied slider	*Trachemys scripta scripta*	North America	NA	NA
Turtles	Geoemydidae	Yellow-headed temple turtle	*Heosemys annandalii*	South East Asia	EN	Appendix II
Turtles	Geoemydidae	Spiny turtle	*Heosemys spinosa*	Indo-Burma, South East Asia	EN	Appendix II
Turtles	Geoemydidae	Reeve's turtle	*Mauremys reevesii*	China, Burma, South Korea, Japan	EN	Appendix III
Turtles	Geoemydidae	Chinese stripe-necked turtle	*Mauremys sinensis*	China, Laos and Vietnam	EN	Appendix III
Turtles	Kinosternidae	Razor back musk turtle	*Sternotherus carinatus*	North America	LC	NA
Turtles	Kinosternidae	Loggerhead musk turtle	*Sternotherus minor*	North America	LC	NA
Turtles	Kinosternidae	Musk turtle	*Sternotherus odoratus*	North America	LC	NA
Turtles	Testudinidae	Radiated tortoise	*Astrochelys radiata*	Madagascar	CR	Appendix I
Turtles	Testudinidae	African spurred tortoise	*Centrochelys sulcata*	Africa	VU	Appendix II
Turtles	Testudinidae	Red-footed tortoise	*Chelonoidis carbonaria*	South America	NA	NA
Turtles	Testudinidae	Pancake tortoise	*Malacochersus tornieri*	East Africa	CR	Appendix I
Turtles	Testudinidae	Leopard tortoise	*Stigmochelys pardalis*	East, South and horn of Africa	LC	NA
Turtles	Trionychidae	Chinese softshell turtle	*Pelodiscus sinensis*	China	VU	NA

Appendix 2. List of exotic reptiles seized by Customs/Enforcement Authority between March 2018– February 2020 arranged chronologically. NA= Not available, IUCN Red List: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Least Concerned (LC).

Date	Place of seizure	Group	Family	Common name	Scientific name	Native Country/region	Quantity	IUCN Redlist category	CITES
24-Mar-18	Guwahati, Assam	Snakes	Viperidae	Gaboon viper	*Bitis gabonica*	Sub-Sahara Africa	4	LC	NA
24-Mar-18	Guwahati, Assam	Snakes	Pythonidae	Reticulated pythons (Albino)	*Malayopython reticulatus*	South-east Asia	2	LC	Appendix II
24-Mar-18	Guwahati, Assam	Snakes	Colubridae	Corn Snakes	*Pantherophis* sp.	North America	13	NA	NA
24-Mar-18	Guwahati, Assam	Turtles	Testudinidae	African spurred tortoise	*Centrochelys sulcata*	Africa	2	VU	Appendix II
24-Mar-18	Guwahati, Assam	lizards	Agamidae	Central bearded dragon lizard	*Pogona vitticeps*	Australia	1	LC	NA
25-Mar-18	Chennai airport, Tamil Nadu	Snakes	Viperidae	Horned pit viper	*Cerastes cerastes*	Northern Africa	1	LC	NA
25-Mar-18	Chennai airport, Tamil Nadu	lizards	Iguanidae	Rhinoceros iguana	*Cyclura stejnegeri*	Hispanaiola	2	EN	Appendix I
25-Mar-18	Chennai airport, Tamil Nadu	lizards	Iguanidae	Rock iguana	*Cyclura pinguis*	West Indies	3	CR	Appendix I
25-Mar-18	Chennai airport, Tamil Nadu	Turtles	Testudinidae	Egyptian tortoise	*Testudo kleinmanni*	Egypt & Libya	22	CR	Appendix I
25-Mar-18	Chennai airport, Tamil Nadu	lizards	Scincidae	Blue-tongued skink	*Tiliqua* sp.	Australia	4	LC	NA
6-Oct-18	Chennai, Tamil Nadu	Turtles	Testudinidae	African spurred tortoise	*Centrochelys sulcata*	Africa	2	VU	Appendix II
10-Oct-18	Chennai airport, Tamil Nadu	Turtles	Emydidae	Red eared slider turtle	*Trachemys scripta elegans*	North America	2300	NA	NA
28-Nov-18	Indore, Madhya Pradesh	Turtles	Testudinidae	African spurred tortoise	*Centrochelys sulcata*	Africa	6	VU	Appendix II
5-May-19	Malharganj , Indore, Madhya Pradesh	lizards	Iguanidae	Iguana	*Iguana Iguana*	South & Central America	NA	LC	Appendix II
5-May-19	Malharganj , Indore, Madhya Pradesh	Turtles	Emydidae	Red eared slider turtle	*Trachemys scripta elegans*	North America	NA	NA	NA
21-Jul-19	Mumbai, Maharashtra	Crocodiles	Crocodylidae	Siamese crocodile	*Crocodylus siamensis*	Indonesia Thailand	21	CR	Appendix I
10-Oct-19	Chennai, Tamil Nadu	Snakes	Pythonidae	Green tree python	*Morelia viridis*	New Guinea	1	LC	Appendix II
10-Oct-19	Chennai, Tamil Nadu	Snakes	Pythonidae	Scrub python	*Morelia amethistina*	Australia	1	LC	Appendix II
10-Oct-19	Chennai, Tamil Nadu	lizards	Varanidae	Black tree monitor lizard	*Varanus beccarii*	Indonesia	2	DD	Appendix II
10-Oct-19	Chennai, Tamil Nadu	lizards	Varanidae	Emarald tree monitor lizard	*Varanus prasinus*	Australia & Indonesia	5	LC	Appendix II
10-Oct-19	Chennai, Tamil Nadu	lizards	Varanidae	Blue spotted tree monitor lizard	*Varanus macraei*	Indonesia	2	EN	Appendix II
10-Oct-19	Chennai, Tamil Nadu	lizards	Varanidae	Reisinger tree monitor lizard	*Varanus reisingeri*	Indonesia	1	DD	Appendix II
10-Oct-19	Chennai, Tamil Nadu	lizards	Agamidae	Sailfin lizard	*Hydrosaurus pustulatus*	Philippine	4	VU	Appendix II
24-Nov-19	Trichy, Tamil Nadu	Turtles	Emydidae	Red eared slider turtle	*Trachemys scripta elegans*	North America	2829	NA	NA

Date	Place of seizure	Group	Family	Common name	Scientific name	Native Country/region	Quantity	IUCN Redlist category	CITES
8-Dec-19	Trichy, Tamil Nadu	Turtles	Emydidae	Red eared slider turtle	*Trachemys scripta elegans*	North America	4856	NA	NA
11-Dec-19	Thane, Maharashtra	lizards	Iguanidae	Iguana	*Iguana Iguana*	South & Central America	2	LC	Appendix II
19-Dec-19	Chennai, Tamil Nadu	Turtles	Emydidae	Red eared slider turtle	*Trachemys scripta elegans*	North America	2400	NA	NA
22-Dec-19	Chennai, Tamil Nadu	lizards	Iguanidae	Blue Iguana	*Cyclura lewisi*	Cayman Islands	5	EN	Appendix I
20-Jan-20	Chennai, Tamil Nadu	lizards	Iguanidae	Blue Iguana	*Cyclura lewisi*	Cayman Islands	12	EN	Appendix I
20-Jan-20	Chennai, Tamil Nadu	lizards	Iguanidae	Green Iguana	*Iguana Iguana*	South & Central America	NA	LC	Appendix II
20-Jan-20	Chennai, Tamil Nadu	lizards	Iguanidae	Yellow Iguana	*Iguana Iguana*	South & Central America	NA	LC	Appendix II
30-Jan-20	Chennai, Tamil Nadu	lizards	Chamaeleonidae	Chameleon	*Chamaeleo* sp.	Africa	1	NA	Appendix II
31-Jan-20	Chennai, Tamil Nadu	lizards	Iguanidae	Green Iguana	*Iguana Iguana*	South & Central America	1	LC	Appendix II

Appendix 3. Live reptiles imported into India for commercial and breeding purposes from 1976–2018 reported by CITES arranged chronologically. IUCN Red List: Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Least Concerned (LC); NA= Not available; C= Animals bred in captivity: bred in captivity in accordance with Resolution Conf. 10.16 (Rev.), as well as parts and derivatives thereof, exported under the provisions of Article VII, paragraph 5, of the Convention; R= Ranched specimens: specimens of animals reared in a controlled environment, taken as eggs or juveniles from the wild, where they would otherwise have had a very low probability of surviving to adulthood, W= Specimens taken from the wild, B= breeding in captivity, and T=c ommercial purposes. Note there were no trade reported to CITES from 1976–1983 for commercial and breeding purposes.

Year	Group	Family	Common name	Scientific name	IUCN Redlist category	CITES	Exporter	Origin	Importer reported quantity	Exporter reported quantity	Purpose	Source
1983	Crocodiles	Crocodylidae	Siamese Crocodile	*Crocodylus siamensis*	CR	Appendix I	United States of America	NA	0	6	T	NA
1983	Crocodiles	Alligatoridae	American Alligator	*Alligator mississippiensis*	LC	Appendix II	United States of America	NA	0	1	T	NA
1987	lizards	Iguanidae	Green Iguana	*Iguana iguana*	LC	Appendix II	Australia	NA	0	5	T	C
2000	Crocodiles	Crocodylidae	African Slender-Snouted Crocodile	*Mecistops cataphractus*	CR	Appendix I	Netherlands	NA	7	7	B	C
2000	Crocodiles	Alligatoridae	Spectacled Caiman	*Caiman crocodilus*	LC	Appendix II	Denmark	Netherlands	3	3	T	C
2000	Crocodiles	Alligatoridae	Dwarf Caiman	*Paleosuchus palpebrosus*	LC	Appendix II	Denmark	NA	6	6	T	C
2000	Crocodiles	Crocodylidae	Johnstone River Crocodile	*Crocodylus johnstoni*	LC	Appendix II	Denmark	Germany	2	3	T	C
2000	Turtles	Pelomedusidae	Helmeted Turtle	*Pelomedusa subrufa*	LC	Appendix III	Ghana	NA	0	50	T	W
2004	Turtles	Testudinidae	Bell's Hingeback Tortoise	*Kinixys belliana*	VU	Appendix II	Togo	NA	0	50	T	R
2004	Turtles	Testudinidae	Home's Hingeback Tortoise	*Kinixys homeana*	VU	Appendix II	Togo	NA	0	10	T	R
2010	Crocodiles	Alligatoridae	American Alligator	*Alligator mississippiensis*	LC	Appendix II	United Arab Emirates	United States of America	0	4	T	W
2011	Crocodiles	Alligatoridae	American Alligator	*Alligator mississippiensis*	LC	Appendix II	United Arab Emirates	United States of America	0	5	T	W
2012	Crocodiles	Alligatoridae	American Alligator	*Alligator mississippiensis*	LC	Appendix II	United Arab Emirates	United States of America	0	1	T	W
2013	Crocodiles	Alligatoridae	American Alligator	*Alligator mississippiensis*	LC	Appendix II	United Arab Emirates	United States of America	0	24	T	W
2014	Turtles	Testudinidae	Aldabra Giant Tortoise	*Aldabrachelys gigantea*	NA	Appendix II	Seychelles	NA	0	6	T	C
2016	Snakes	Pythonidae	Ball Python	*Python regius*	LC	Appendix II	Togo	NA	0	200	T	R
2017	lizards	Iguanidae	Rhinoceros Iguana	*Cyclura cornuta*	EN	Appendix I	Denmark	Spain	0	2	B	C
2017	lizards	Iguanidae	Rhinoceros Iguana	*Cyclura cornuta*	EN	Appendix I	Denmark	United Kingdom	0	1	B	C
2017	Snakes	Boidae	Green Anaconda	*Eunectes murinus*	NA	Appendix II	Denmark	NA	0	3	B	C
2017	Crocodiles	Crocodylidae	Nile Crocodile	*Crocodylus niloticus*	LC	Appendix II	Denmark	NA	0	3	B	C
2017	Snakes	Pythonidae	Ball Python	*Python regius*	LC	Appendix II	Denmark	Germany	0	3	B	C
2017	Snakes	Pythonidae	Ball Python	*Python regius*	LC	Appendix II	Ghana	NA	0	200	T	R
2017	Turtles	Testudinidae	African Spurred Tortoise	*Centrochelys sulcata*	VU	Appendix II	Ghana	NA	0	200	T	C
2017	lizards	Varanidae	Savannah Monitor	*Varanus exanthematicus*	LC	Appendix II	Ghana	NA	0	200	T	W
2018	Turtles	Testudinidae	African Spurred Tortoise	*Centrochelys sulcata*	VU	Appendix II	Ghana	NA	0	300	T	C

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COMMUNICATION

Legal or unenforceable? Violations of trade regulations and the case of the Philippine Sailfin Lizard *Hydrosaurus pustulatus* (Reptilia: Squamata: Agamidae)

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Abstract: The Philippine Sailfin Lizard (Agamidae: *Hydrosaurus pustulatus*) is a nationally protected Philippine endemic species. It is threatened by habitat destruction, pollution and overexploitation for the domestic pet trade, yet less is known about the international component of the trade. Here we investigate the international trade in *Hydrosaurus* spp. (*H. weberi*, *H. amboinensis*, and *H. pustulatus*) with an emphasis on *H. pustulatus*. We analysed international seizures combined with international online sales and trade data for the United States of America (USA). The export of *H. pustulatus* from the Philippines has been prohibited since 1991, except under special circumstances, yet they continue to be traded internationally, and we found evidence for trade in Asia, Europe, and North America. Most of these animals, however, were declared to be captive-bred. While imports to and exports from the US consisted mostly of other species of *Hydrosaurus*, *H. pustulatus* was by far the most coveted species online, with prices significantly higher for *H. pustulatus* than any of the other species. While not many seizures have occurred outside the Philippines, even wild-caught individuals were found to be 'legally' imported to the USA – in apparent violation of the Lacey Act. We recommend H. pustulatus to be listed in CITES Appendix III, in order for countries other than the USA to have a legal basis to seize wild-caught animals trafficked from the Philippines and to monitor trade in captive-bred specimens. Further, we suggest the use of automated cross-referencing between imported species and the national protection status of the species' native range states to ensure that legislation violations are detected at the point of import.

Keywords: CITES, conservation, Lacey Act, LEMIS, reptiles, wildlife trade.

Abbreviations: CITES—The Convention on International Trade in Endangered Species of Wild Fauna and Flora | DAO—Department of Environment and Natural Resources Administrative Order | DENR—Department of Environment and Natural Resources | LEMIS—Law Enforcement Management Information System | USA—United States of America | USD—US Dollars | Wildlife Act—Wildlife Resources Conservation and Protection Act of 2001 (Republic Act No. 9147).

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Author contributions: SH designed the study, collected, curated and analysed the data and wrote the manuscript. AT contributed to the data collection and analysis. AT and JJ contributed critically to the development of the drafts and writing of the manuscript and gave final approval for publication.

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INTRODUCTION

Unsustainable wildlife trade, both illegal and legal, threatens an increasing number of species globally (Rosser & Mainka 2002; Marshall et al. 2020). To ensure that international trade in wildlife does not threaten their survival, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) entered into force in 1975. Currently, more than 38,000 taxa that are threatened by international trade are listed in one of the three Appendices of CITES, which regulate the trade in these species to varying levels; however, many species that are traded internationally are not included in the CITES Appendices, often because international trade data and/or other assessments are lacking for these species (Purcell et al. 2014; Vincent et al. 2014; Janssen & Shepherd 2018; Janssen & Leupen 2019; Jensen et al. 2019). The pet trade in particular has increased substantially in recent years and reptiles are among the most heavily exploited taxa for this purpose (Herrel & van der Meijden 2014; Auliya et al. 2016; Jensen et al. 2019; Marshall et al. 2020). While not the largest in terms of volume, more species are traded for the international trade for pets than for any other purpose (Janssen: in press). Yet, as of November 2019, only ~954 reptile species are listed in the Appendices of CITES (https://cites.org/eng/disc/species.php) – approximately 8% of all currently recognised reptile species (Uetz et al. 2020).

Non-CITES species can usually be traded without international restrictions that would ensure the sustainability of the species' exploitation, and only few national legislations protect non-native, non-CITES species in trade (Vinke & Vinke 2015; Janssen & Leupen 2019; Jensen et al. 2019). This is especially relevant when it comes to nationally protected species that are found in international trade. Many of these, such as the Borneo Earless Monitor *Lanthanotus borneensis* prior to its Appendix II listing in 2017 (Janssen & Krishnasamy 2018), are illegally extracted from the wild in their range states and exported to international destinations, where a lack of or inadequate legislation impedes efforts to counter this trade (Altherr 2014; Auliya et al. 2016; Altherr & Lameter 2020). Once these animals have entered a consumer country, they often continue to be traded 'legally' (Vinke & Vinke 2015; Heinrich et al. 2021).

Hydrosaurus spp. represent the largest members of the Agamidae family and can grow over a meter in length (Denzer et al. 2020). These oviparous, omnivorous, semi-aquatic lizards are restricted to riparian vegetation in coastal regions of different islands in Indonesia, New Guinea, and the Philippines (Ledesma et al. 2009; Denzer et al. 2020). *Hydrosaurus* spp. are known to be threatened by habitat loss and pollution, local subsistence hunting, as well as overexploitation for the pet trade, for which the hatchlings and subadults are especially targeted (Ledesma et al. 2009; Siler et al. 2014; Department of Environment and Natural Resources 2020). One nationally protected species negatively affected by trade is the endemic Philippine Sailfin Lizard *Hydrosaurus pustulatus* (Image 1). While *H. pustulatus* is classified as 'Vulnerable' on the IUCN Red List of Threatened Species (Ledesma et al. 2009), the remaining *Hydrosaurus* species have not been assessed to date.

It has been suggested that there are two species occurring in the Philippines, *H. pustulatus* in the north and *H. amboinensis* in the south, but that their exact distribution is unclear due to identification issues (Ledesma et al. 2009); however, there is a general uncertainty regarding *Hydrosaurus* taxonomy and species distribution, with more recent studies suggesting that only *H. pustulatus* occurs in the Philippines (Siler et al. 2014; Denzer et al. 2020). Further, Siler et al. (2014) suggested that there are four species of *Hydrosaurus* based on genetical analyses, but noted that further research is required. Denzer et al. (2020) conclude that there are currently five species within the genus *Hydrosaurus*, mainly based on morphological features. Due to the unresolved nature of the genus taxonomy, there is a high likelihood of mislabelling during trade, deliberately or otherwise. Siler et al. (2014) also describe at least six genetically distinct clades of *H. pustulatus* restricted to different Philippine islands and note that the sailfin lizards found in the illegal domestic trade (at least in Manila) originate from a single clade of *H. pustulatus* sourced from the Bicol Faunal Region, particularly the island of Luzon.

The Philippines has strong wildlife legislation in place, which pertaining to terrestrial wildlife, mainly consists of the Wildlife Resources Conservation and Protection Act of 2001 (Republic Act No. 9147, hereafter also referred to as the 'Wildlife Act') and its implementing Rules and Regulations. Pursuant to Section 5 and 22 of the Wildlife Act, the preliminary 'List of Threatened Wildlife' was established in 2004 by the Department of Environment and Natural Resources (DENR) Administrative Order (DAO) No. 2004-15, which was last updated in 2019 by DAO No. 2019-09. Since 2004, *H. pustulatus* is classified as 'Other Threatened Species' and it is illegal to collect or trade the species (including exportation), except

Image 1. The Philippine Sailfin Lizard *Hydrosaurus pustulatus*.

under special circumstances (such as an exemption for captive-bred animals) which need to be accompanied by a permit issued by DENR. Before 2004, *H. pustulatus* was classified as a 'Rare' species from 1991 according to DAO 91-48, equally prohibiting its collection and trade (including export) unless permitted by DENR, as is the case today. Since 1991 there have only been three legal exports of *H. pustulatus* from the Philippines, all of which were captive-bred animals, and no facilities currently have a permit to export *H. pustulatus* for commercial purposes in the Philippines (DENR Biodiversity Management Bureau, in litt., April 2021).

The Philippine Sailfin Lizard is known to be exploited for the domestic trade (Sy 2018; Sy 2021), yet less is known about its availability on the international market. They have been observed in low quantities, e.g., in mainland China (Yunrui et al. 2020) and Taiwan (Shiau et al. 2006), and anecdotal evidence suggests that they were more common in the United States of America (USA) and Europe in the 1970s and 80s, until the Philippines restricted the species' export in 1991. Grey literature documenting the husbandry and captive breeding of this species dates back to the 1970s (e.g., Gonzales 1974) with scattered reports on husbandry and breeding results over time (Krasula 1988; Gábriš 2003; Wirth & Riedel 2011; Fischer 2020a,b). Yet, despite a history of being kept and bred in captivity, its large size and resulting husbandry requirements, in combination with export restrictions, have likely contributed to them not being widely available on the international market to date.

Due to the relatively small captive population and thus limited available offspring, *H. pustulatus* is potentially at risk of unsustainable harvesting if emergent demand exceeds the availability of animals. Moreover, the unresolved taxonomy presents an opportunity for laundering, as *H. pustulatus* may be labelled as other *Hydrosaurus* species that are similar in appearance yet have fewer trade regulations. Here we investigate and characterise the scale of the international trade in *H. pustulatus* and other *Hydrosaurus* species, with specific focus on illegal trade in wild-caught specimens and the conservation implications.

METHODS

Seizure data were requested from the Philippines Department of Environment and Natural Resources; however, no response was received. We thus collated seizure data on sailfin lizards (*Hydrosaurus* spp.) from open-source media reports, such as the Robin des Bois On the Trail bulletins (https://robindesbois.org; containing seizure incidents available from 2013–2020), ad hoc online searches, and grey literature (e.g., Sy 2021). For two incidents where no quantity was

recorded, we assumed the incidents had to involve at least one animal, noting that the true number of animals involved may have been higher.

Data for the USA from 2000–2018 were obtained from the Law Enforcement Management Information System (LEMIS) database through a Freedom of Information Request. LEMIS *Hydrosaurus* trade data consisted almost exclusively of live animals. As we were mostly interested in the pet trade, we excluded the 49 'scientific or museum specimens' from seven trade records, as well as the 525 mollusc or turtle shell products from one trade record (which we also assumed must have been misclassified by the Fish and Wildlife Service).

We collated online trade data from English language and Japanese websites. Japanese websites were chosen because of anecdotal reports, it being known as a popular destination for exotic pets (Vall-Llosera & Su 2018; Wakao et al. 2018; McMillan et al. 2020), as well as Japan being reported as a destination in the previously recorded seizure incidents. Following the framework of Stringham et al. (2020) we obtained human research ethics committee approval from the University of Adelaide (Australia) to use automated data mining and searched a total of eight international English language and eight Japanese websites, using the keywords 'sailfin' and '*Hydrosaurus*', as well as 'ホカケトカゲ' in October 2020. For ethical reasons we keep the identities of the websites anonymous (see also Stringham et al. 2020), however, they are international classifieds that receive a high frequency of daily trade. We manually checked each entry to confirm the animals in the listings were in fact referring to sailfin lizards of the genus *Hydrosaurus*, as 'sailfin' also led to results for other species (e.g., chameleons, geckos, Australian water dragons). During the data curation process we recorded characteristics from the listing text description, including but not limited to: i) the species (*H. pustulatus, H. amboinensis*, or *H. weberi*); ii) price; iii) source (captive-bred or wild-caught); and iv) life stage (juvenile, subadult, or adult).

If the species was not specifically mentioned in the listing text, we classified it as *Hydrosaurus* spp. Due to the uncertain and changing taxonomy of the genus *Hydrosaurus*, it is possible that the advertised *H. amboinensis* and *H. weberi* may be individuals that are now recognised as *H. celebensis* or *H. microlophus,* therefore we regard the observed *H. amboinensis* and *H. weberi* as sensu lato. The price per animal was recorded as described in the listing text and later transformed to 'price per animal' in American Dollars (USD). If the total price was given for all advertised animals in the listing, price was converted to price per individual. If the price was given in a currency other than USD, the price per animal was converted to USD in December 2020 (www.xe.com). We also recorded whether the animal for sale was a hybrid or morph (i.e., colour variety), all of which were later classified as '*Hydrosaurus* spp.' and assumed to be captive-bred, even if the source was not stated specifically in the listing text. 'CB' was assumed to mean captive-bred. 'Captive born' or 'Farm bred' animals were also classified as captive-bred. Animals were only classified as 'wild-caught' if this was specifically stated in the listing text. If not otherwise stated whether the animals were wild-caught or captive-bred, all other listings were classified as 'unknown' regarding the source of the animals. The life stage of the animals was recorded as reported in the listing text, being either 'juvenile', 'subadult', or 'adult'. 'Babies' were classified as juveniles. In n= 32 listings the size of the animals was reported in conjunction with the life stage and following the data distribution of these listings we later added the life stage according to the size of the animal, for instances where only the size, but not the life stage, was reported in the listing text (n= 34). For this we assumed that the total length of the animals was reported in all instances and if animals were below 45cm they were classified as juveniles, between 46 and 85 cm as subadults, and above 85cm as adults. The quantity of the animals per listings were recorded from the listing text description. If not stated otherwise, each listing was assumed to include at least one animal. If not stated otherwise and the listing text indicated that 'sailfins' (i.e., more than one animal) were involved, we assigned two animals to the listing, noting that the true number of available animals per listing may have been higher. If a 'clutch' of animals was advertised we assumed that seven animals would be involved (Meiri et al. 2020).

Median prices and data distribution were displayed using the 'ggplot2' package (Wickham 2016). Generalised linear models (GLMs) were used to test for effects of species, source and life stage on market price. Advertisements of people looking to buy animals were excluded from the price analysis. Candidate models were selected based on the lowest Akaike's Information Criterion ($\Delta AIC > 5$). New explanatory variables, including interactive effects, were added to models in a stepwise fashion if the inclusion of such variables sufficiently reduced the AIC. We conducted pairwise comparisons between variable levels with the 'emmeans' package (Lenth et al. 2020). Wald χ^2 tests for independence were used to test for differences in the quantity of traded animals per species recorded in the LEMIS data, as well as

between the quantity of advertised animals per species in online listings. We used contingency-type frequency tests to assess the independence of categorical variables, using the mosaic function of the '*vcd*' package (Meyer et al. 2017). All data were curated and analysed in the R software environment for statistical computing, version 4.0.1 (R Core Team 2020).

RESULTS

Seizure data

We found 15 seizure incidents involving at least 233 sailfin lizards since 2010 from four countries (Table 1). In five incidents, involving 120 animals, the species was confirmed as *H. pustulatus*. In another nine incidents, involving at least 109 animals, the seizures occurred in the Philippines and the species was very likely also *H. pustulatus*, although this was not specifically mentioned. Only three of the seizures occurred in countries outside the Philippines, namely Indonesia, India, and Hong Kong (Table 1). Reported destinations included Japan, Taiwan, and Sweden.

LEMIS data

From 2000 to 2018 there were 421 trade records involving 12,479 live sailfin lizards. The majority of these consisted of animals of the species *H. weberi* (Figure 1). During this timeframe, there were only four imports into the USA involving 117 live *H. pustulatus*, and 15 exports involving 70 *H. pustulatus*, which was thereby the least traded of the three recorded species (Figure 1).

Hydrosaurus weberi was more likely to be declared wild-caught and less likely to be captive-bred; whereas *H. amboinensis* and *H. pustulatus* were more likely to be captive-bred and, in the case of *H. amboinensis*, less likely to be wild-caught (n= 421, χ^2= 62.54, degrees of freedom df= 3, p <0.001; Figure 2). There were only seven shipments (one import, seven exports) involving a total of 123 wild-caught Philippine Sailfin Lizards. Only two of these shipments (involving five animals) originated in the Philippines, while the remaining five supposedly originated in Taiwan (one incident, 76 animals) and Indonesia (four incidents, 42 animals).

Online trade data

We recorded a total of 369 listings involving at least 811 animals of the genus *Hydrosaurus* on six of the eight English and two of the eight Japanese language websites. *Hydrosaurus pustulatus* was by far the most popular species online with 141 listings involving at least 418 animals. It was followed by unidentified *Hydrosaurus spp*. (106 listings/187 animals), *H. weberi* (75/138), and *H. amboinensis* (47/68). Of all listings, 281 (76%) were advertising sailfin lizards for sale, while the remaining 88 listings concerned people looking to

Table 1. International seizures of sailfin lizards from January 2010 – February 2021.

Seizure date	Species	Seizure location	Origin country	Transit country	Destination country	Quantity seized[1]
18.ii.2021	*Hydrosaurus* spp.	Philippines			Taiwan	15
05.vi.2020	*H. pustulatus*	Philippines	Philippines			18
04.vi.2020	*H. pustulatus*	Indonesia	Philippines			85
10.x.2019	*Hydrosaurus* spp.	India		Malaysia		4
iii.2018	*Hydrosaurus* spp.	Philippines			Japan	-
26.x.2017	*Hydrosaurus* spp.	Philippines			Sweden	10
28.i.2016	*H. pustulatus*	Philippines			Japan	8
05.vi.2014	*H. pustulatus*	Philippines				4
viii.2013	*Hydrosaurus* spp.	Philippines				-
08.ii.2012	*H. pustulatus*	Hong Kong	Philippines			5
16.vii.2011	*Hydrosaurus* spp.	Philippines				3
02.vii.2011	*Hydrosaurus* spp.	Philippines				4
22.vi.2011	*Hydrosaurus* spp.	Philippines				1
19.vi.2010	*Hydrosaurus* spp.	Philippines				37
15.iii.2010	*Hydrosaurus* spp.	Philippines				37

[1] Where the exact quantity was not provided, we assumed the incident involved at least one animal, noting that the true number of animals may have been higher.

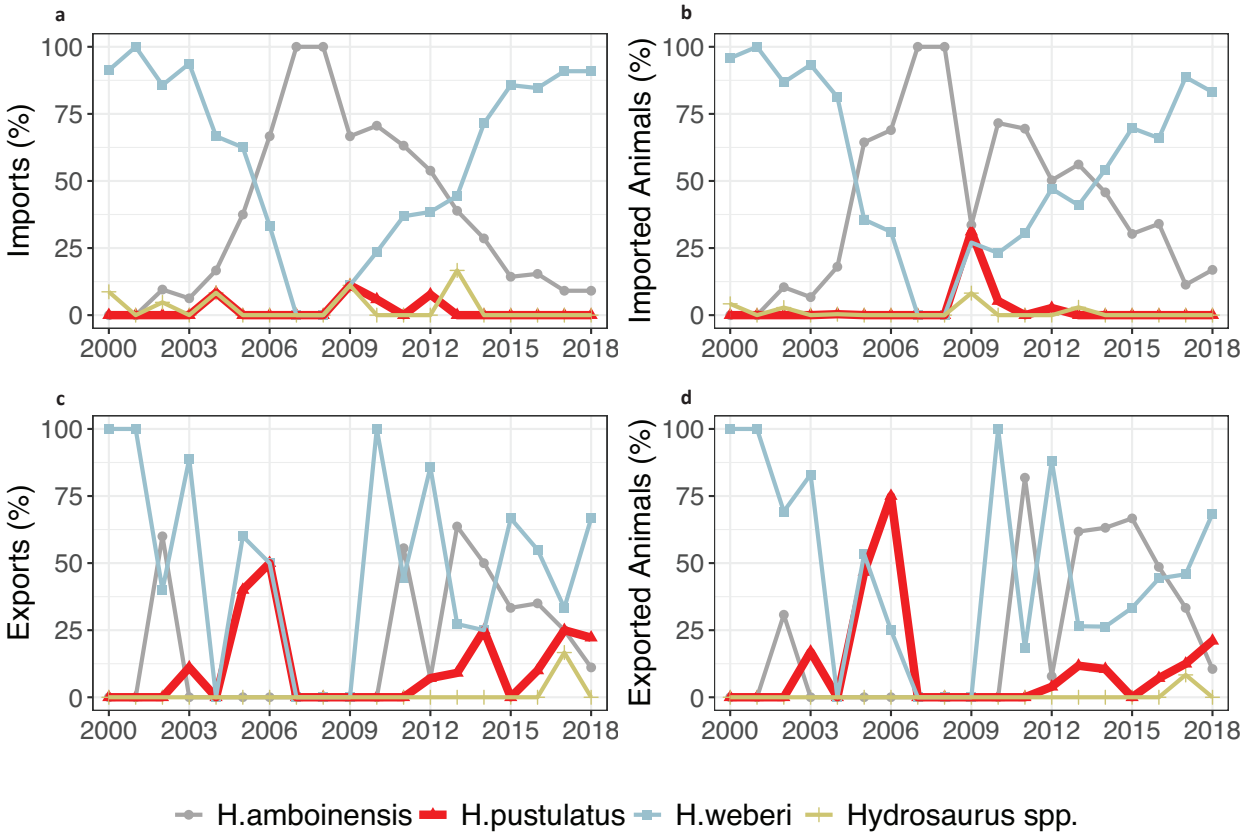

Figure 1. Imports to (a and b) and Exports from (c and d) the United States of America involving live sailfin lizards (*Hydrosaurus* spp.). Displayed are the proportions of trade records and traded animals for each species (if known).

buy sailfin lizards. Of the listings where people were searching for sailfin lizards, 49 (56%) were looking for *H. pustulatus* specifically. Most listings were recorded from people in the USA with 295 listings (80%), followed by listings from Japan (18 listings), the United Kingdom (UK; four), Portugal (three), Ukraine (two), Spain (one), and Canada (one). The country of the trader could not be identified in 45 listings.

Our selected candidate GLM included the effects of price, life stage and source, as well as interactions between levels of all three variables. The price per animal for *H. pustulatus* was significantly higher compared to *H. amboinensis* for captive juveniles (305.38 ± 106.1; p= 0.0209), yet lower for adults (-1169.37 ± 139.5; p <0.0001). *Hydrosaurus pustulatus* were significantly higher in price than *H. weberi* regardless of life stage (see Supplementary Data 1 for pairwise comparisons). The median price per animal for *H. pustulatus* (700 USD) was significantly higher compared to *H. amboinensis* (Estimate= -275.52, SE= 70.22, p < 0.001), *H. weberi* (Estimate= -527.85, SE= 61.59, p <0.001), or unidentified *Hydrosaurus spp*. (Estimate= -347.48, SE= 57.5, p <0.001; Figure 3). Overall, prices were lowest for *H. weberi* (median= 140 USD), but *H. amboinensis* (median= 183 USD) had a few notable outliers, including the maximum price of any recorded listing of 2,500 USD for a single captive-bred adult animal (Figure 3). Adult *H. pustulatus* were significantly less valuable than juveniles (-708.18 ± 266; p= 0.0458) if they were wild-caught and were significantly more valuable than juveniles (309.24 ± 107.3; p= 0.0205) and sub-adults (459.4 ± 124.2; p= 0.0012) if they were captive-bred (Figure 4).

Hydrosaurus weberi and *H. amboinensis* were more likely to be of wild-caught origin in online trade, and, in the case of *H. amboinensis*, less likely to be captive-bred (n= 369, χ^2= 45.1, df= 6, p <0.001; Figure 5). The opposite was true for *H. pustulatus* in trade, which were more likely to be captive-bred, and less likely to be of either wild or unknown origin (Figure 5).

Of all listings, 13% noted difficulties in keeping sailfins and reported either physical injuries of the animals, such as nose rubbing, missing or damaged tails and digits, or behavioural problems, such as skittishness, aggressiveness and/or fear towards the owner or

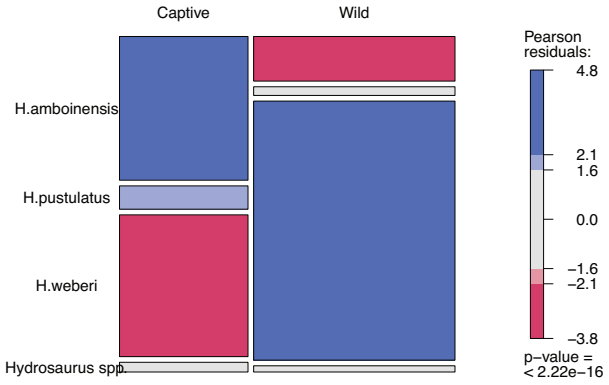

Figure 2. Mosaic plot of the deviation in conditional independence between source (wild or captive) and species, based on the number of shipments of live imported and exported sailfin lizards reported in LEMIS data from 2000 – 2018. The size of each cell is proportional to the observed cell frequency for each trait. Following Zeileis et al. (2007), the residual-based shading reflects the cell contribution to the χ2 statistic: Higher Pearson residuals indicate the observed frequency is significantly greater than expected under independence.

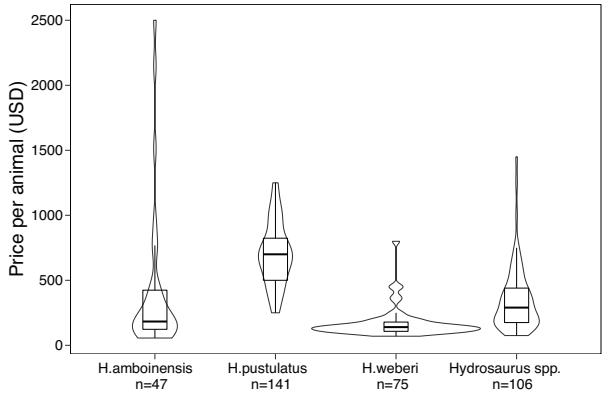

Figure 3. Median price per animal per species of sailfin lizards (*Hydrosaurus* spp.) recorded in online advertisements on two Japanese and six English language websites. Shown is the data distribution as well as the median price and interquartile range.

conspecifics, head bumping and/or deliberate running into cage walls (noting that most advertisements did not include detailed descriptions of the animals or reasons for selling). Private owners also reported an inability to provide enough space, time, and/or appropriate conditions for the animals as a reason for selling the sailfins, while breeders often remarked on the special requirements that sailfins need. For the 13% of listings that did mention difficulties in keeping sailfins, most of these were in regard to unidentified *Hydrosaurus* spp. (23 listings / 22% of all unidentified *Hydrosaurus* spp. listings), and relatively equally distributed between *H. pustulatus* (14 listings/10% of all *H. pustulatus* listings), *H. weberi* (8/11%), and *H. amboinensis* (4/9%). The proportion involving wild-caught animals (23% of all listings involving wild-caught animals were noted having difficulties in keeping the animals), however, was greater than for captive-bred animals (11%) or animals of unknown origin (14%).

DISCUSSION

Our results demonstrate that sailfin lizards of the genus *Hydrosaurus* are coveted pets on the international market, and *H. pustulatus* in particular appears to be the most popular of the *Hydrosaurus* species, as shown with the online trade data. It is possible, however, that idiosyncrasies exist between *Hydrosaurus* trade dynamics of online versus 'brick and mortar' pet shops (e.g., Siriwat & Nijman 2020). The USA featured most prominently in the international sailfin trade, and while this could be due to our sampling method of collating online trade data predominantly from English language websites, European countries were comparatively less represented despite English-language websites being commonly used to trade reptiles. Seizure data revealed, however, that Sweden was one of the intended destinations for a shipment of live *H. pustulatus*. Japan, a known destination country for a variety of exotic pet species (Vall-Llosera & Su 2018; Wakao et al. 2018; McMillan et al. 2020), was another destination in seizure incidents, as well as Taiwan. Given that seizure data is subject to biases due to imperfect detection (Symes et al. 2018), illegal trade is likely occurring at greater rates and across a greater diversity of European and Asian countries than is currently recorded. In terms of the online advertisements, it should be noted that more data may have been acquired using search terms from a greater diversity of languages (see also Stringham et al. 2020).

LEMIS data revealed that the majority of imports to and exports from the USA consisted of animals of the species *H. weberi* and *H. amboinensis* in the last ~20 years (noting that due to the uncertain taxonomy, species misidentifications are a genuine possibility and individuals that were recorded as these species are also likely to include the currently recognised species *H. microlophus* and *H. celebensis* (Denzer et al. 2020)). In the same timeframe, only four imports involving 117 live animals and 15 exports involving 70 live animals of *H. pustulatus* were recorded. Yet, *H. pustulatus* is the most traded species in online marketplaces, 80% of which were recorded on the American market, indicating that either the traded animals are bred in captivity in

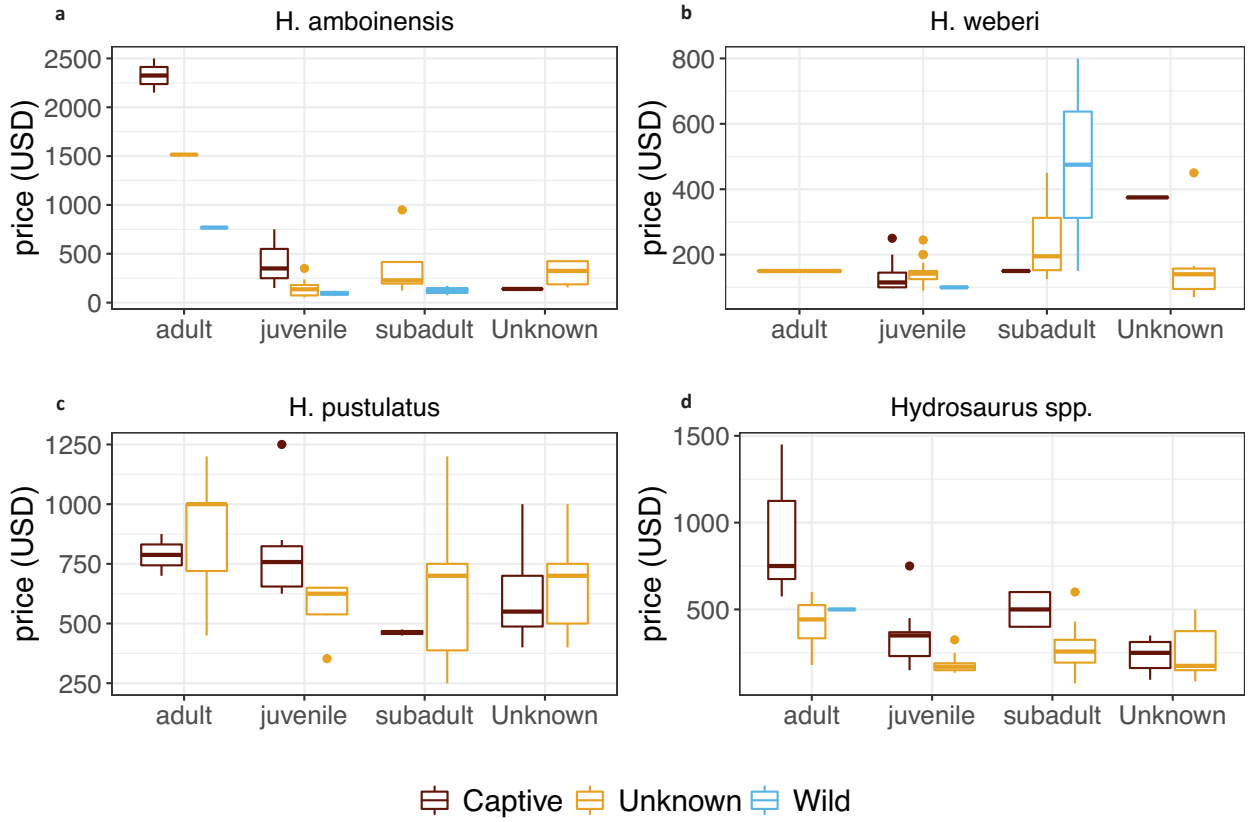

Figure 4. Median price per animal per species of sailfin lizard (*Hydrosaurus* spp., *H. amboinensis*, *H. pustulatus*, *H. weberi*), their life stage (adult, juvenile, subadult, unknown) and source (captive, unknown, wild) recorded in online advertisements on two Japanese and six English language websites. Note the different y-scales in each plot.

the USA predominantly from stock imported prior to 1991, captive-bred elsewhere and imported to the USA predominantly after 2018, or that there continues to be an influx of illegal *H. pustulatus* into the USA. If *H. pustulatus* trade is being supplied, or partly supplied, by the illegal trade, wild-caught individuals are likely to be falsely declared as captive-bred. Alternatively, individuals bred in other nations may be imported without declaration, however this is less likely, as there are no national or international regulations that prevent legal captive-bred importations.

No online advertisements detected in our study mention *H. pustulatus* to be of wild-caught origin and *H. pustulatus* is significantly more likely to be captive-bred, even compared to unknown origins. Whether this is due to people being aware of the illegality of their (wild-caught) pets, and fraudulently declaring them as captive-bred, or because export restrictions from the Philippines resulted in a captive population primarily consisting of captive-bred animals, is unclear. We recognise that there are genuine captive breeding efforts from specialised enthusiasts, however, grown *H. pustulatus* are large

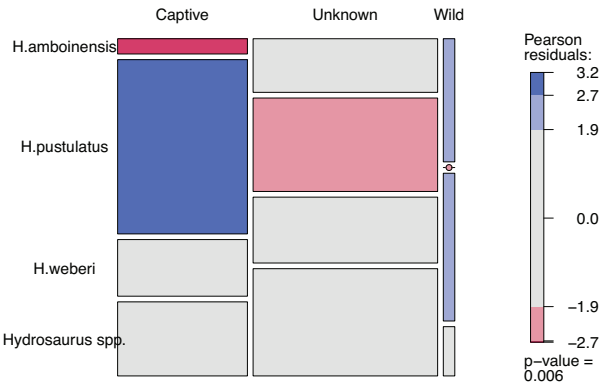

Figure 5. Mosaic plot of the deviation in conditional independence between source (wild, unknown, or captive) and species of sailfin lizard (*Hydrosaurus* spp., *H. amboinensis*, *H. pustulatus*, *H. weberi*) listed in online advertisements on eight international websites. The size of each cell is proportional to the observed cell frequency for each trait. Following Zeileis et al. (2007), the residual-based shading reflects the cell contribution to the χ2 statistic. Higher Pearson residuals indicate the observed frequency is significantly greater than expected under independence.

animals and can provide challenges to keep and breed in captivity when considering husbandry requirements. Further, with continuing demand and the comparatively high prices that can be obtained for *H. pustulatus*, the possibility remains that wild-caught animals are illegally imported to the USA and elsewhere. As confirmed by the Philippine's Biodiversity Management Bureau, there have only been three legal exports of captive-bred animals since 1991, and at the moment, no facilities in the Philippines have a permit to export *H. pustulatus* for commercial purposes.

It is clear that *H. pustulatus* is being traded internationally, and given the high prices that can be attained with these animals and the associated high commercial incentive to obtain and trade this species, this would suggest that illegal trade is likely to occur. There do not appear, however, to be many seizures of *H. pustulatus*, which could be due to the fact that internationally, very few countries have a legal framework to intercept nationally protected animals that were illegally sourced from their origin country (Altherr 2014; Vinke & Vinke 2015). Therefore, in the case of *H. pustulatus*, a lack of international seizures does not necessarily mean that there is no illegal trade, but rather that there is no legal basis to confiscate the species once it has been smuggled out of its origin country (see also Vinke & Vinke 2015). This is often the case for nationally protected species that are illegal to be exported, and exceptions usually involve CITES-listed species, countries with legislation similar to the Lacey Act in the USA, or additional protections such as the regulation of certain non-CITES species in the European Union (Council Regulation (EC) No 338/97). *Hydrosaurus pustulatus* is threatened domestically and largely unprotected internationally; therefore, to address these issues, we recommend that *H. pustulatus* be listed in CITES Appendix III by the Government of the Philippines.

The genus *Hydrosaurus* was once proposed to be listed in CITES Appendix I at the first Conference of the Parties in 1976 (Proposal 470); however, the proposal was rejected and no *Hydrosaurus* species was ever listed in any of the CITES Appendices. *Hydrosaurus pustulatus* is a nationally protected threatened species that is evidently found in international trade, thereby fulfilling the most important criteria for a CITES Appendix III listing (Res. Conf. 9.25 (Rev. CoP18)). A listing of this species in Appendix III may therefore assist in protecting wild populations in the Philippines. For the right candidate species, an Appendix III listing can have multiple benefits, including an ability to monitor legal international trade (which in the case of *H. pustulatus* should essentially only occur in captive-bred animals if they are traded commercially) and a legal basis internationally to confiscate illegal specimens that are detected in trade. Moreover, Appendix III listings have the potential to curtail trade without rapidly increasing the perceived value of a traded species, as is known to occasionally happen with Appendix I listings (e.g., Janssen & Krishnasamy 2018).

The merits of a species- versus genus-level listing should be considered carefully. Due to the unresolved taxonomy and similar looking species with lower levels of protection, there is strong potential that a species-level Appendix III listing may stimulate laundering via deliberate mislabelling. A genus-level Appendix III listing would reduce the likelihood of laundering, yet the impacts on trade of potentially less threatened sailfin species should be weighed against the need to protect *H. pustulatus*. Given the changing taxonomy of the genus, the newly recognised *Hydrosaurus* species may need to be re-assessed in terms of their conservation status, as they may be more threatened than previously assumed.

Beyond CITES, individual nations benefit from legislation that prevents the import of non-native wildlife if they were illegally exported or harvested in their native range states. A well-known example of this is the Lacey Act; under the Lacey Act, the import, export, sale, acquisition, or purchase of wildlife taken, possessed, transported, or sold in violation of any USA or foreign law is prohibited. Our study, however, shows 123 wild-caught *H. pustulatus* that were approved for import or export at some point into the USA despite being in violation of the Lacey Act. Only two of these shipments (one in 2013 and one in 2017 involving a total of five animals) originated in the Philippines, while the remaining five shipments supposedly originated in Taiwan (one incident, 76 animals in 2009) and Indonesia (four incidents, 42 animals between 2003 and 2006). All shipments except the one from Taiwan were exports from the USA, however, it remains uncertain how they were supposed to be legally imported to the USA beforehand. The only possibility is that these animals were imported prior to the export restrictions from the Philippines in 1991, however, this seems unlikely. Further, the Philippine Sailfin Lizard does not occur in Indonesia nor Taiwan and all of these shipments should have been seized; however, the only shipment of live *Hydrosaurus* spp. that was ever refused in the USA concerned a single shipment of two *H. amboinensis* that originated in Indonesia and were about to be exported to Canada. It is noteworthy that both Indonesia and Taiwan were also found to be involved in illegal trade

of *H. pustulatus*, as evidenced with the international seizure data.

The approved importation of illegally acquired wildlife, even in countries that do have a legal framework to prevent such incidents, is not restricted to Philippine Sailfin Lizards. Other studies have found similar inconsistencies and violations of the Lacey Act (Altherr 2014; Auliya et al. 2016; Janssen & Leupen 2019; Janssen & Gomez 2021). Clearly, further measures need to be taken to ensure that this valuable legislation is used effectively. We therefore propose the establishment of a database where law enforcement officials and other interested parties can check whether a non-CITES species is protected in its origin country/countries, and whether wild-caught individuals are allowed to be exported. This database could be automatically cross referenced against shipment information, including species, location of import and captive/wild status, in order to rapidly detect violations of the Lacey Act or other relevant legislation elsewhere. While resources are inevitably required to establish such a database, the long-term benefits to enforcement efficacy are likely to be substantial. In the first instance, this database could include only nationally protected, endemic, non-CITES species, and subject to funding and resources, could be expanded to include other nationally protected native non-CITES species at a later stage, as well as further information on life history traits, and the ability to breed the species in captivity. Such a database could also be of value for the pet-keeping community to help in the decision process of whether to purchase an animal. Overall, these recommendations have the potential to curtail the trade in wild-caught *H. pustulatus*, as well as other threatened nationally protected species with international trade demand.

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Supplementary Data 1. Pairwise comparisons of the GLM output of the market price for all combinations of sailfin lizard species (*H. amboinensis*, *H. pustulatus*, *H. weberi*, *Hydrosaurus* spp.), source (captive-bred, wild-caught, unknown), and life stage (juvenile, subadult, adult, unknown).

Species = *H. amboinensis*, Source = Captive				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	1783.99	132.9	13.428	<.0001
adult - subadult	1702.06	176.1	9.665	<.0001
adult - Unknown	1843.17	148.9	12.377	<.0001
juvenile - subadult	-81.93	135.8	-0.603	0.931
juvenile - Unknown	59.18	108.5	0.546	0.9477
subadult - Unknown	141.11	148.2	0.952	0.7765
Species = *H. pustulatus*, Source = Captive				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	309.24	107.3	2.883	0.0205
adult - subadult	459.4	124.2	3.698	0.0012
adult - Unknown	455.25	107.1	4.25	0.0001
juvenile - subadult	150.16	105	1.43	0.4804
juvenile - Unknown	146.01	79.3	1.841	0.2542
subadult - Unknown	-4.15	105.4	-0.039	1
Species = *H. weberi*, Source = Captive				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	223.56	213.6	1.047	0.7219
adult - subadult	169.9	226.7	0.75	0.8769
adult - Unknown	298.17	220.2	1.354	0.5285
juvenile - subadult	-53.67	110.5	-0.486	0.9623
juvenile - Unknown	74.61	100.2	0.745	0.8789
subadult - Unknown	128.27	129	0.994	0.7527
Species = *Hydrosaurus* spp., Source = Captive				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	518.8	77.4	6.706	<.0001
adult - subadult	444.56	99.8	4.453	<.0001
adult - Unknown	599.18	85.9	6.979	<.0001
juvenile - subadult	-74.24	87.7	-0.847	0.832
juvenile - Unknown	80.37	71.8	1.12	0.6772
subadult - Unknown	154.62	95	1.627	0.3631
Species = *H. amboinensis*, Source = Unknown				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	1587.73	137.6	11.54	<.0001
adult - subadult	1417.57	159.7	8.875	<.0001
adult - Unknown	1485.9	147.1	10.103	<.0001
juvenile - subadult	-170.16	100.7	-1.69	0.3287
juvenile - Unknown	-101.83	87.6	-1.162	0.6507
subadult - Unknown	68.33	113	0.605	0.9307
Species = *H. pustulatus*, Source = Unknown				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	112.99	90.9	1.243	0.5996
adult - subadult	174.92	79.9	2.189	0.1261
adult - Unknown	97.98	88.2	1.11	0.6832
juvenile - subadult	61.93	89.2	0.694	0.8993
juvenile - Unknown	-15.01	89.7	-0.167	0.9983
subadult - Unknown	-76.94	86.7	-0.888	0.8113

Species = *H. weberi*, Source = Unknown				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	27.31	189.9	0.144	0.9989
adult - subadult	-114.59	197.6	-0.58	0.9381
adult - Unknown	-59.1	196.5	-0.301	0.9906
juvenile - subadult	-141.89	78.3	-1.812	0.2675
juvenile - Unknown	-86.4	76.9	-1.123	0.6751
subadult - Unknown	55.49	95.2	0.583	0.9372
Species = *Hydrosaurus* spp., Source = Unknown				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	322.55	92.5	3.487	0.0027
adult - subadult	160.08	98.6	1.624	0.3648
adult - Unknown	241.91	89.5	2.703	0.0347
juvenile - subadult	-162.47	78.6	-2.067	0.1639
juvenile - Unknown	-80.64	67.3	-1.198	0.6281
subadult - Unknown	81.84	74.2	1.103	0.6878
Species = *H. amboinensis*, Source = Wild				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	766.57	218.9	3.502	0.0026
adult - subadult	550.43	218.9	2.514	0.0577
adult - Unknown	NA	NA	NA	NA
juvenile - subadult	-216.13	143.9	-1.502	0.436
juvenile - Unknown	NA	NA	NA	NA
subadult - Unknown	NA	NA	NA	NA
Species = *H. pustulatus*, Source = Wild				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	-708.18	266	-2.663	0.0388
adult - subadult	-692.22	272.6	-2.539	0.0541
adult - Unknown	NA	NA	NA	NA
juvenile - subadult	15.96	169.7	0.094	0.9997
juvenile - Unknown	NA	NA	NA	NA
subadult - Unknown	NA	NA	NA	NA
Species = *H. weberi*, Source = Wild				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	-793.86	318.2	-2.494	0.0607
adult - subadult	-981.73	325.2	-3.019	0.0135
adult - Unknown	NA	NA	NA	NA
juvenile - subadult	-187.87	143.9	-1.306	0.5591
juvenile - Unknown	NA	NA	NA	NA
subadult - Unknown	NA	NA	NA	NA
Species = *Hydrosaurus* spp., Source = Wild				
Contrast	**Estimate**	**SE**	**Z ratio**	**P value**
adult - juvenile	-498.62	260	-1.918	0.2205
adult - subadult	-707.06	271.7	-2.602	0.0458
adult - Unknown	NA	NA	NA	NA
juvenile - subadult	-208.44	164.1	-1.27	0.5818
juvenile - Unknown	NA	NA	NA	NA
subadult - Unknown	NA	NA	NA	NA

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COMMUNICATION

Conservation breeding of Northern River Terrapin *Batagur baska* (Gray, 1830) in Sundarban Tiger Reserve, India

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Abstract: The population of Northern River Terrapin *Batagur baska* is 'Critically Endangered' and threatened with extinction. In India, the species was once known to occur in the mangroves of West Bengal and Odisha. The sub-population in Odisha is suspected to have been wiped out. The Sundarban Tiger Reserve and the Turtle Survival Alliance launched a modest conservation breeding program in 2012 to recover the species using a small number of adults as founders. Gravid adult females are kept in a dedicated breeding enclosure with minimal disturbance, eggs are incubated outdoor on an artificial nesting beach, and hatchlings are raised to develop assurance colonies for purposes of reintroduction in future. Currently, the project holds 12 adults and over 350 juveniles of various size classes. Three additional assurance colonies were developed for 70 sub-adults from 2012–13 batches, using rain-fed ponds within STR.

Keywords: Critically Endangered, Four-toed Terrapin, Freshwater turtles, Geomydidae, river turtle, Testudines.

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Competing interests: The authors declare no competing interests.

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INTRODUCTION

Distribution and status of *Batagur baska*

The Indian subcontinent has one of the richest assemblages of chelonians in the world, with 29 freshwater turtles (Mital et. al 2019) and tortoises, of which all the members of the genus *Batagur* are seriously threatened. *Batagur baska* (Gray, 1830), commonly known as the Northern River Terrapin or Four-toed Terrapin, is a giant river turtle belonging to the family Geoemydidae within the order Testudines. *B. baska* is listed as 'Critically Endangered' in the IUCN Red List (Praschag & Singh 2019), and is recognised as one of the top 25 endangered turtle species in world (Turtle Conservation Coalitions 2018). The species is also listed in the Appendix–I of the CITES.

Formerly believed to have been a single species ranging across the entire southeastern Asian region, *B. baska* is actually one of two genetically distinct species (Praschag et al., 2007). The populations of river terrapins of Thailand, Malaysia, and Indonesia are now listed as the Southern River Terrapin *Batagur affinis*, while the northern species from India to Myanmar has retained the name *B. baska* (Praschag et al. 2008b, 2009; Weissenbacher et al. 2015; Praschag & Singh 2019).

Historically, *B. baska* was found in Odisha and the Hooghly River mouth, West Bengal (Blyth in. Gunther, 1864) in India, through to Bangladesh and Myanmar (lower Ayayarwady, Sittanug, and Thanlwin), and possibly as far south as the Andaman Sea side of Thailand at the Kra River. Batagur was distributed in all the coastal districts of Odisha (Orissa), particularly the deltaic regions of Mahanadi, Brahmani, Baitarani, Dhamra and Subarnarekha, but Mishra, et al. (1996) believed it might have got extinct. During the last recorded river survey in West Bengal and Odisha, while no evidence of a single population of *B. baska* was found from well-known habitats of this species in Odisha (Praschag et. al 2008a), nesting females were confirmed to be surviving in the Indian Sundarbans of West Bengal. Furthermore, of the last 10 nesting females informed by Bhupathy (1995), Prachag's survey only reported one of these females to be nesting on the beaches of Mechhua Island (Praschag 2008a; Moll et al. 2009). *B. baska* is now primarily limited to the Sundarbans area of India and Bangladesh, with the exception of three females in two different temple ponds in Myanmar (Praschag & Singh 2019).

Though an aquatic species, it also uses sandy nesting beaches along the sea, frequenting the tidal zones of estuaries, large rivers and mangroves (Asian Turtle Trade Working Group, 2000). Nests are often subject to predation by Water Monitor Lizards *Varanus salvator* or Rhesus Macaques *Macaca mulatta*. Singh et al. (2014) also found spoors and signs of severe digging by Wild Boar *Sus scrofa*, possibly in search of turtle nests in Mechhua and other sea facing sandy beaches in the Indian Sundarbans. Also, intense exploitation of the eggs and adults pertaining to illegal wildlife trade is considered to be the key driver of massive decline of *Batagur* population.

With an estimate of less than 40 animals in India (Praschag & Singh 2019) the only plausible solution to recover this species is conservation breeding followed by supplementation in the wild. Sundarban is the only known abode of *B. baska* in India, and some successful hatching of the species has occurred at the Madras Crocodile Bank Trust (Whitaker, in Singh 2014). West Bengal Forest Department, with the help of the Turtle Survival Alliance (TSA) has been attempting to recover *Batagur baska* species since 2008. In August of the same year, 12 adults were captured and examined by researchers with assistance from local fishermen in the Sajnekhali range of the Indian Sundarbans (Singh & Saha 2008), which led to re-instating the breeding programme in the STR after a gap of about 20 years. The objective in the present note is to put in record the information about the efforts made for conservation of *B. baska* in Sundarbans, West Bengal in India.

CONSERVATION OF *BATAGUR* IN SUNDARBANS

The *Batagur* population

The local Bengali name for Batagur baska is 'pore katha' for male, and 'sundi' or 'balli katha' for female (Das 1985). Since the 1980's ex situ conservation program for the Olive Ridley Turtle *Lepidochely solivacea* was operational in STR, when eggs of the species were collected from wild nests and incubated in controlled environment at Sajnekhali. Subsequently, the hatchlings were released in the sea. During the nesting season of 1983, amongst the Olive Ridley hatchlings there were nine hatchlings of some other species, which were later identified as *B. baska* (Ghosh & Mandal 1990).

In 1988, three clutches of eggs of *Batagur* were translocated from Mechhua to Parkhiralaya (Ghosh & Mandal 1990), followed by 24 more nests in 1988 to 1991 (Ghosh & Mandal 1990; Moll et al. 2009). Subsequently, the West Bengal Forest Department began captive breeding followed by hatch-and-release program for *B. baska* in the Sajnekhali Range Station within STR, where less than 50% of the eggs hatched after artificial incubation (Bhupathy et al 1995). In the late 1990s,

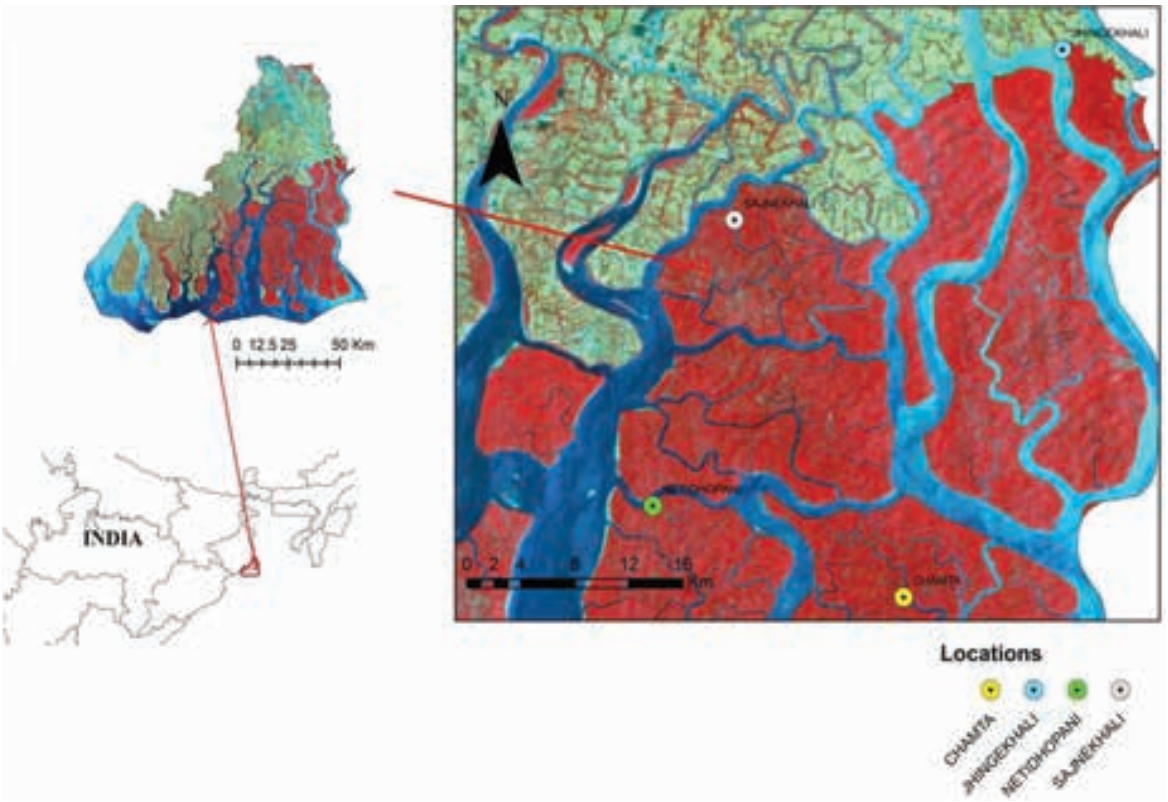

Figure 1. Map showing the colonies of *Batagur baska* in Sundarbans Tiger Reserve at Chamta, Jhingekhali, Netidhopani and Sajnekhali.

the hatch-and-release program was abandoned and the remaining captives were subsequently released in nature (Moll et al. 2009).

Observations recorded from Sajnekhali or its surroundings from 2008 onwards included detection of turtles, their relocations, occasional escapes, nesting, collection of eggs, incubation of eggs under supervision, hatching of young turtles, and housing of turtles in the available facility (Singh & Saha 2008; Pandit 2013; Singh 2013).

Housing facilities for Batagur in Sajnekhali, Sundarbans

1. The breeding enclosure, built in 2018 is of length (L) x width (W) x depth (D) of 16.40m × 14.50m x 9m, provided with artificial sand bank (7m × 5.8m) for nesting and two basking platform of 3m ×3m size (Figure 3 iii). The enclosure is covered with agro-net, topped with nylon net fencing to avoid predators as well as excessive sun. Females Batagurs of 2012 constituted the founder colony for nesting (Table 1).

2. The temporary nesting enclosure/ yearling pool is a make-shift '8'-shaped enclosure, measuring LxWxD 20.6m × 5.5-9.40m x 3.5m (Figure 3 i), with nylon net fencing on all sides. During the nesting season a few gravid females are shifted here for nesting. The turtles of 2016 batch are also retained here.

3. The retention pond is an earthen pond of 39.70m x 35.31m size x 3.65m depth (Figure 3 ii). It is the main holding facility in Sundarbans. It holds Batagurs of the founder colony and turtles of batch 2013 and 2014.

4. The old nursery is 7.55m x 3.5m x 50cm (Figure 3; no. v) and the new nursery is 9m x 2.5m x 70cm (Figure 3 iv) with two hatchling ponds. This facility is enclosed from all sides for thermoregulation and to avoid predation. After the incubation period of about 60 to 66 days the hatchlings are collected and shifted to this enclosure. After the transfer, hatchlings are retained here for the next six months.

Assurance facilities at Chamta, Jhingekhali, and Netidhopani and their usage

As the Sundarbans is prone to storm, it became essential to set up assurance colonies in order to avoid total wipe-outs, as was feared in 2009, when tropical storm Aila hit the Sundarbans, when one adult male escaped due to overflow of water from the original earthen pond. Aiming for circumventing overcrowding, natural disaster and also as a precautionary measure in case of an outbreak of any contagious disease, the assurance colony ponds were set up at three islands

Table 1. Year-wise captive stock of *Batagur baska* in Sundarbans

Stock	Numbers	Source	Place of housing	Usage
2008	12 founders	Reported from Sajnekhali pond	Retention pond at Sajnekhali	Founder colony
2012	33 hatchlings	founder colony of 12 individuals	Retention pond at Sajnekhali	Development of assurance colony and wild supplementation
2013	55 hatchlings	Founder colony of 12 individuals	Retention pond at Sanjekhali	Development of assurance colony and wild supplementation
2014	57 hatchlings	Founder colony of 12 individuals	Retention pond at Sanjekhali	Development of a ssurance colony and wild supplementation
2016	96 hatchlings	Founder colony of 12 individuals	Temporary breeding cum holding facility in Sajnekhali	Development of assurance colony, survival dispersal study
2017	74 hatchlings in 2017,	Founder colony of 12 individuals	Old Nursery in Sajnekhali	Development of assurance colony and wild supplementation
2019	50 hatchlings	Founder colony of 12 individuals	New Nursery in Sajnekhali	Development of assurance colony and wild supplementation

namely Chamta, Jhingekhali, and Netidhopani, near forest department head-quarters, besides Sajnekhali, within STR.

These facilities are rain-fed earthen ponds, the embankments of which are fenced to ward off predatory animals such as *V. salvator*. These ponds measure, Netidhopani: 40m x 7m x 2m depth (Figure 4, i); Chamta: 30m x 32m x 3m depth (Figure 4, ii), and Jhingekhali: 25m x 16m x 2m (Figure 4, iii).

Turtles from the 2012–2014 batches were transferred to these ponds, and now they hold 70 individuals of *B.baska* juveniles and subadults. Other shifting were 20 individuals (13 female, 7 male) in March 2017, 34 in September 2017 to the Netidhopani sweet water pond and 16 individuals (13 female, 3 male) in November 2017 to the Jhingekhali sweet water pond.

The characteristics of water in captivity

The pH of Sajnekhali rain-fed pond is 7.68 and the salinity is 0.86 PSU, assumed to be conducive for long term retention of the species. Thus, basic physiochemical parameters of the three assurance colony ponds were tested (Table 2) to keep the level of salinity and pH adjusted in reference to the Sajnekhali; however, the result depicted a higher measure of salinity in the pond located at Jhingekhali compared to other ponds (Figure 2). Therefore, all three ponds were conditioned by adding fresh river water to keep the salinity under 10 part per thousand (ppt), and to correct the alkalinity and pH of the water matching with the specifications of the Sajnekhali Pond.

Hatching of the eggs and tending of the hatchlings and transfer to yearling pool

Gravid females after examination for calcified eggs in late February or early March are shifted to the breeding pond for nesting. By the third week of March the females lay their eggs, which are determined with emergence, nesting tracks and camouflaging of nest cavity by the females. During 2015 and 2018, no eggs hatched, the reason for which is non-conclusive

The eggs laid by the females are kept on an artificial

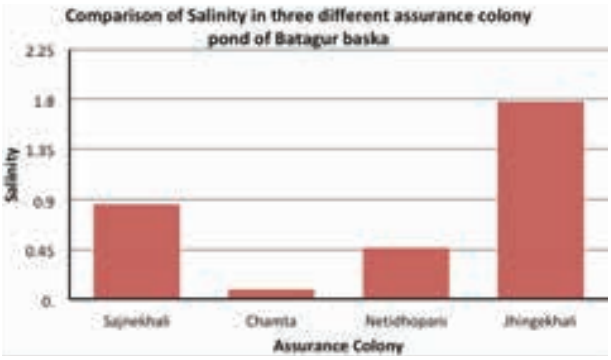

Figure 2. Salinity ranges in different sweet water ponds used for housing *Batagur baska* in Sundarban Tiger Reserve, West Bengal.

Table 2. Results of water tests done on three assurance colonies by an external laboratory recognised by the West Bengal Pollution Control Board.

Parameters	Assurance colonies		
	Chamta	Netidhopani	Jhingekhali
pH Value (at 25"C) (APHA 22ND'Edition4. 500-H -B)	6.02	6.88	6.97
Total Alkalinity (as CaCO3), mg/ml (IS: 3025(Part-23)-I986)	<5.0	77.2	198
Nitrate (as NO3), mg/ml (APHA 22ND Edition,4 500N Or'E)	< 0.5	< 0.5	< 0.5
Salinity (PSU) (Electrical Conductivity Method)	0.09	< 0.5	1.78

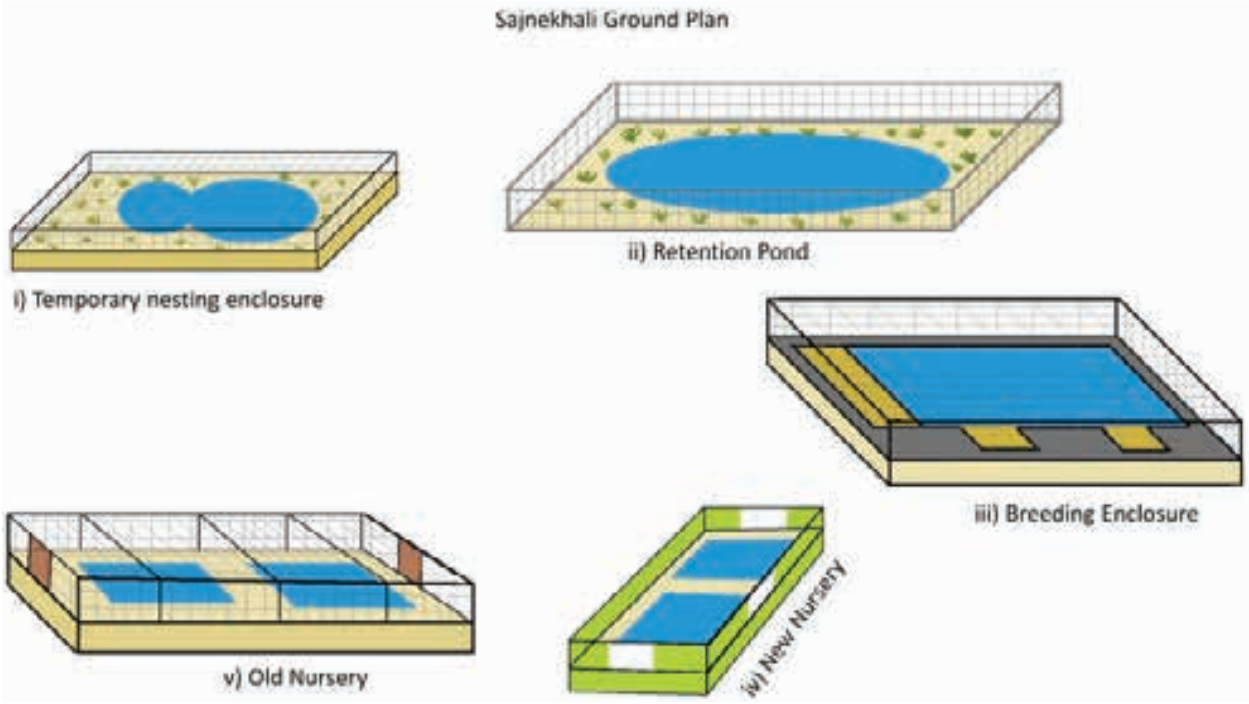

Figure 3. Ground plan of captive facilities of *Batagur baska* in Sajnekhali, Sundarbans Tiger Reserve. Design—Sreeparna Dutta.

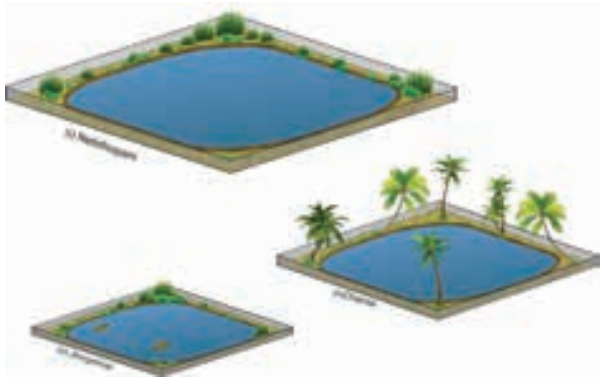

Figure 4. Ground plan of three assurance colony facilities of *Batagur baska* in Sundarban Tiger Reserve. Design—Sreeparna Dutta.

Image 1. Male *Batagur baska* displaying distinct and contrasting breeding colouration of black head with reddish neck.

sand beach and a temperature of about 30–32 °C is maintained by mimicking the reported nest depth and providing additional shade in breeding enclosure. Temperature and humidity of the nest were continuously tracked using temperature data loggers. After an incubation period of about 60–66 days the eggs hatch during end of May. The hatchlings are then collected and shifted to the nursery (hatchling enclosure). The artificial nesting bed is monitored for about five days from the time of emergence of the first hatchling. Generally, all the eggs hatch in about two days' time. The hatchlings are transferred to the nursery pens, and are fed with aquatic plants and vegetables for the next six months. After one year, when the hatchlings weigh approximately 250g, they are transferred to the yearling ponds, which offer a larger area and deeper water.

In July 2018, five juveniles from the 2017 batch showed symptoms like sloughing off part of the face, including the mouth region, nose and eye. Two of these individuals succumbed to death during treatment. Four swab samples examined at the Institute of Animal Health and Veterinary Biologicals, Kolkata tested negative for bacteriological infections, but tested positive for the

Image 2. Assurance colony being released into the pond in Chamta.

Image 4. Release of turtles in the newly 2018-built breeding enclosure.

Image 3. Hatchlings of *Batagur baska* from captive programme in Sundarban Tiger Reserve.

Herpesvirus glycoprotein B. All the infected individuals died in a few weeks' time and carcasses were carefully disposed. The remaining non-infected individuals were taken out of the adult pool for necessary treatment and observation and later quarantined as a precaution.

Currently, there is no data on survival and dispersal of *Batagur* in Sundarban. The soft-release enclosure was blown away in a storm in February 2016 and all 10 telemetered animals escaped.

DISCUSSION

Batagur baska is not known to have any viable wild population in the last 20 years, which possibly suggest that the species has become functionally extinct from much of its range. Sundarbans Tiger Reserve has carried out assisted breeding program since 2012, and has 359 individuals in captivity today, making it the largest holding of *Batagur* anywhere. *Batagur* recovery initiative is also carried out in Bangladesh in association with Vienna Zoo and TSA. The present account shows that the entire process in Sundarbans has been a learning experience.

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Author contributions: Design and conception of the study: Nilanjan Mallick and Shailendra Singh. Field setup design and structure: Nilanjan Mallick and Shailendra Singh. Data collection and analysis: Shailendra Singh, Dibyadeep Chatterjee, and Souritra Sharma. Wrote the paper: Shailendra Singh, Dibyadeep Chatterjee, and Souritra Sharma.

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COMMUNICATION

Discovery of two new populations of the rare endemic freshwater crab *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019 (Brachyura: Potamonautidae) from the Ebo Forest near Yabassi in Cameroon, Central Africa, with recommendations for conservation action

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Abstract: The endemic freshwater crab, *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, is currently only known from three populations in the biodiversity-rich rainforests of southwestern Cameroon. The first record of *L. yabassi* dates back to 1908 from Yabassi, while the other two populations were discovered in December 2019 and March 2020 from the Ebo Forest near Yabassi. These specimens were initially identified as *L. edeaensis* (Bott, 1969), but were subsequently assigned to *L. yabassi*. The newly-discovered populations of *L. yabassi* provided important data on its habitat, population structure and geographical distribution, all critical knowledge for conservation measures. Reported here are the anthropogenic threats to *L. yabassi* and its rainforest habitat, which include forest destruction, agricultural encroachment, water pollution and firewood collection. This information is inherently useful in the assessment of the extinction risk of *L. yabassi* and highlights the importance of implementing strategies for preserving primary rainforest and its associated aquatic habitats in Central Africa.

Keywords: Cameroon, Conservation action plan, diversity, Ebo Forest, freshwater crab, *Louisea edeaensis*, *L. yabassi*, threats, Yabassi.

Résumé : Le crabe d'eau douce, *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, est endémique et exclusivement connu par trois populations dans les riches forêts du sud du Cameroun. Il a été collecté pour la première fois en 1908 dans la zone de Yabassi, les deux autres populations ont été échantillonnées en décembre 2019 et mars 2020 dans la forêt d'Ebo près de Yabassi. Les spécimens, initialement identifiés comme *L. edeaensis* (Bott, 1969), ont par la suite été reconnus comme étant des représentants de la nouvelle espèce *L. yabassi*. Les spécimens nouvellement collectés ont fourni des données importantes sur l'habitat, la structure des populations et la répartition géographique de *L. yabassi*, toutes ces connaissances étant préalables pour décider des mesures de conservation de l'espèce. Les menaces anthropiques pesant sur *L. yabassi* sont signalées ici, notamment la destruction des forêts, les activités agricoles, la pollution de l'eau et la collecte du bois de chauffage. Ces informations sont importantes pour l'évaluation du risque d'extinction de *L. yabassi* et soulignent l'importance de la mise en œuvre de stratégies de préservation de la forêt tropicale primaire et de ses habitats aquatiques associés en Afrique Centrale.

Mots clés: Plan d'action de conservation, crabe d'eau douce, *Louisea edeaensis*, *L. yabassi*, menaces, diversité, forêt d'Ebo, Yabassi, Cameroun.

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INTRODUCTION

The present work arises from the discovery of two new populations of *Louisea yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, from the Ebo Forest near Yabassi in southwestern Cameroon. This rare endemic species of freshwater crab is currently known from just three small populations found in Yabassi (collected in 1908; Cumberlidge 1994b, 1999), and the Ebo Forest (collected in December 2019 and March 2020; Mvogo Ndongo et al. 2019).

The Ebo Forest, where *L. yabassi* was rediscovered (Figure 1, Image 2), is the largest remaining tract of primary lowland and submontane rainforest in this part of Africa, and is drained by the Wouri and Dibamba rivers that flow into the Atlantic Ocean. This forested area represents a key biodiversity hotspot in southwestern Cameroon for a number of freshwater taxa including crabs. The freshwater catchments of the Ebo Forest are important spawning grounds for fish and invertebrates, and the forest is also a refuge for charismatic wildlife including monkeys, chimpanzees, gorillas, manatees, elephants, birds, turtles, snakes, and amphibians (Cumberlidge 1994b, 1999; Morgan & Abwe 2006; Morgan et al. 2013).

The rediscovery of *L. yabassi* after over 110 years means that living specimens of this species are now available for scientific studies that allow for DNA analysis, a description of its habitat, and ecological and population studies. The difficult taxonomy and the chronic lack of material in the past meant that the original specimens from Yabassi were initially identified as *L. edeaensis* (Bott, 1969) by Cumberlidge (1994a, 1999) and Mvogo Ndongo et al. (2017a).

Preliminary surveys indicated that this newly-rediscovered species is facing immediate threats to its freshwater habitat from forest destruction, agricultural encroachment, water pollution, and firewood collection. Presented here is the necessary field data for an IUCN Red List extinction risk assessment of this species including its specific habitat requirements, population trends, distribution, and threats (Mvogo Ndongo et al. 2017a). The importance of assessing the extinction risk of *L. yabassi* is underlined by the status of two other rare endemic species assigned to *Louisea* in southwestern Cameroon, *L. edeaensis* (Cumberlidge, 1994) and *L. balssi* (Bott, 1969) that are both currently listed as Endangered species (EN) on the International Union for Conservation of Nature (IUCN) Red List.

Freshwater crab diversity in southwestern Cameroon

The rainforests of southwestern Cameroon are emerging as a leading biodiversity hotspot in Sub-Saharan Africa for freshwater crabs (Cumberlidge 1999; Cumberlidge et al. 2019; Mvogo Ndongo et al. 2020). This part of the country currently harbours 22 species of freshwater crabs in five genera all assigned to Potamonautinae (*Buea* Cumberlidge, Mvogo Ndongo, Clark & Daniels, 2019; *Louisea* Cumberlidge, 1994; *Potamonemus* Cumberlidge & Clark, 1992; *Potamonautes* Macleay, 1838; and *Sudanonautes* Bott, 1955 (Cumberlidge 1987, 1989, 1993a–c, 1994a,b, 1995a–d, 1999; Cumberlidge & Clark 1992; Cumberlidge & Boyko 2000; Cumberlidge et al. 2019; Mvogo Ndongo et al. 2017a–c, 2018, 2019, 2020)).

The semi-terrestrial species of freshwater crabs endemic to the rainforests of southwestern Cameroon are of great conservation importance and are also the most threatened by anthropogenic activities in these forests (see Table 1). These species are: *Buea asylos* (Cumberlidge, 1993), *B. bangem* Mvogo Ndongo, von Rintelen, Tomedi-Tabi & Cumberlidge, 2020, *B. mundemba* Mvogo Ndongo, von Rintelen & Cumberlidge, 2020, *B. nlonako* Mvogo Ndongo, von Rintelen & Cumberlidge, 2020, *Louisea balssi* (Bott, 1969), *L. edeaensis* (Bott, 1969), *L. nkongsamba* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, *L. yabassi* Mvogo Ndongo, von Rintelen & Cumberlidge, 2019, and *Sudanonautes tiko* Mvogo Ndongo, Schubart & Cumberlidge, 2017. Two of these species, *L. balssi* and *L. edeaensis*, are already assessed as EN by the IUCN Red List, and were previously thought to be extinct until their rediscovery in 2017 and 2018 (IUCN 2003; Cumberlidge 2008a,b; Cumberlidge et al. 2009; Mvogo Ndongo et al. 2017a; 2018). These threatened species of freshwater crabs are found in an area of great conservation interest, because their aquatic habitats also serve as key spawning grounds for fish and invertebrates, as well as refugia for other forest wildlife, e.g., monkeys, drills, chimpanzees, and gorillas as well as manatees, elephants, birds, turtles, snakes and amphibians (Cumberlidge et al. 2019; Mvogo Ndongo et al. 2017a–c, 2018, 2019, 2020). Consequently, these areas increasingly attract scientists and tourists.

The high rate of endemism of freshwater crabs in southwestern Cameroon reflects their low dispersal abilities arising from a lifecycle that includes direct development of eggs into young crabs, without the highly dispersive planktonic larval stages seen in marine crabs (Cumberlidge & Daniels 2007). Most of these endemic species of freshwater crabs (*B. bangem*, *B. mundemba*, *L. balssi*, and *L. edeaensis*) are still only known from

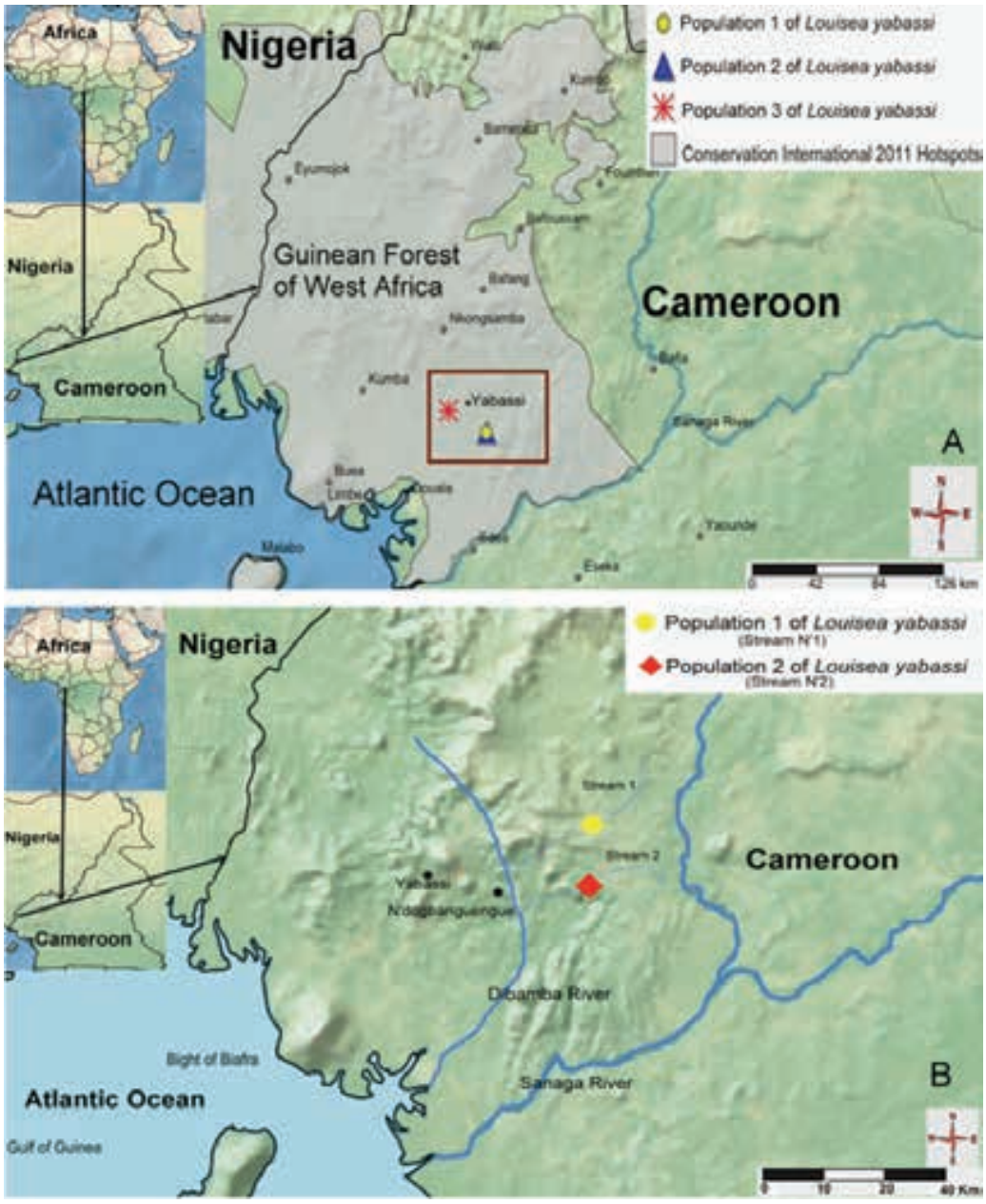

Figure 1. Collection localities of the populations of *Louisea yabassi* endemic to southwestern Cameroon. A—Population 1 (circle), population 2 (triangle) both found in the Ebo Forest, population 3 (asterisk) collected between 1900 and 1909 near Yabassi | B—Sampling sites of the newly discovered populations found in the Ebo Forest.

a single population. Other species are better known and are represented by at least two populations, most likely revealing strong phylogeographical structuring. Despite advances in our knowledge of the taxonomy, habitat, and distributional range of each of these species, information on their reproductive biology, ecology, phylogeography, and evolutionary relationships is still extremely limited. This is a problem because of the urgent need to provide vital biological data that are necessary for the management of the freshwater crabs of southwestern Cameroon and to monitor changes in their populations and habitat as a result of conservation interventions. The present study aims to formulate guidelines towards a more sustainable use of forest and aquatic resources from southwestern Cameroon, and lay the groundwork for a conservation assessment of those species of endemic freshwater crabs most vulnerable to anthropogenic threats.

MATERIAL AND METHODS

The data presented here for *L. yabassi* were compiled during field surveys of the rivers, streams, wetlands, and nearby land in the Ebo Forest near Yabassi in December 2019 and March 2020. The number of plants destroyed by natural and human activities was assessed at the locality and around the sampling sites. The pH and temperature of water samples where crabs occurred were measured (Table 2), and specimens were identified using the keys provided by Cumberlidge et al. (2019) and Mvogo Ndongo et al. (2019; 2020). Carapace measurements of each specimen were taken using digital callipers, and sex and age were recorded. Photographs of freshly caught specimens and the habitat from where they were collected (Image 1) are also provided. Most specimens were returned to their place of origin, except for one adult male and female, which were preserved in ethanol for subsequent detailed morphological and molecular analyses.

RESULTS

The updated distributional range of *L. yabassi* is presented in Figure 1A. The two populations recently discovered in the Ebo Forest were collected from two small streams ('stream-1' and 'stream-2') that flow independently into the Dibamba River at the locality N'dogbanguengue (Figure 1B). The first population (15 males and five females) was found ca. 10m from the middle of stream-1 in December 2019 (Figure 1B, Image 2A). At that time of the year, the water levels of the streams and rivers are at their peak and are difficult to sample, so all of our specimens of *L. yabassi* were collected from semi-aquatic habitats on land, adjacent to the streams in damp conditions in puddles, under fallen leaves, and in burrows. The second population of *L. yabassi* (nine males and six females) was found ca. 8m from the middle of stream-2 in March 2020 (Figure 1B, Image 2B). At this time of the year, the water levels of the streams and rivers are much lower, so that sampling in the large streams was now possible under the rocks and boulders that sheltered crabs (Image 2). Most of the natural vegetation at these localities had been destroyed as a result of human activities (by foresters, farmers, and others). The trees had been logged to build huts, camps, and toilets. The remaining vegetation in these locations had been removed for intensive agricultural practices and for firewood. In addition, the farmers encroaching on these habitats use agro-chemicals and pesticides on their crops, and these pollutants eventually drain into the aquatic systems and can poison the freshwater communities.

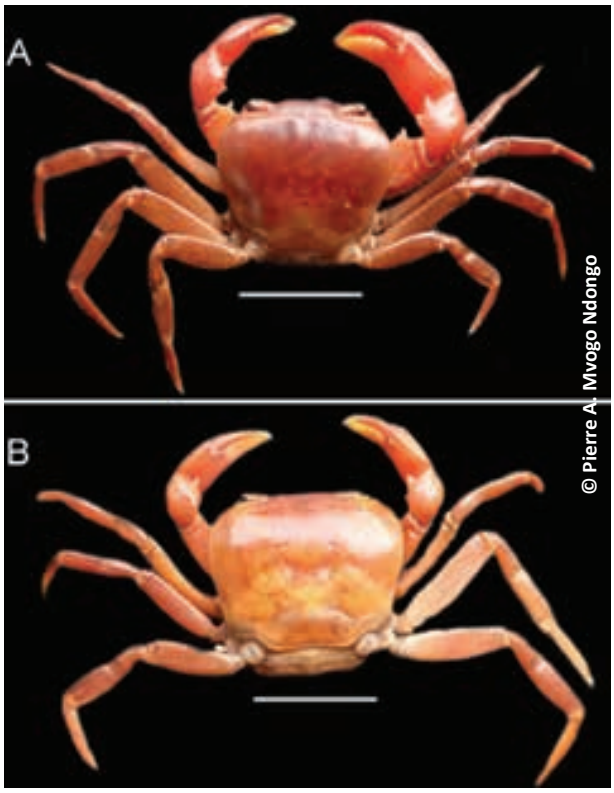

Image 1. *Louisea yabassi* in their natural colour: A—largest adult male | B—largest adult female. Scale bars A, B: 12mm.

DISCUSSION

Current threats to *Louisea yabassi*

Deforestation, together with intensive and encroaching agricultural practices, are serious issues. These activities present imminent threats to southwestern Cameroon's rich aquatic biodiversity, which is of concern, because this area includes a number of rare endemic species. Large scale habitat disturbance also has a negative impact on the culture of the indigenous people of this region, who depend on the intact forest for their livelihoods. For example, the Pygmy forest people of this part of Cameroon express their problems as follows. "[…] We are in the midst of huge desolation, we no longer recognize the forest, we no longer understand what is happening. Our forests change from one day to the next. What future awaits our children? The settlements destroy the forest, and the felling of trees prevents us from gathering honey to feed our children. The noise

Table 1. Semi-terrestrial species of primary freshwater crabs endemic to southwestern Cameroon that have been described or redescribed in the last five years, along with the number of populations, locality, habitats, main threats, and IUCN Red List status.

Genus	Species	Number of known populations	Locality	Habitat	Main threats	IUCN Red List status
Buea	*B. asylos*	2	Kumba (Southwestern region)	Streams	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Mvogo Ndongo et al. 2020)	VU (Cumberlidge 2008a,b)
	B. bangem	1	Bangem (Southwestern region)	Streams, puddles, and in the damp conditions under stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Ndongo et al. 2020)	NA
	B. mundemba	1	Mundemba (Southwestern region)	Streams, puddles, and in the damp conditions under stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation (Mvogo Ndongo et al. 2020)	NA
	B. nlonako	2	Nlonako (Eastern and northern slopes) (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation, agro-chemical release (Mvogo Ndongo et al. 2020)	NA
Louisea	*L. balssi*	1	Manengouba (Southwestern region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment habitat fragmentation (Mvogo Ndongo et al. 2018, 2019)	EN (Cumberlidge 2008a,b)
	L. edeaensis	1	Bedimet Island of Lake Ossa (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, agro-chemical release invasive plants, (Mvogo Ndongo et al. 2017a, 2019)	EN (Cumberlidge 2008a,b)
	L. nkongsamba	3	Nlonako (Eastern, southern, northern slopes) (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation, agro-chemical release. (Mvogo Ndongo et al. 2019)	NA
	L. yabassi	2	Ndogbanguegue, Yabassi (Littoral region)	Streams, puddles, and in the damp conditions under fallen leaves, stones, and in burrows	Forest destruction, firewood collection, agricultural encroachment, habitat fragmentation	NA
Sudanonautes	*S. tiko*	2	Tiko, Edea (Littoral and southwestern regions)	Wetlands, in puddles, and in the damp conditions under small stones	Forest destruction, firewood collection, agricultural encroachment, agro-chemical release. (Mvogo Ndongo et al. 2017b)	NA

NA—not assessed | EN—endangered | VU - Vulnarable.

Table 2. Field information of two distinct populations of *Louisea yabassi* from the Ebo Forest in southwestern Cameroon, central Africa, showing the geographical coordinates, water pH, water temperature, and the number of specimens at each locality (all collected by P.A. Mvogo Ndongo).

Louisea yabassi	Geographical coordinates	pH	Water temperature	Number of specimens	Date rediscovered	Plant covering around the locality
Population N°1 in Stream-1	N04.41715°, E010.20021°	6.26	26.9° C	20	10/12/2019	Heavily disturbed
Population N°2 in Stream-2	N04.41646°, E010. 20213°	6.70	26.5° C	15	13/12/2019	Heavily disturbed

of their huge machines is causing the animals to flee far away. The trees falling into the rivers and small streams alter the water flow, and the muddy stream beds harm the animals and plants. Some fruits are becoming scarce and we have to walk for a long time to find them. And the mushrooms we used to gather everywhere are gone. [...] Our children have no future. Where will they find animals to hunt? The bark, the leaves and the fruits for curing and eating? [...]" (See World Rainforest Movement Report, November, 2002, Page 36).

Image 2. Streams in Ebo Forest where the newly discovered populations of *Louisea yabassi* were collected: A—Stream-1 | B—Stream-2. © Pierre A. Mvogo Ndongo.

Deforestation has direct effects on the aquatic environment and indirect impacts from changes within the drainage basin, both of which will affect rare endemic forest species, such as *L. yabassi*, that depend on the forest canopy remaining closed and intact (Cumberlidge & Sachs 1991; Dudgeon et al. 2005; Mvogo Ndongo et al. 2018). Not only does deforestation expose aquatic systems and their inhabitants to the heating and drying effects of direct sunlight, but local farming practices also release pollutants such as agro-chemicals potentially affecting the eggs, hatchling-carrying females, and adults of *L. yabassi*. In addition, clearing the tropical rainforest leads to increased agricultural encroachment and firewood collection, which further impacts the habitat of *L. yabassi*.

Conservation recommendations

The extinction risk status of *L. yabassi* has not yet been assessed, but the data now available allow us to present a preliminary pre-assessment. Unfortunately, the two additional localities for this species are so close together that IUCN Red List protocols treat them as a single location. This is because the calculation of the extent of occurrence (EOO, the area contained within the minimum convex polygon around all sites of present occurrence) and the area of occupancy (AOO, the area within the EOO that is actually occupied by the taxon) requires at least three locations. Despite this, if an IUCN Red List extinction risk assessment were to be made, then we anticipate that *L. yabassi* would be assessed as Critically Endangered (CR) under criterion B alone using the small number of locations, the low population levels, the disruption of the habitat, and the severity of the immediate known threats.

The obvious nature and the large scale of the threats to the habitat of *L. yabassi* in the Ebo Forest mean that a conservation action plan needs to be formulated if this threatened species is to be protected from the anthropogenic threats it is facing. Conservation actions include the monitoring of populations, studies of population genetics, and protection against threats. These actions would also include a strategy for communication and education of the stakeholders in the local community about the consequences of engaging in forest destruction, firewood collection, and agricultural encroachment. Local knowledge from indigenous people should also form part of the conservation messaging. Conservation action on a local scale is feasible because of its 'low-tech' approach that is necessary (and successful) in the context of rural Africa. The content of the educational messaging needs to be structured to highlight the need for protection and to emphasise the potential advantages brought to the area by increased numbers of visitors (eco-tourists and scientists). The targeted stakeholders in the local communities should be brought to understand that *L. yabassi* is found only in the remaining rainforest tracts around Yabassi, and that this habitat is globally unique. The semi-terrestrial lifestyle of *L. yabassi* means that its habitat ranges from permanent streams to seasonal shallow waters and wetlands, all of which are impacted by intensive destructive agricultural practices that degrade and pollute the natural vegetation. The release of pesticides into the environment containing substances that either harm or kill most species of invertebrates and vertebrates (most certainly including *L. yabassi*) needs to be mitigated. In addition, these pesticides have been linked to a wide range of human health hazards ranging from headaches and nausea to cancer, reproductive harm, and endocrine disruption. Pesticides have also been linked to nerve, skin, and eye irritation, dizziness, fatigue, and even sometimes fatal systemic poisoning (Roberts & Reigart 2013).

In addition to highlighting the problems facing the rainforest around Yabassi and the Ebo Forest, the education of the local people and the Government includes the need for awareness building about the

broader lasting benefits of conservation action. These include hosting and guiding tourists and scientists from Cameroon and all around the world attracted by Africa's intact tropical rainforest ecosystems and associated unique wildlife. Further, the local markets and hospitality industry in the area will benefit from the increased flow of visitors, and this will contribute to the development of the local community. The problem of firewood collection requires the promotion of the legal harvesting of forest resources found in the forested habitat of *L. yabassi*. This distinction is important because there are no alternative sources of firewood other than the natural rainforest itself. Legal exploitation of forest resources involves avoiding cutting young trees and bushes, and only cutting off dead branches or using parts of the trees that fall naturally. It also means that the vegetation that falls around streams should be left untouched, because this constitutes good habitat for aquatic invertebrates, including *L. yabassi*. As for agricultural encroachment, it is necessary to recommend to farmers to focus their attention on land that has already been used for cultivation and direct them away from the natural vegetation around the streams that form the habitat of *L. yabassi*. What this study suggests is that farmers should curtail their activities, avoid disturbing the natural vegetation near aquatic habitats and keep these watersheds free from pesticides.

The success of this conservation action also requires public training/education sessions (workshops) aimed at involving a wider section of the local community beyond those individuals encountered during field work. Monitoring strategies for *L. yabassi* mean that local young people, students, and engineers need to be trained in how to communicate the above educational messages, and how to undertake routine monitoring to collect data on the organisms present in a habitat and general ecosystem health. The local authorities (e.g., the chiefs of the villages, sub-prefets, and prefets) need to be directly involved, because educational messaging in the community is an ongoing process, and the involvement of community leaders is key to engaging the wider community in these conservation efforts. The targets of the educational messages (local people, fishermen, farmers, foresters, hunters, and other scientists) should also be made aware of the need to constantly monitor the health of the habitat, such as monitoring changes in forest cover, agricultural practices, and the expansion of farms. As conservationists it is of great importance to inform people on the broader role of biodiversity (vertebrates and invertebrates) in the rainforest ecosystem and why illegal poaching of wildlife (e.g., gorillas, chimpanzees, and numerous bird species) and unsustainable fishing practices (such as small mesh size of nets, unenforced fishing seasons, and fishing with poison) requires controlling.

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COMMUNICATION

Checklists of subfamilies Dryptinae and Panagaeinae (Insecta: Coleoptera: Carabidae) from the Indian subcontinent

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Abstract: Distribution patterns and literature details of 45 Dryptinae and 33 Panagaeinae species reported from the Indian subcontinent are provided. Out of the 45 Dryptinae species, six species are endemic to the Western Ghats & Sri Lanka hotspot of biodiversity, two species are endemic to the Indo-Burma hotspot of biodiversity and two species are endemic to the Himalaya hotspot of biodiversity. Distribution patterns revealed that 24 Dryptinae species are endemic to the Indian subcontinent with 22 species recorded from the Oriental (ORR) region and two from the Palearctic (PAR) region. Out of the 33 Panagaeinae species, 20 species are endemic to the Indian subcontinent with 17 of these species distributed in the Oriental region; two in the Palearctic region and one species in both Oriental and Palearctic regions. Seven species are endemic to the Western Ghats & Sri Lanka hotspot of biodiveristy and two endemic to the Himalaya hotspot of biodiversity. Six Panagaeinae species and seven Dryptinae species recorded only from the Western Ghats and Sri Lanka hotspot of biodiversity are likely to be representatives of the Gondwana remnants. Genus *Ardistomopsis* with five species is endemic to the Indian subcontinent.

Keywords: Dryptini, Galeritini, ground beetle, Panagaeini, Peliciini, Zuphini.

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Author contribution: SKT and Jithmon VAJ reviewed the earlier works and discussed the distribution patterns. VAJ conducted the field studies, preparations of the plates and specimens.

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INTRODUCTION

Globally, 560 species from 30 genera have been described from the subfamily Dryptinae (Lorenz 2005) and 387 species in 29 genera are described from the subfamily Panagaeinae (Hackel & Farkac 2012). Dryptinae (Dryptiini Bonelli, 1810, Zuphiini Bonelli, 1810 & Galeritiini Leconte, 1853) and Panagaeinae (Peliciini Chaudoir, 1880 & Panagaeini Bonelli, 1810) are two lesser known Carabidae subfamilies from the Indian subcontinent with 45 species and 33 species, respecitively. Andrewes (1930) recorded 15 Dryptinae species and 11 Pangaeinae species from Indian subcontinent. Taxonomic studies on these groups from Indian subcontinent have been infrequent since 1930 (Jedlicka 1935; Andrewes 1936; Landin 1955; Jedlicka 1956; Darlington 1968; Mateu 1981; Straneo & Ball 1989; Baehr 1990; Xie & Yu 1991; Mateu 1992; Baehr 1998; Kirschenofer 2000; Liang & Kavanaugh 2007; Kirschenhofer 2011; Hackel & Kirschenhofer 2014; Jithmon & Sabu 2018).

World Catalogue of Carabidae (Lorenz 2005) provided up to date nomenclatural information on Dryptinae and Panagaeinae and the Catalogue of Palearctic Coleoptera (Lobl & Lobl 2017) provided countrywise details and related bibliographic references of Palearctic region. World Checklist of Panagaeinae (Hackel & Farkac 2012) provided country wise data including India for the subfamily Panagaeinae but no species specific regional distribution data. In general, lack of species specific regional distribution data and reference details hinders taxonomic analysis of the Dryptinae and Panagaeinae fauna of the Indian subcontinent. In this paper, we provide an up to date checklist of both subfamilies, with distribution and reference details of all species recorded in the Indian subcontinent (Indian mainland, Sri Lanka, and Bangladesh).

MATERIALS AND METHODS

Distribution data for each species was collected by verifying records and descriptions of listed species between the years of 1781 and 2020. Listed references were collected by analysing the primary literature, websites (e.g., Carabidae of the World, Catalogue of Life), and contacting various carabidologists. Data for 12 Panagaeinae species was collected by examination of the insect collections of host institutions from various forest insect diversity projects. Indian locality details of 65 species from the descriptions and records are provided, 13 species with no locality details in the descriptions are marked as from 'India', species from Oriental (ORR) and Palaeractic (PAR) localities of Indian subcontinent have been categorised as ORR - India/ PAR - India.

Specimens were collected from forests and agricultural lands in the south Indian states, Kerala and Tamil Nadu using light traps and by active collecting. Specimens were identified with the aid of keys available in Liang and Kavanaugh (2004, 2007), Hackel & Kirschenhofer (2014a,b), Fedorenko (2016), Jithmon & Sabu (2018) and with aid of species descriptions available in various publications. Verifications were done by comparing with the types in: MNHN—Muséum National d'Histoire Naturelle, Paris, France; ZMUC—University of Copenhagen Zoological Museum, Denmark; ZMHB—Museum für Naturkunde, Humboldt Universität, Berlin, Germany; MPC—National Museum of Natural History, Prague, Czech Republic; and NHMW—Naturhistoriches Museum, Wien, Austria. Images were taken using Leica M205C Stereo zoom microscope fitted with Leica MC 170 HD digital camera. Measurements are taken with Leica LAS V4.5 software and provided in millimetres. Verified specimens were added to the insect collections of Zoological Survey of India, Kozhikode station.

Separation of the Indian species from the World catalogue of Carabidae (Lorenz 2005) was done with the aid of Andrewes (1930), Hackel & Farkac (2012), and Löbl & Löbl (2017) and by verifying the distribution pattern of each species in the cited literature. One species, *Dischissus alaticollis* Bates 1892 (Panagaeinae), known only from the Andamans is excluded from the list of species in Indian subcontinent.

Abbreviations and markings Used

id. "Idem" (the same; as just mentioned)
ORR Oriental Region
PAR Palaearctic Region
IAR Indo-Australian Region
* Species assessed by the authors.
\# Species with Indian regional distribution data not available.

Checklist of the Indian Dryptinae with distribution records

I. Tribe Dryptini Bonelli , 1810

Genus 1. *Drypta* Latreille, 1796

Latreille, 1796: 75; Fabricius, 1801: 230; Latreille, 1806: 117; Dejean, 1825: 182; Schmidt-Goebel, 1846: 22; Lacordaire, 1854: 79; Andrewes, 1924: 51; id. 1930: 157; Lorenz, 2005: 503.

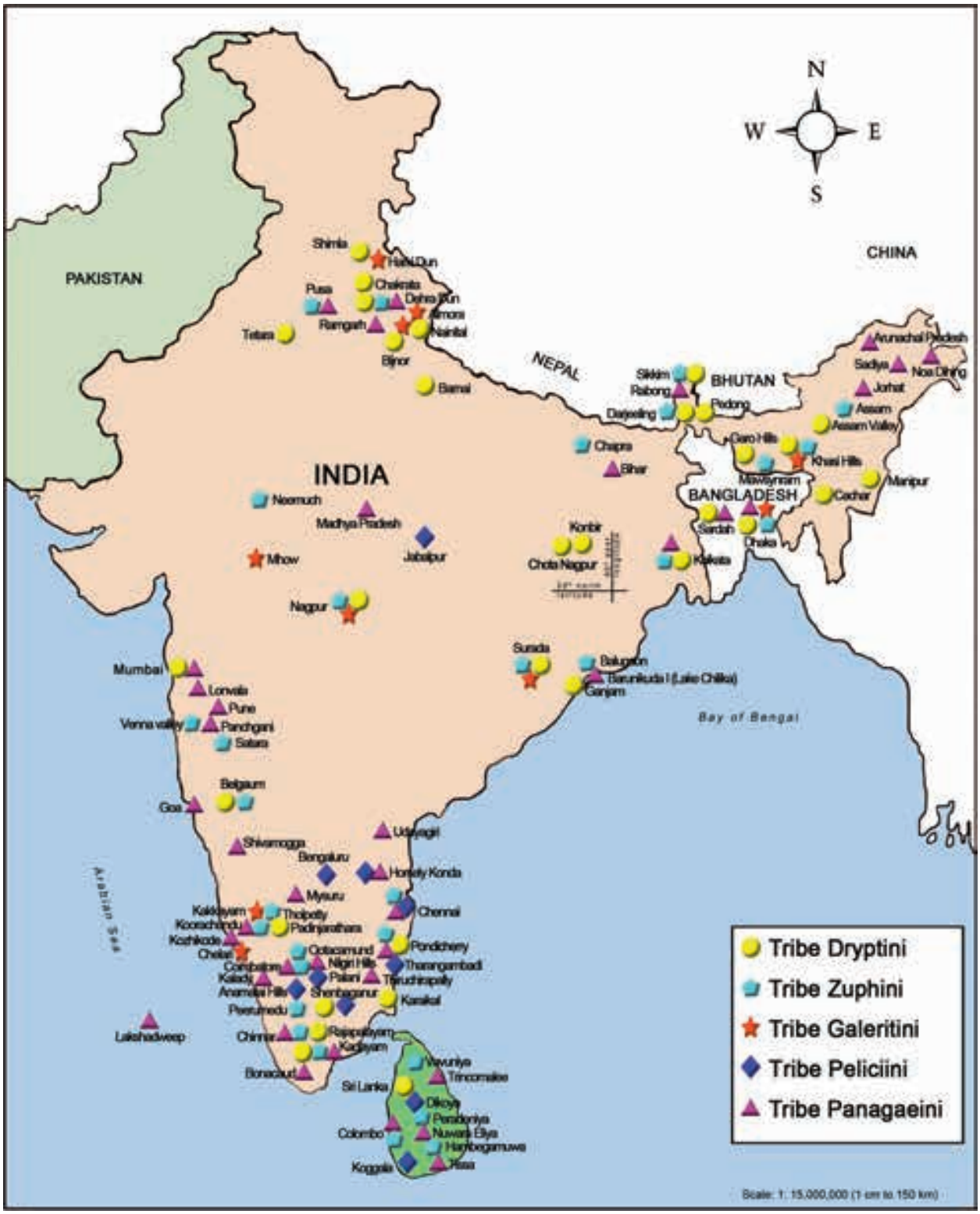

Figure 1. Distribution pattern of the tribes Dryptini, Zuphini and Galeritini of subfamily Dryptinae and Peliciini and Panagaeni of subfamily Panagaeinae from Indian subcontinent.

1. *Drypta aenipes* Wiedemann, 1823 [#]

Wiedemann, 1823: 60; Andrewes, 1921: 173; Heller, 1923: 304; Andrewes, 1930: 157; id. 1936: 135; Lorenz, 2005: 503.

Geographical Distribution: ORR - India, Bangladesh (Dhaka), Myanmar.

2. *Drypta aetheria* Andrewes, 1936

Andrewes, 1936: 135; Lorenz, 2005: 503.

Geographical Distribution: ORR - India (Assam).

3. *Drypta argillacea* Andrewes, 1924

Andrewes, 1924: 106; id. 1930: 157; id. 1936: 135; Lorenz, 2005: 503.

Geographic Distribution: ORR - India (Uttar Pradesh: Bijnor; Maharashtra: Nagpur; Odisha: Ganjam, Surada), Bangladesh (Dhaka), PAR - India (Uttarakhand: Chakrata, Dehra Dun, Nainital).

4. *Drypta cyanopus* Andrewes, 1936

Andrewes, 1936: 136; Lorenz, 2005: 503.

Geographic Distribution: ORR - Bangladesh (Sardah).

5. *Drypta crassiuscula* Chaudoir, 1861

Chaudoir, 1861: 550; Andrewes, 1923: 6; id. 1930: 157; id. 1936: 135; Lorenz, 2005: 503.

Geographic Distribution: PAR - India (Uttarakhand: Dehra Dun).

6. *Drypta flavipes* Wiedemann, 1823

Wiedemann, 1823: 60; Dejean, 1826: 442; Schmidt-Goebel, 1846: 24; Andrewes, 1921: 173; id. 1930: 158; id. 1936: 135; Lorenz, 2005: 503; Lobl & Lobl, 2017: 500.

= *pallipes* Chaudoir, 1850: 33; id. 1861: 518.

Geographic Distribution: PAR - India (Himachal Pradesh: Shimla; Sikkim), Nepal, Bhutan, ORR - India (Assam).

7. *Drypta lineola* Macleay, 1825 (Image 1a) *

Macleay, 1825: 27; Dejean, 1825: 184; Redtenbacher, 1867: 4; Chaudoir, 1877: 262; Bates, 1883: 279; id. 1891: 336; id. 1892: 383; Heyne-Tasch, 1898: 13; Bouchard, 1903: 173; Andrewes, 1919: 167; id. 1923 (1924): 460; id. 1924: 469; id. 1930: 158; id. 1936: 135; Lorenz, 2005: 503.

Specimens examined (n= 5): SJC-ZO-CAR001, 15.x.2015, 2 ex. Rajapalayam, 9.450^{0}N, 77.566^{0}E, 275m, light trap, coll. Jithmon V.A. & Akhil S.V.; 18.x.2015, 2 ex. Kadayam, 8.832^{0}N, 77.357^{0}E, 367m, light trap, coll. Jithmon V.A. & Akhil S.V.; 03.iii.2015, 1 ex. Padinjarathara, 11.672^{0}N, 75.939^{0}E, 734m, light trap, coll. Jithmon V.A. & Akhil S.V.

Geographical Distribution: ORR - Throughout India (Tamil Nadu: Rajapalayam, Kadayam; Kerala: Padinjarathara), Sri Lanka, Myanmar, Malaysia, Thailand, Cambodia, Vietnam, and Indonesia (Java, Sumatra, Borneo).

8. *Drypta longicollis* Macleay, 1825 #

Macleay, 1825: 28; Liang *et al.* 2004: 380.

= *Drypta longicollis* Dejean, 1825: 185.

= *Dendrocellus longicollis* Dejean; Bates, 1892: 385.

= *Desera longicollis* Macleay; Andrewes, 1919: 168; id. 1930: 142; Heller, 1923: 303; Jedlicka, 1963: 486; Lorenz, 2005: 504.

Geographic distribution: ORR - India, Myanmar (Karen hills, Thagata, Tenasserim).

9. *Drypta siderea* Bates, 1892

Bates, 1892: 382; Andrewes, 1923: 6; id. 1930: 159; id. 1936: 135; Lorenz, 2005: 503.

Geographic Distribution: ORR - India (Meghalaya: Garo hills), Myanamar (Karen Hills), Laos. PAR - India (Uttarakhand: Dehra Dun), China.

Genus 2. *Dendrocellus* Schmidt Geobel, 1846

Schmidt-Goebel, 1846: 24; Lacordaire, 1854: 80; Chaudoir, 1861: 545; id. 1872: 101; Bates, 1892: 385; Andrewes, 1930: 141; id. 1939: 133; Jeannel, 1949: 1064; Liang et al. 2004: 379.

= *Desera* Hope, 1838: 105; Lacordaire, 1854: 80; Dupuis, 1912: 319; Heller, 1923: 303; Csiki, 1932: 1553; Basilewsky, 1960: 177; Jedlicka, 1963: 486; Hansen, 1967: 400; Habu, 1967: 277; Lorenz, 2005: 503.

1. *Dendrocellus coelestinus* (Klug, 1834) #

Chaudoir 1861: 545; Liang & Kavanaugh, 2007: 15; Lobl & Lobl, 2017: 499.

= *Drypta coelestina* Klug 1834: 53.

= *Desera coelestina* (Klug), Andrewes 1927: 100; id. 1930: 141; Lorenz, 2005: 503.

= *Dendrocellus parallelus* Chaudoir 1872: 101.

Geographic distribution: ORR - North India, Myanmar (Carin Cheba), Thailand, Indonesia (Sumatra, Java, Sulawesi), Malaysia, Laos (Pakneun), PAR - Pakistan (Chiringa), Bhutan, China (Yunnan, Hainan).

2. *Dendrocellus confusus* (Hansen, 1968) #

Liang & Kavanaugh, 2007: 16; Lobl & Lobl, 2017: 499.

= *Desera confusa* Hansen, 1968: 164; Lorenz, 2005: 503.

Geographic Distribution: ORR - India, Indonesia (Sumatra, Java, Kalimantan), Laos, Thailand. PAR - Pakistan (Ichamati), China (Fujiang; Guangdong; Guangxi), Japan.

3. *Dendrocellus geniculatus* (Klug, 1834)

Schmidt-Geobel, 1846: 25; Liang & Kavanaugh, 2007: 19.

= *Drypta geniculata* Klug, 1834: 52; Chaudoir, 1872: 192; Bates, 1883: 279; id. 1889: 280; id. 1891: 336; Bouchard, 1903: 173; Andrewes, 1921: 173; Heller, 1921: 530; Andrewes, 1923: 8; Heller, 1923: 303; Andrewes, 1924: 469; id. 1930: 142; Lorenz, 2005: 503.

= *Desera (Dendrocellus) gilsoni* Dupuis 1912: 319.

= *Desera gilsoni continentalis* Hansen 1967: 405.

Var. *Dendrocellus rugicollis* Chaudoir, 1861: 546; id. 1872: 102; Andrewes, 1919: 170.

Geographic Distribution: ORR - India (Tamil Nadu: Pondicherry: Karaikal), Bangladesh, Cambodia, Malaysia (Malacca), Indonesia (Batoe Doelang; Sumatra), Laos, Thailand (Chiang Mai; Chonburi; Nakhon Nayok), Vietnam (Annam; Tonkin Hoabinh; Quang Nam). PAR - India (Sikkim), Bhutan, Pakistan (Ichamati), China (Formosa; Hainan; Fujian; Shanghai; Guangxi; Guizhou; Guangdong; Yunnan; Sichuan; Tibet), Japan. IAR - Philippines (Ile Basilan; Laguna; Mindoro).

4. *Dendrocellus inexpectus* Liang & Kavanaugh, 2007

Liang & Kavanaugh, 2007: 23.

Geographic Distribution: ORR - India (Jharkhand: Chota Nagpur: Barway, Konbir; Maharashtra: Mumbai; Karnataka: Belgaum; Uttar Pradesh: Barnai).

5. *Dendrocellus nepalensis* (Hope, 1831)

Chaudoir, 1872: 102; Liang & Kavanaugh, 2007: 27.

= *Desera nepalensis* Hope, 1831: 21; Dohrn, 1879: 457; Andrewes, 1919: 170; Heller, 1923: 303; Andrewes, 1930: 142; Lorenz, 2005: 504.

= *Dendrocellus discolour* Schmidt-Goebel, 1846: 24; Bates, 1891: 336; Andrewes, 1923: 7; Heller, 1923: 304.

Geographic Distribution: ORR - India (Assam: Assam valley, Khasi hills, Cachar; Sikkim; West Bengal: Darjiling, Gopaldhara, Pedong; Jharkhand: Chota Nagpur, Konbir; Rajasthan: Tetara; Tamil Nadu: Shenbaganur; Manipur), Bangladesh, Myanmar (Martaban), Vietnam (Tongking). PAR - Nepal, China (Tibet; Yunnan), Bhutan.

6. *Dendrocellus rugicollis* Chaudoir, 1861

Chaudoir, 1861: 546; Lorenz, 2005: 504.

= *Dendrocellus flavipes*, Schmidt-Goebel, 1846: 24.

Geographic Distribution: ORR - North India (West Bengal: Kolkata). PAR - China (Guangxi), Nepal.

7. *Dendrocellus unidentatus* (Macleay, 1825)

Chaudoir, 1861: 545, Liang and Kavanaugh, 2007: 35; Lobl & Lobl, 2017: 499.

= *Drypta unidentata* Macleay, 1825: 28; Andrewes, 1919: 167; Heller, 1923: 303. Andrewes, 1930: 143.

= *Desera unidentata* Andrewes, 1919: 167; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (Assam: Khasia hills; Andaman Islands), Indonesia (Java; Sumatra), Vietnam, Thailand, Myanmar (Matupi; Tenasserim; Carin Cheba), PAR - Pakistan (Ichamati), China (Yunnan).

II. Tribe Zuphini Bonelli, 1810

Genus 1. *Paraleleupidia* BASILEWSKY, 1951

Basilewsky, 1951: 176; id. 1953: 271 ; Baehr, 1990: 10; Mateu, 1981: 717 ; Lorenz, 2005: 504.

1. *Paraleleupidia linearis* Baehr, 1990

Baehr, 1990: 10; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (Tamil Nadu: Ootacamund).

2. *Paraleleupidia loebli* Mateu, 1981

Mateu, 1981: 719; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (Tamil Nadu: Nilgiri Hills).

3. *Paraleleupidia besucheti* Mateu, 1981

Mateu, 1981: 717; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (Kerala: Cardamon hills, Pambanar, Peermedu).

Genus 2. *Gunvorita* Landin, 1955

Landin, 1955: 467; Darlington, 1968: 208; Mateu, 1981: 721; Perrault, 1982: 76; Casale 1985: 41; Baehr, 1988: 115; id. 1990: 16; id. 1991: 194; Lorenz, 2005: 504; Lobl & Lobl, 2017: 835.

1. *Gunvorita besucheti* Baehr, 1998

Baehr, 1998: 288; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (West Bengal: Darjeeling: Algarah).

2. *Gunvorita depressipennis* Baehr, 1998

Baehr, 1998: 295; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (Meghalaya: Khasi hills- Nongpoh).

3. *Gunvorita elegans* Landin, 1955

Landin, 1955: 467; Darlington, 1968: 210; Mateu, 1981: 721; Casale, 1985: 41; Baehr, 1998: 269; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (West Bengal: Darjeeling). PAR - India (Sikkim), Nepal.

4. *Gunvorita indica* Darlington, 1968

Darlington, 1968: 208; Mateu, 1981: 722; Baehr,

1998: 274; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (West Bengal: Darjeeling, Ghoom).

5. *Gunvorita inermis* Baehr, 1998

Baehr, 1998: 272; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (West Bengal: Darjeeling: Mahanadi).

6. *Gunvorita laeviceps* Baehr, 1998

Baehr, 1998: 270; Lorenz, 2005: 504.

Geographic Distribution: ORR - India (West Bengal: Darjeeling).

7. *Gunvorita minor* Baehr, 1998

Baehr, 1998: 291; Lorenz, 2005: 505.

Geographic Distribution: ORR - India (Meghalaya: Khasi Hills: Mawsynram - Balat).

8. *Gunvorita ovaliceps* Baehr, 1998

Baehr, 1998: 275; Lorenz, 2005: 505.

Geographic Distribution: ORR - India (West Bengal: Darjeeling: Ghoom).

Genus 3. *Agastus* Schmidt-Goebel, 1846

Schmidt-Goebel, 1846: 30; Lacordaire, 1854: 87; Andrewes, 1930: 12; Lorenz, 2005: 505.

1. *Agastus lineatus* Schmidt-Goebel, 1846

Schmidt-Goebel, 1846: 31; Gestro, 1875: 867; Bates, 1889: 280; id. 1892: 388; Andrewes, 1923: 10; id. 1930: 13; Lorenz, 2005: 505.

Geographic Distribution: ORR - India (West Bengal: Kolkata), Myanmar, Vietnam (Cochinchina), Cambodia, PAR - Hong Kong, IAR - Philippines.

Genus 4. *Zuphium* Latreille, 1806

Latreille, 1806: 198; Latreille et Dejean, 1824: 121; Dejean, 1825: 192; Schmidt-Goebel, 1846: 27; Lacordaire, 1854: 85; Chaudoir, 1862: 310; K & J Daniel, 1898: 24; Bedel, 1913: 295; Andrewes, 1930: 358; Lorenz, 2005: 506.

1. *Zuphium dabreui* Andrewes, 1922 (Image 1b) *

Andrewes, 1922: 168; id. 1930: 359; Lorenz, 2005: 506.

Specimens examined (n=1): SJC-ZO-CAR002, 18.x.2015, India: Kadayam, 8.832˚N, 77.357˚E, 367m, light trap, coll. Jithmon V.A. & Akhil S.V.

Geographic Distribution: ORR - India (Maharashtra: Nagpur, Karnataka: Belgaum, Tamil Nadu: Chennai, Kadayam), Sri Lanka (Vauniya, Horawupotana).

2. *Zuphium erebeum* Andrewes, 1923 #

Andrewes, 1923: 243; id. 1930: 359; Lorenz, 2005: 506.

Geographic Distribution: ORR - Sri Lanka.

3. *Zuphium erythrocephalum* Chaudoir, 1862 (Image 1c) *

Chaudoir, 1862: 311 Andrewes, 1930: 359; Lorenz, 2005: 506.

Specimens examined (n= 1): SJC-ZO-CAR003, India: Rajapalayam, 9.450˚N, 77.566˚E, Pitfall, 275 m, 14.II.2015, coll. Jithmon V.A. & Akhil S.V.

Geographic Distribution: ORR - India (Madhya Pradesh: Neemuch; Maharashtra: Nagpur; Kerala: Malabar; Tamil Nadu: Rajapalayam, Ooty, Chennai, Pondicherry).

4. *Zuphium indicum* Andrewes, 1922

Andrewes, 1922: 167; id. 1930: 359; Lorenz, 2005: 506.

Geographic Distribution: ORR - India (Maharashtra: Nagpur).

5. *Zuphium modestum* Schmidt-Goebel, 1846

Schmidt-Goebel, 1846: 29; Chaudoir, 1862: 312; Bates, 1892: 387; Andrewes, 1923: 10; id. 1930: 359; Lorenz, 2005: 506.

Geographic Distribution: ORR - India (West Bengal: Kolkata; Maharashtra: Nagpur, Venna Valley, satara), Myanmar (Tharrawaddy, Palon), Malaysia (Penang), Thailand, Cambodia, Vietnam (Cochinchina).

6. *Zuphium olens* (Rossi, 1790)

Rossi, 1790: 217; Chaudoir, 1862: 311; Bates, 1889: 280; id. 1892: 386; Andrewes, 1921: 155; id. 1923: 9; id. 1927: 99; id. 1930: 359; Lorenz, 2005: 506; Lobl & Lobl, 2017: 837.

= *clermonti* Jeannel, 1949a: 49

= *kochi* Schatzmayr, 1936a: 106

= *longiusculum* Chaudoir, 1842a: 804

= *pubescens* Nietner, 1858: 182

= *rufifrons* Chaudoir, 1863d: 312

Geographic Distribution: ORR - India (West Bengal: Kolkata; Delhi: Pusa; Bihar: Chapra; Odisha: Balugaon), Sri Lanka, Myanmar (Tharrawaddy, Moulmein, Palon, Tikekee (Pegu), Tenasserim), Malayasia (Langkawi I), Thailand, Vietnam (CochinChina, Annam), Indonesia (Java), PAR-China, Albania, Austria, Bulgaria, Cyprus, Corsica, Italy, France, Spain, Ukrain, Malta, Israel,

southern European Russia, Africa (Egypt).

Genus 5. *Metazuphium* Mateu, 1992

Mateu, 1992: 196; Lorenz, 2005: 506.

1. *Metazuphium spinangulus* Mateu, 1992 #

Mateu, 1992: 196; Lorenz, 2005: 506.

Geographic Distribution: ORR - Sri Lanka

Genus 6. *Parazuphium* Jeannel, 1942

Jeannel, 1942: 1094; Lorenz, 2005: 507; Lobl & Lobl, 2017: 836.

1. *Parazuphium inconspicuum* (Schmidt-Goebel, 1846)

Schmidt-Goebel, 1846: 30; Bates, 1892: 387; Andrewes, 1923: 10; id. 1930: 359; Jeannel, 1942: 1094; Lorenz, 2005: 507.

Geographical Distribution: ORR - India (Karnataka: Belgaum), Myanmar (Palon), Thailand, Indonesia, IAR - Philippines.

Genus 7. *Planetes* Macleay, 1825

Macleay, 1825: 28; Lacordaire, 94; Bates, 1873: 304; Andrewes, 1924: 52; id. 1930: 278; Lorenz, 2005: 507; Lobl & Lobl, 2017: 501.

= *Heteroglossa* Nietner, 1857: 141; id. 1857: 279.

1. *Planetes bimaculatus* Macleay, 1825

Macleay, 1825: 29; Chaudoir, 1872: 139; Bates, 1892: 388; Andrewes, 1919: 169; id. 1930: 278; Lorenz, 2005: 507.

Geographic Distribution: ORR - India (Assam), Sri Lanka, Myanmar (Karen Hills), Malaysia (Kuala Lumpur), Thailand, Indonesia (Java, Sumatra), PAR - Japan (Nagasaki, Hiogo), China.

2. *Planetes indicus* Andrewes, 1922

Andrewes, 1922: 166; id. 1930: 278; Lorenz, 2005: 507.

Geographic Distribution: ORR - India (Maharashtra: Nagpur).

3. *Planetes ruficeps* Schaum, 1863 (Image 1e) *

Schaum, 1863: 81; Chaudoir, 1872: 139; Andrewes, 1924: 53; id. 1930: 279; Lorenz, 2005: 507.

= *bimaculatus* (*Heteroglossa*) Nietner, 1857: 144; id. 1857: 282; Andrewes; 197: 106.

Specimens examined (n= 2): SJC-ZO-CAR004, 1 ex, India: Tholpetty, 11.960˚N, 76.064˚E, 882m, light trap, 05.v.2015, coll. Jithmon V.A. & Akhil. S.V.; 1 ex, Koorachundu, 11.538˚N, 75.845˚E, 95m, hand picking, 12.xi.2016, coll. Jithmon V.A.

Geographic Distribution: ORR - India (Kerala: Tholpetty, Koorachundu; Odisha: Surada; Tamil Nadu: Chennai, Nilgiri Hills), Bangladesh (Dhaka), Sri Lanka (Colombo, Hambegamuwa, Kotte), Myanmar (Tharrawaddy). PAR - India (Uttarakhand: Dehra Dun).

4. *Planetes ruficollis* (Nietner, 1857)

Nietner, 1857: 144; id. 1857: 282; Chaudoir, 1872: 140; Vuillet, 1912: 17; Andrewes, 1927: 106; id. 1930: 279; Lorenz, 2005: 507.

Geographic Distribution: ORR - India (Delhi: Pusa), Bangladesh (Dhaka), Sri Lanka (Colombo), Vietnam (CochinChina), Indonesia, Thailand, Malaysia, Cambodia.

5. *Planetes simplex* Bates, 1886

Bates, 1886: 199; Andrewes, 1930: 279; Lorenz, 2005: 507.

Geographic Distribution: ORR - Sri Lanka (Peradeniya).

III. Tribe- Galeritini Leconte, 1853

Genus 1. *Galerita* Fabricius, 1801

Fabricius, 1801: 214; Latreille, 1806: 117; Dejean, 1825: 186; Schmidt-Goebel, 1848: 26; Lacordaire, 1854: 82; Andrewes, 1924: 52; id. 1930: 167; Lorenz, 2005: 508.

= *Galeritula* Strand, 1936: 168

= *Galeritina* Jeannel, 1949c: 1058

= *Galeritella* Jeannel, 1949c: 1058

= *Galeritiola* Jeannel, 1949c: 1059

1. *Galerita batesi* Andrewes, 1923 #

Andrewes, 1923: 9; id. 1930: 168; Lorenz, 2005: 508.

= *orientallis* (not Schmidt-Goebel) Bates, 1889: 109; id. 1892: 385.

Geographic Distribution: ORR - India, Bangladesh (Sylhet), Myanmar (Karen hills, Teinzo, Palon, Thagata, Tenasserim, Annam), Vietnam.

2. *Galerita indica* Chaudoir, 1861 #

Chaudoir, 1861: 557; id. 1877: 255; Andrewes, 1930: 168; Lorenz, 2005: 508; Lobl & Lobl, 2017: 500.

Geographic Distribution: ORR - northern India.

3. *Galerita orientalis* Schmidt-Goebel, 1846 (Image 1d) *

Schmidt-Goebel, 1846: 26; Bates, 1889: 109; Andrewes, 1923: 8; id. 1930: 168; Lorenz, 2005: 509; Kushwaha *et al.* 2015: 22; Lobl & Lobl, 2017: 500.

= *Galerita nigripennis* Chaudoir, 1861: 557; id, 1877: 255; Andrewes, 1924: 52; id. 1930: 168; Lorenz, 2005:

509.

Specimens examined (n= 2): SJC-ZO-CAR005, 15.iii.2015, 1ex, India: Chelari, 11.100˚N, 75.883˚E, 55m, hand picking, coll. Akhil S.V.; 26.xi.2017, 1ex, Kakkayam, 11.551˚N, 75.925˚E, 755m, hand pickinging, coll. Jithmon V.A.

Geographic Distribution: ORR - India (Kerala: Chelari, Kakkayam; Assam: Khasi Hills; Madhya Pradesh: Mhow; Maharashtra: Nagpur; Odisha: Surada), Bangladesh (Dhaka), Myanmar (Patkai hills), Indonesia, PAR - Taiwan, Japan, China, North Korea, South Korea.

4. *Galerita ruficeps* Chaudoir, 1861

Chaudoir, 1861: 556; Andrewes, 1930: 168; Lorenz, 2005: 509.

Geographic Distribution: PAR - India (Uttarakhand: Harki Dun, Nainital, Almora).

Checklist of the Indian Panagaeinae with distribution records

I. Tribe Peliciini Chaudoir, 1880

Genus 1. *Ardistomopsis* Straneo & Ball, 1989

Straneo & Ball,1989.123; Lorenz, 2005: 318.

= *Disphaericus* (in part) Schaum,1864: 122; Bates,1886: 73; Andrewes, 1923: 228; id. 1927: 109; id. 1930: 153; Csiki,1929: 400.

1. *Ardistomopsis andrewesi* Straneo & Ball, 1989

Straneo & Ball, 1989: 126; Lorenz, 2005: 318.

Geographic Distribution: ORR - India (Tamil Nadu: Shenbaganur, Palani Hills).

2. *Ardistomopsis batesi* Straneo & Ball, 1989

Straneo & Ball, 1989: 126; Lorenz, 2005: 318.

Geographic Distribution: ORR - India (Madhya Pradesh: Jabalpur).

3. *Ardistomopsis marginicollis* (Schaum, 1864)

Straneo & Ball, 1989: 124; Lorenz, 2005: 318.

= *Disphaericus marginicollis* Schaum, 1864: 122; Andrewes, 1923: 228; id. 1927: 109; id. 1930: 153; Csiki, 1929: 400.

Geographic Distribution: ORR - India (Tamil Nadu: Chennai, Tharangambadi; Karnataka: Bengaluru; Andhra Pradesh: Horseley Konda).

4. *Ardistomopsis myrmex* (Andrewes, 1923)

Straneo & Ball, 1989: 125; Lorenz, 2005: 318.

= *Disphaericus myrmex* Andrewes, 1923: 228; id. 1930: 153; Csiki, 1929: 400.

Geographic Distribution: ORR - India (Tamil Nadu: Anamalai Hills), Sri Lanka (Koggala, Velverry).

5. *Ardistomopsis ovicollis* (Bates, 1886)

Straneo & Ball, 1989: 125; Lorenz, 2005: 318.

= *Disphaericus ovicollis* Bates, 1886: 73; Andrewes, 1923: 229; id., 1930: 153; Csiki, 1929: 400.

Geographic Distribution: ORR - Sri Lanka (Dikoya).

II. Tribe- Panagaeini Bonelli, 1810

Genus 1. *Craspedophorus* Hope, 1838

Hope, 1838: 165; Lacordaire, 1854: 210; Chaudoir, 1878: 90; Andrewes, 1919: 126; id. 1924: 22; id. 1930: 133; Kirschenhofer, 2000: 328; Lorenz, 2005: 320; Hackel & Kirschenhofer, 2014: 276; Fedorenko, 2016: 2.

= *Camptoderus* Hope, 1838: 66.

= *Eudema* Castelnau, 1840: 137; Lacordaire, 1854: 210; Chaudoir, 1878: 133.

= *Isotarsus* Laferte-Senectere, 1851: 217.

= *Epicosmus* Chaudoir, 1846: 512; id. 1854: 338; id. 1861: 335; id. 1878: 104.

= *Brachycosmus* Jeannel, 1949: 857 (subgenus)

= *Acanthocosmus* Jeannel, 1949: 855 (subgenus)

1. *Craspedophorus angulatus* (Fabricius, 1781) (Image 1f) *

Andrewes, 1919: 125; id. 1921: 154; id. 1924: 115; id. 1924b: 462; id. 1930: 133; Jedlicka 1965: 3; Kirschenhofer, 2000: 323; Baehr, 2003: 446; Lorenz, 2005: 320; Pang & Tian, 2012: 265; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 357; Fedorenko, 2016: 4; Manthen & Hegde, 2018: 206.

= *Carabus angulatus* Fabricius, 1781: 302; id. 1787: 197; id. 1792: 148; Oliver,35.38.

= *Carabus reflexus* Fabricius, 1801: 166 (not 1781).

= *Cychrus reflexus* Fabricius 1801: 166.

= *Panagaeus angulatus* Hope, 1838: 92; Chaudoir, 1861: 336; Heyne-Tasch, 1898: 21.

= *Pimelia fasciatus* Fabricius, 1781: 318; id. 1787: 209; id. 1792: 104; Schaum, 1847: 42; Motschulsky, 1855: 69.

= *Panagaeus tomentosus* Vigors, 1825: 537; Dejean, 1826: 284; Dejean, 1831: 598; Schaum, 1847: 42.

= *Panagaeus fabricii* Hope, 1838: 66.

= *Pimelia bifasciata* Chaudoir, 1861: 336.

= *Eudema bifasciatum* Chaudoir, 1878: 133. Alluaud, 1895: 130

= *Eudema michardi* Fairmaire 1880: 307; Alluaud, 1895: 130.

Specimens examined (n= 1): SJC-ZO-CAR006, 26.v.2017, India: Bonacaud, 8.756˚N, 77.188˚E, 933m, hand picking, coll. Jithmon V.A. & Akhil S.V.

Geographic Distribution: ORR - India (Andra Pradesh; Tamil Nadu: Coimbatore, Pondicheri; Karnataka: Shivamogga, Mysuru; Kerala: Bonacaud; Maharashtra: Pune), Sri Lanka, Bangladesh, Myanmar.

2. *Craspedophorus bifasciatus* (Castelnau, 1835) (Image 2a) *

Andrewes, 1919: 126; id. 1921: 341; Andrewes, 1930: 134; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 346; Fedorenko, 2016: 4.

= *Panagaeus bifasciatus* Castelnau, 1835: 155.

= *Isotarsus bifasciatus* Laferte-Senectere, 1851: 220; Schaum, 1853: 431; Motschulsky, 1855: 69.

= *Epicosmus bifasciatus* Chaudoir, 1861: 336;

= *Epicosmus castelnaui* Chaudoir, 1878: 112; Bates, 1886: 73; Andrewes 1919: 126.

= *Eudema bifasciatum* Heyne-Tasch, 1898: 21;

Specimens examined (n= 3): SJC-ZO-CAR007, 10.ix.2015, 1 ex, India: Bharathiyar, 11.047˚N, 76.880˚E, 514m, hand picking, coll. Akhil. S.V.; 06.xii.2017, 1 ex, Chinnar, 10.3˚N, 77.175˚E, 627m, hand picking, coll. Divya M.; 18.x.2015, 1 ex, Kadayam, 8.832˚N, 77.357˚E, Hand picking, coll. Jithmon V.A. & Akhil S.V.

Geographic Distribution: ORR - India (Kerala: Chinnar; Tamil Nadu: Kadayam, Coimbatore, Bharathiyar, Chennai, Mahabalipuram, Nilgiri Hills, Thiruchirapally, Pondicherry; Andhra Pradesh: Udayagiri, Horsely Konda; Madhya Pradesh; Odisha: Barunikuda I. - Lake Chilika), Sri Lanka (Colombo, Trincomalee, Suriya Ara, Tissa, Maha, Illupalama).

3. *Craspedophorus geniculatus* (Wiedemann, 1823)

Andrewes, 1921: 170, 187; id. 1930: 135; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 301.

= *Panagaeus geniculatus* Wiedemann, 1823: 56; Schaum, 1853: 28.

= *Isotarsus rufipalpis* Laferte-Senectere, 1851: 221 (*nomen nudum* Andrewes 1924b: 588); Chaudoir, 1878: 110; Andrewes, 1930: 135; Kirschenhofer, 2000: 323; Hackel & Farkac, 2012: 77, 79.

= *Epicosmus geniculatus* Chaudoir, 1861: 351; id. 1869: 351; id. 1878: 112. Andrewes, 1924: 588.

= *Epicosmus hilaris* Chaudoir, 1878: 110; Csiki, 1929: 357.

Geographic Distribution: ORR - India (West Bengal; Delhi: Pusa; Bihar).

4. *Craspedophorus gracilipes* (Bates, 1892)

Andrewes, 1930: 135. Saha & Biswas, 1985: 123; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 370; Lobl & Lobl, 2017: 638.

= *Epicosmus gracilipes* Bates, 1892: 302.

Geographic Distribution: ORR - India (Assam: Sadiya; Arunachal Pradesh: Noa Dihing), Myanmar (Kachin), PAR - China (Yunnan).

5. *Craspedophorus hexagonus* (Chaudoir, 1861)

Andrewes, 1930: 135. Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 329; Lobl & Lobl, 2017: 638.

= *Epicosmus hexagonus* Chaudoir, 1861: 338; id. 1878: 114.

Geographic Distribution: ORR - India (Indes orientales), PAR - India (Uttarakhand: Dehra Dun).

6. *Craspedophorus hilaris* (Laferte-Senectere, 1851)

Andrewes, 1921: 170; id. 1924: 588; id. 1930: 135; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Kirschenhofer, 2011: 47; Hackel & Farkac, 2012: 77; Hackel & Kirschenhofer, 2014: 276 & 303; Manthen & Hegde, 2018: 206.

= *Isotarsus hilaris* Laferte-Senectere, 1851: 221.

= *Epicosmus hilaris* Chaudoir, 1861: 345; id. 1878: 110.

Geographic Distribution: ORR - India (West Bengal; Maharashtra: Pune).

7. *Craspedophorus incostatus* Kirschenhofer, 2000

Kirschenhofer, 2000: 349; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 276 & 349.

Geographic Distribution: PAR - India (Uttarakhand: Ramgarh).

8. *Craspedophorus mandarinellus* (Bates, 1892) (Image 2b) *

Andrewes, 1921: 187; Andrewes, 1930: 135; Baehr, 2003: 447; Xie & Yu, 1991: 170; Kirschenhofer, 2000: 324; Lorenz, 2005: 321; Kirschenhofer, 2011: 40, 47; Hackel & Farkac, 2012: 77; Hackel & Kirschenhoffer, 2014: 309 ; Fedorenko, 2016: 30; Lobl & Lobl, 2017: 638.

= *Epicosmus mandarinellus* Bates, 1892: 299.

= *Craspedophorus vietnamensis* Kirschenhofer, 2000: 339; Hackel & Farkac, 2012: 77; Fedorenko, 2016: 30.

= *Craspedophorus freudeellus* Hackel & Kirschenhofer, 2014: 299; Fedorenko, 2016: 30.

Specimens examined (n= 2): SJC-ZO-CAR008,

16.x.2016, 1 ex, India: Koorachundu, 11.538˚N, 75.845˚E, 95m, light trap, coll. Jithmon V.A.; 10.ii.2017, 1 ex, Peruvannamoozhi, 11.596˚N, 75.823˚E, 128m, light trap, coll. Jithmon V.A.

Geographic Distribution: ORR - India (Karnataka: Shivamogga; Kerala: Koorachundu, Peruvannamoozhi), Myanmar (Kachin, Nam Tamai, Tenasserim), Vietnam (Dongnai), PAR - China (Guangxi, Guangdong, Yunnan).

9. *Craspedophorus pubiger* (Chaudoir, 1861) #

Andrewes, 1930: 136; Kirschenhofer, 2000: 324; Lorenz, 2005: 321; Hackel & Farkac, 2012: 79; Hackel & Kirschenhofer, 2014: 354; Fedorenko, 2016: 4.

= *Epicosmus pubiger* Chaudoir, 1861: 337; id. 1878: 122.

Geographic Distribution: ORR - 'Indes orientales'

10. *Craspedophorus assamensis* Hackel & Kirschenhofer, 2014

Hackel & Kirschenhofer, 2014: 341.

Geographic Distribution: ORR - India (Assam).

11. *Craspedophorus sikkimensis* Hackel & Kirschenhofer, 2014

Hackel & Kirschenhofer, 2014: 337; Lobl & Lobl, 2017: 638.

Geographic Distribution: PAR - India (Sikkim: Rabong).

12. *Craspedophorus maharashtraensis* Kirschenhofer, 2011

Kirschenhofer, 2011: 43; Hackel & Farkac, 2012: 77; Hackel & Kirschenhofer, 2014: 308 Manthen & Hegde, 2018: 207.

Geographic Distribution: ORR - India (Maharashtra: Panchgani).

13. *Craspedophorus cereus* (Macleay, 1825)

Andrewes, 1919: 135; id. 1930: 134; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 80; Hackel & Kirschenhofer, 2014: 73; Hackel, 2015: 238; Fedorenko, 2016: 31; Manthen & Hegde, 2018: 206.

= *Panagaeus cereus* Macleay, 1825: 12.

= *Craspedophorus buruensis* Hackel & Kirschenhofer, 2014: 295.

= *Craspedophorus formosanus* Jedlicka, 1939: 1; id. 1965: 5; Habu, 1978: 71; Kirschenhofer, 2000: 330; Hackel & Farkac, 2012: 77; Hackel & Kirschenhofer, 2014: 298.

= *Craspedophorus chinensis* Jedlicka, 1965: 5; Kirschenhofer, 2000: 331; Hackel & Kirschenhofer, 2014: 297.

= *Craspedophorus saddlepeakensis* Kirschenhofer, 2011: 45; Hackel & Kirschenhofer, 2014: 319.

= *Craspedophorus laosensis* Kirschenhofer, 2012: 231; Hackel & Kirschenhofer, 2014: 305.

= *Craspedophorus punensis* Hackel & Kirschenhofer, 2014: 318.

= *Craspedophorus batesi* Hackel, 2014: 3.

= *Craspedophorus maculatus*: Hackel & Kirschenhofer, 2014: 307.

= *Craspedophorus philippinus* Jedlicka, 1939: 1.

Geographic Distribution: ORR - India (Maharashtra: Mumbai, Pune; Andaman Is.), Laos, Vietnam, Indonesia (Java, Buru), PAR - southern China, southern Japan, IAR - Philippines.

14. *Craspedophorus bisemilunatis* (Xie & Yu, 1991).

Xie & Yu, 1991: 161; Lobl & Lobl, 2017: 638.

= *Craspedophorus dehradunensis* Hackel & Kirschenhofer, 2014: 281.

= *Dischissus dehradunensis* Kirschenhofer, 2000: 355; Lorenz, 2005: 320; Hackel & Farkac, 2012: 84.

= *Dischissus guangdongensis* Hackel & Kirschenhofer, 2014b: 282.

= *Dischissus sapaensis* Kirschenhofer, 1994: 1044.

Geographic Distribution: PAR - India (Uttarakhand: Dehra Dun), China (Guangdong, Guizhou, Guangxi, Yunnan).

15. *Craspedophorus microspilotus* Andrewes, 1924

Andrewes, 1924: 131; id. 1930: 136; id. 1933: 1; Kirschenhofer, 2000: 324, 330; Lorenz, 2005: 321; Kirschenhofer, 2011: 47; Hackel & Farkac, 2012: 77; Hackel & Kirschenhofer, 2014: 314.

Geographic Distribution: ORR - Sri Lanka (Nuwara Eliya).

16. *Craspedophorus halyi* Andrewes, 1923

Andrewes, 1923: 230; id. 1930: 135; Kirschenhofer, 2000: 323; Lorenz, 2005: 320; Hackel & Farkac, 2012: 78; Hackel & Kirschenhofer, 2014: 302.

Geographic Distribution: ORR - Sri Lanka (Niroddumunai).

17. *Craspedophorus lankaensis* Hackel & Kirschenhofer, 2014 #

Hackel & Kirschenhofer, 2014: 351.

Geographic Distribution: ORR - Sri Lanka

Genus 2. *Adischissus* Fedorenko, 2015

Fedorenko, 2015: 273; Lobl & Lobl, 2017: 637.

1. *Adischissus notulatus* (Fabricius, 1801) (Image 2c) *

Fedorenko, 2015: 277; Lobl & Lobl, 2017: 637.

= *Carabus notulatus* Fabricius, 1801: 201; Hope, 1838: 90; Schaum, 1847: 48; id. 1853: 432; Motschulsky, 1855: 70;

= *Dischissus notulatus* Andrewes, 1921: 162; id. 1930: 153; Lorenz, 2005: 322.

= *Dischissus longicornis* (*Craspedophorus*) Schaum, 1863: 84; Chaudoir, 153; Bates, 1892: 303; Heller, 1916: 276; Andrewes, 1927: 108.

= *Dischissus sumatranus (Panagaeus*) Dohrn, 1891: 253 and 254; Andrewes, 1922: 246.

= *Dischissus tibialis* Andrewes, 1933:

Specimens examined (n=2): SJC-ZO-CAR009, 15.vi.2015, 1 ex, India: Koorachundu, 11.538˚N, 75.845˚E, 95m, hand picking, coll. Jithmon V.A.; 10.ii.2017, 1 ex, Peruvannamoozhi, 11.596˚N, 75.823˚E, 128m, Light trap, coll. Jithmon V.A.

Geographic Distribution: ORR - India (West Bengal: Kolkata; Goa: Margo, Calangut; Tamil Nadu: Nilgiri hills; Kerala: Koorachundu, Peruvannamoozhi), Myanmar (Insein, Toungoo, Rangoon, Kawkareik), Vietnam (Annam, Dongnai, Lam Dong, Binh Duong, Tay Ninh, Phuoc Vinh), Malaysia (Kuala Lumpur), Singapore, PAR – India (Sikkim: Namsoo; Uttarakhand: Almora), China (Anhui, Foochow, Guangdong, Guizhou, Guangxi, Hunan, Shanghai), Hongkong.

2. *Adischissus quadrinotatus* (Motchulsky, 1865)

Fedorenko, 2015: 277; Lobl & Lobl, 2017: 637.

= *Peranomus quadrinotatus* Motschulsky, 1864: 333;

= *Dischissus quadrinotatus* Bates, 1873: 244; Chaudoir, 1878: 152; Andrewes, 1928: 22; id. 1930: 153; Lorenz, 2005: 322.

Geographic Distribution: ORR - India (Karnataka: Shivamogga: Sringeri), Vietnam (Annam), PAR - Japan.

Genus 3. *Microcosmodes* Strand, 1936

Strand, 1936: 169; Lorenz, 2005: 322; Fedorenko, 2015: 278; Lobl & Lobl, 2017: 639.

= *Microshemus* Andewes, 1940: 536.

= *Microcosmus* Chaudoir, 1878: 139.

1. *Microcosmodes flavopilosus* (Laferte-Senectere, 1851)

Lorenz, 2005: 322; Lobl & Lobl, 2017: 639.

= *Isotarsus flavopilosus* Laferte-Senectere, 1851: 222; Chaudoir, 1861: 348; id. 1878: 142; Bates, 1873: 243.

= *Epicosmus transversus* Motschulsky, 1864: 332; Andrewes, 1928: 11.

Geographic Distribution: ORR - India (Delhi: Pusa; West Bengal: Kolkata; Maharashtra: Nagpur, Mumbai, Bandra; Tamil Nadu: Chennai, Coimbatore; Lakshadweep: Minikoi; Gopkuda), Bangladesh (Dhaka, Sardah), Indonesia (Sumatra), Vietnam (Tongking), PAR – India (Uttarakhand: Dehra Dun), Nepal, Japan, China, Taiwan (Formosa).

2. *Microcosmodes elegans* (Dejean, 1826) #

Fedorenko, 2015: 278; Lobl & Lobl, 2017: 639.

= *Panagaeus elegans* Dejean, 1826: 290.

= *Isotarsus elegans* Laferte-Senectere, 1851: 221; Schaum, 1853: 432.

= *Craspedophorus elegans* Andrewes, 1921: 162; id. 1924: 23; id. 1930: 134; Kirschenhofer, 2000: 323, 347; Lorenz, 2005: 320; Kirschenhofer, 2011: 47; Hackel & Farkac, 2012: 77; Hackel & Kirschenhofer, 2014: 276 & 284.

Geographic Distribution: ORR - Throughout India, Sri Lanka. PAR – Nepal, Pakistan.

Genus 4. *Euschizomerus* Chaudoir, 1850

Chaudoir, 1850: 413; Lacordaire, 1854: 212; Chaudoir, 1878: 157; Andrewes, 1930: 165; Kirschenhofer, 2000: 359; Lorenz, 2005: 322; Hackel & Farkac, 2012: 86; Lobl & Lobl, 2017: 639.

= *Euschiromerus* Chaudoir, 1869: (in error)

= *Praeschizomerus* Kirschenhofer, 2000: 359. (Subgenus).

1. *Euschizomerus aeneus* Chaudoir, 1869

Chaudoir, 1869: 118; id. 1878: 160; Bates, 1892: 303; Andrewes, 1930: 165; Lorenz, 2005: 322; Hackel & Farkac, 2012: 86.

Geographic Distribution: ORR - Bangladesh (Dhaka), Myanmar (Taik Kyi, Pegu).

2. *Euschizomerus denticollis* (Kollar, 1836) (Image 2e) *

Andrewes, 1930: 165; Lorenz, 2005: 322; Hackel & Farkac, 2012: 86.

= *Panagaeus denticollis* Kollar, 1835: 334; Chaudoir, 1878: 161.

Specimens examined (n= 1): SJC-ZO-CAR010, 10.v.2017, India: Ernakulam, Kalady, 17m, 10.166˚N, 76.438˚E, hand picking, coll. Divya M.

Geographic Distribution: ORR - India (West Bengal: Kolkata, Kerala: Ernakulam: Kalady), Sri Lanka.

3. *Euschizomerus devagiriensis* Jithmon & Sabu, 2018 (Image 2d) *

Jithmon & Sabu, 2018: 362.

Specimens examined (n= 1): SJC-ZO-CAR011,

Table 1. Geographic distribution pattern of the Dryptinae and Panagaeinae species recorded from India.

	Species	Region
Subfamily Dryptinae		
I.	**Tribe Dryptiini Bonelli, 1810**	
	Drypta Latreille, 1796	
1.	*Drypta aenipes* Wiedemann, 1823	Oriental
2.	*Drypta aetheria* Andrewes, 1936	Oriental
3.	*Drypta argillacea* Andrewes, 1924	Oriental, Palearctic
4.	*Drypta cyanopus* Andrewes, 1936	Oriental
5.	*Drypta crassiuscula* Chaudoir, 1861	Palearctic
6.	*Drypta flavipes* Wiedemann, 1823	Oriental, Palearctic
7.	*Drypta lineola* Macleay, 1825	Oriental
8.	*Drypta longicollis* Macleay, 1825	Oriental
9.	*Drypta siderea* Bates, 1892	Oriental, Palearctic
	Dendrocellus Schmidt Geobel, 1846	
10.	*Dendrocellus coelestinus* (Klug, 1834)	Oriental, Palearctic
11.	*Dendrocellus confusus* (Hansen, 1968)	Oriental, Palearctic
12.	*Dendrocellus geniculatus* (Klug, 1834)	Oriental, Palearctic, Indo- Australian
13.	*Dendrocellus inexpectus* Liang & Kavanaugh, 2007	Oriental
14.	*Dendrocellus nepalensis* (Hope, 1831)	Oriental, Palearctic
15.	*Dendrocellus rugicollis* Chaudoir, 1861	Oriental, Palearctic
16.	*Dendrocellus unidentatus* (Macleay, 1825)	Oriental, Palearctic
II.	**Tribe Zuphini Bonelli, 1810**	
	Paraleleupidia Basilewsky, 1951	
17.	*Paraleleupidia linearis* Baehr, 1990	Oriental
18.	*Paraleleupidia loebli* Mateu, 1981	Oriental
19.	*Paraleleupidia besucheti* Mateu, 1981	Oriental
	Gunvorita Landin, 1955	
20.	*Gunvorita besucheti* Baehr, 1998	Oriental
21.	*Gunvorita depressipennis* Baehr, 1998	Oriental
22.	*Gunvorita elegans* Landin, 1955	Oriental, Palearctic
23.	*Gunvorita indica* Darlington, 1968	Oriental
24.	*Gunvorita inermis* Baehr, 1998	Oriental
25.	*Gunvorita laeviceps* Baehr, 1998	Oriental
26.	*Gunvorita minor* Baehr, 1998	Oriental
27.	*Gunvorita ovaliceps* Baehr, 1998	Oriental
	Agastus Schmidt-Goebel, 1846	
28.	*Agastus lineatus* Schmidt-Goebel, 1846	Oriental, Palearctic, Indo-Australian
	Zuphium Latreille, 1806	
29.	*Zuphium dabreui* Andrewes, 1922	Oriental
30.	*Zuphium erebeum* Andrewes, 1923	Oriental
31.	*Zuphium erythrocephalum* Chaudoir, 1862	Oriental
32.	*Zuphium indicum* Andrewes, 1922	Oriental
33.	*Zuphium modestum* Schmidt-Goebel, 1846	Oriental
34.	*Zuphium olens* (Rossi, 1790)	Oriental, Palearctic
	Metazuphium Mateu, 1992	
35.	*Metazuphium spinangulus* Mateu, 1992	Oriental
	Parazuphium Jeannel, 1942	
36.	*Parazuphium inconspicuum* (Schmidt-Goebel, 1846)	Oriental, Indo-Australian
	Planetes Macleay, 1825	
37.	*Planetes bimaculatus* Macleay, 1825	Oriental, Palearctic
38.	*Planetes indicus* Andrewes, 1922	Oriental
39.	*Planetes ruficeps* Schaum, 1863	Oriental, Palearctic
40.	*Planetes ruficollis* (Nietner, 1857)	Oriental
41.	*Planetes simplex* Bates, 1886	Oriental
III.	**Tribe Galeritini Leconte, 1853**	
	Galerita Fabricius, 1801	
42.	*Galerita batesi* Andrewes, 1923	Oriental
43.	*Galerita indica* Chaudoir, 1861	Oriental
44.	*Galerita orientalis* Schmidt-Goebel, 1846	Oriental, Palearctic
45.	*Galerita ruficeps* Chaudoir, 1861	Palearctic
Subfamily Panagaeinae		
I.	**Tribe Peliciini Chaudoir, 1880**	
	Ardistomopsis Straneo & Ball, 1989	
1.	*Ardistomopsis andrewesi* Straneo & Ball, 1989	Oriental
2.	*Ardistomopsis batesi* Straneo & Ball, 1989	Oriental
3.	*Ardistomopsis marginicollis* (Schaum, 1864)	Oriental
4.	*Ardistomopsis myrmex* (Andrewes, 1923)	Oriental
5.	*Ardistomopsis ovicollis* (Bates, 1886)	Oriental
II.	**Tribe Panagaeini Bonelli, 1810**	
	Craspedophorus Hope, 1838	
6.	*Craspedophorus angulatus* (Fabricius, 1781)	Oriental
7.	*Craspedophorus bifasciatus* (Castelnau, 1835)	Oriental
8.	*Craspedophorus geniculatus* (Wiedemann, 1823)	Oriental
9.	*Craspedophorus gracilipes* (Bates, 1892)	Oriental, Palearctic
10.	*Craspedophorus hexagonus* (Chaudoir, 1861)	Oriental, Palearctic
11.	*Craspedophorus hilaris* (Laferte-Senectere, 1851)	Oriental
12.	*Craspedophorus incostatus* Kirschenofer, 2000	Palearctic
13.	*Craspedophorus mandarinellus* (Bates, 1892)	Oriental, Palearctic
14.	*Craspedophorus pubiger* (Chaudoir, 1861)	Oriental
15.	*Craspedophorus assamensis* Hackel & Kirschenhofer, 2014	Oriental
16.	*Craspedophorus sikkimensis* Hackel & Kirschenhofer, 2014	Palearctic
17.	*Craspedophorus maharashtraensis* Kirschenhofer, 2011	Oriental
18.	*Craspedophorus cereus* (Macleay, 1825)	Oriental, Palearctic, Indo-Australian
19.	*Craspedophorus bisemilunatis* (Xie & Yu, 1991)	Palearctic
20.	*Craspedophorus microspilotus* Andrewes, 1924	Oriental
21.	*Craspedophorus halyi* Andrewes 1923	Oriental
22.	*Craspedophorus lankaensis* Hackel & Kirchenhofer, 2014	Oriental
	Adischissus Fedorenko, 2015	
23.	*Adischissus notulatus* (Fabricius, 1801)	Oriental, Palearctic
24.	*Adischissus quadrinotatus* (Motchulsky, 1865)	Oriental, Palearctic

	Species	Region
	Microcosmodes Strand, 1936	
25.	*Microcosmodes flavopilosus* (Laferte-Senectere, 1851)	Oriental, Palearctic
26.	*Microcosmodes elegans* (Dejean, 1826)	Oriental, Palearctic
	Euschizomerus Chaudoir, 1850	
27.	*Euschizomerus aeneus* Chaudoir, 1869	Oriental
28.	*Euschizomerus denticollis* (Kollar, 1836)	Oriental
29.	*Euschizomerus devagiriensis* Jithmon & Sabu, 2018	Oriental
30.	*Euschizomerus indicus* Jedlicka, 1956	Oriental
31.	*Euschizomerus metallicus* Harold, 1879	Oriental
	Trichisia Motschulsky, 1864	
32.	*Trichisia morio* (Laferte-Senectere, 1851)	Oriental, Palearctic
33.	*Trichisia violacea* Jedlicka, 1935	Oriental, Palearctic, Indo-Australian

25.v.2017, India: Kozhikode, Devagiri, 11.265˚N, 75.835˚E, 45m, hand picking, coll. Divya M.

Geographic Distribution: ORR - India (Kerala: Kozhikode: Devagiri).

4. *Euschizomerus indicus* Jedlicka, 1956 (Image 2f) *

Jedlicka, 1955: 207; Lorenz, 2005: 322; Hackel & Farkac, 2012: 86.

= *Euschizomerus schuhi* Kirschenhofer, 2000: 360; Hackel & Farkac, 2012: 87.

Specimens examined (n= 6): SJC-ZO-CAR012, 18.iv.2017, 4 ex, India: Kozhikode (East Devagiri), 11.265˚N, 75.835˚E, 45m, light, coll. Divya M.; 05.x.2016, 2 ex, Govindapuram, 11.233˚N, 75.8˚E, 11m, UV light, coll. Anju.

Geographic Distribution: ORR - India (Maharashtra: Mumbai: Lonvala; Goa: Benaulin beach; Kerala: Kozhikode: East Devagiri, Govindapuram).

5. *Euschizomerus metallicus* Harold, 1879 #

Harold, 1879: 331; Vuillet, 1912: 19; Andrewes, 1927: 109; Andrewes, 1930: 165; Lorenz, 2005: 322; Hackel & Farkac, 2012: 86.

Geographic Distribution: ORR - "Indes orientales", Myanmar (Karen Hills, Rangoon, Tenasserim); Cambodia.

Genus 5. *Trichisia* Motschulsky, 1864

Motschulsky, 1864: 331; Chaudoir, 1878: 164; Lorenz, 2005: 322; Hackel & Farkac, 2012: 98; Lobl & Lobl, 2017: 640.

1. *Trichisia morio* (Laferte-Senectere, 1851)

Andrewes, 1930: 350; Lorenz, 2005: 323; Hackel & Farkac, 2012: 98.

= *Isotarsus morio* Laferte-Senectere, 1851: 221; Chaudoir, 1861: 348; Id. 1878: 165; Gardner, 1927: 66.

= *cyanescens* Motschulsky, 1864: 332; Andrewes, 1928: 24.

Geographic Distribution: ORR - India (Assam: Jorhat; Delhi: Pusa), Bangladesh (Dhaka), Indonesia (Sumatra), PAR - India (Uttarakhand: Dehra Dun), Pakistan (Rawalpindi).

2. *Trichisia violacea* Jedlicka, 1935 #

Jedlicka, 1935: 2; Lorenz, 2005: 323; Hackel & Farkac, 2012: 98.

Geographic Distribution: ORR - India, IAR - Philippines; PAR - China.

DISCUSSION

Out of the 45 Dryptinae species recorded from India, 24 species (53.3%) are endemic to the Indian subcontinent, with two species endemic to the Indian palaerctic region (PAR) and 22 species endemic to the Indian Oriental region (ORR). Among the 21 species endemic to the Indian ORR region, six species (*Paraleleupidia linearis*, *P. loebli*, *P. besucheti*, *Zuphium erebeum*, *Metazuphium spinangulus*, and *Planetes simplex*) are endemic to the Western Ghats & Sri Lanka hotspot of biodiversity, two species (*Gunvorita depressipennis* and *G. minor*) are endemic to the Indo Burma hotspot of biodiversity and two species (*Drypta crassiuscula* and *Galerita ruficeps*) are endemic to the Himalaya hotspot of biodiversity. Six species endemic to the Western Ghats & Sri Lanka hotspot of biodiversity (*Paraleleupidia linearis*, *P. loebli*, *P. besucheti*, *Zuphium erebeum*, *Metazuphium spinangulus*, and *Planetes simplex)* could be remnants of the ancient Indian fauna existed on Indian part of Gondwanaland which broke away from Gondwana land along with Madagascar in the early Cretaceous (about 160 million years ago) leading to the formation of Indian subcontinent (Mani 1974; Courtillot et al. 1988; Sabu et al. 2008).

Out of the 33 Panagaeinae species recorded from Indian subcontinent, 20 species (60.6%) are endemic to the Indian subcontinent with genus *Ardistomopsis* with five species. Two species (*Craspedophorus sikkimensis*, *Craspedophorus incostatus*) reported only from Indian PAR region, 17 Panagaeinae species reported only from Indian ORR region and *Craspedophorus hexagonus* reported from both Indian ORR and PAR regions. Among the 20 Indian subcontinent endemic species, seven species (*Ardistomopsis andrewesi*, *A. myrmex, A. ovicollis*, *Craspedophorus maharashtraensis*, *C. microspilotus*, *C.*

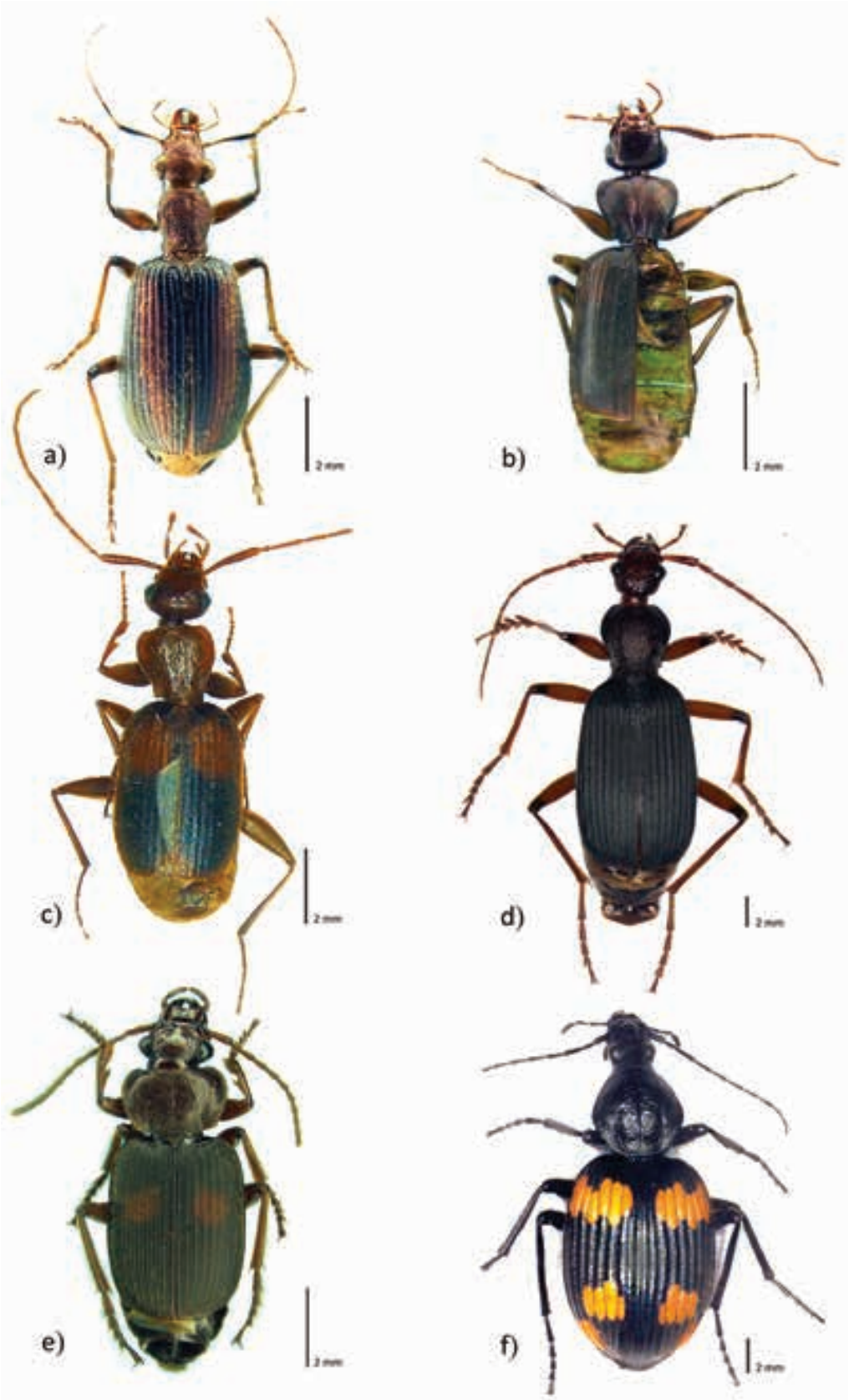

Image 1. Habitus of Dryptinae and Panagaeinae species collected: a—*Drypta lineola* Maclaey, 1825 | b—*Zuphium dabreui* Andrewes, 1922 | c—*Z. erythrocephalum* Chaudoir, 1862 | d—*Galerita orientalis* Schmidt-Geobel, 1848 | e—*Planetes ruficeps* Schaum, 1863 | f—*Craspedophorus angulatus* (Fabricius, 1781). © Jithmon V.A. & Akhil S.V.

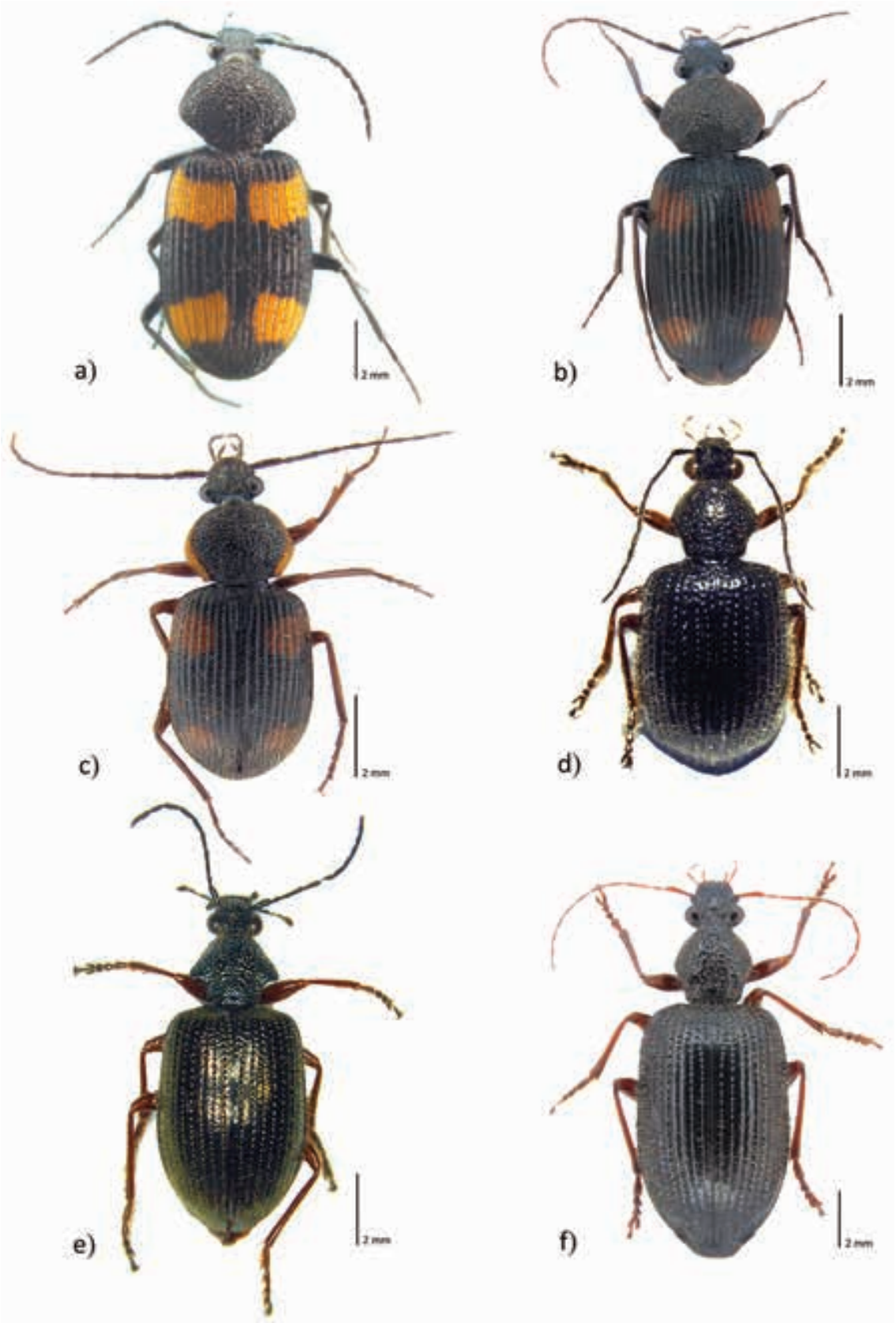

Image 2. Habitus of Panagaeinae species collected: a—*Craspedophorus bifasciatus* (Castelnau, 1835) | b—*C. mandarinellus* Bates, 1892 | c—*Adischissus notulatus* (Fabricius, 1801) | d—*Euschizomerus devagiriensis* Jithmon & Sabu, 2018 | e—*E. denticollis* Kollar, 1836 | f—*E. indicus* Jedlicka, 1955. © Jithmon V.A. & Akhil S.V.

halyi and *C. lankaensis*) are endemics to the Western Ghats and Sri Lanka Hotspot of biodiversity and two species, (*Craspedophorus sikkimensis*, *Craspedophorus incostatus*) endemics to Himalaya hotspot of biodiversity. Remaining 11 Indian subcontinent endemic species of subfamily Panagaeinae have a wide range distribution across India. Seven species (*Ardistomopsis andrewesi*, *A. myrmex, A. ovicollis*, *Craspedophorus maharashtraensis*, *C. microspilotus*, *C. halyi* and *C. lankaensis*) recorded only from the Western Ghats and Sri Lanka are likely to be representative of the Gondwana remnants that got isolated in Indian subcontinent following the separation of the subcontinent.

Present study provides the distribution patterns and literature details of 45 Dryptinae and 33 Panagaeinae species reported from the Indian subcontinent. Primary aim of the present effort was to prepare a checklist with regional distribution patterns and reference details which will make it easier for taxonomists and will lead to more taxomonic works across the Indian subcontinent. Distribution records show poor representation of both the groups from Central and north western regions of the Indian subcontinent indicating the need for further taxonomic explorations. Additionally, our analysis revealed the presence of a large number of species endemic to the Indian mainland, local endemics (endemic to the hotspots of biodiveristy in India: the Western Ghats & Sri Lanka hotspot of biodiversity, the Indo Burma hotspot of biodiversity and the Himalaya hotspot of biodiversity), species confined to the PAR or ORR regions of Indian mainland and a few ancient species with possible Gondwana linkages which will attract the attention of evolutionary and conservation biologists also to these two lesser known subfamilies.

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Mantids (Insecta: Mantodea) of Uttar Pradesh, India

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Abstract: Several surveys of mantid fauna from eastern Uttar Pradesh, India were carried out during the period 2017–2019. The collected materials include 21 species of 17 genera from six families and nine subfamilies. The Family Mantidae contributed the highest numbers of mantid fauna. In total, 10 species of mantis are reported for the first time from the present Uttar Pradesh (after division of the state) while *Tenodera costalis* (Blanchard, 1853) is recorded for the first time from the country.

Keywords: Insecta, Mantidae, new country record.

Hindi: सन 2017 से 2019 की अवधि के दौरान पूर्वी उत्तर प्रदेश, भारत में मैंटिड जीवों के लिए कई सर्वेक्षण किए गए । सर्वेक्षण के दौरान एकत्रित सामग्रियों में छः कुलों और नौ उपकुलों से 17 वंशों की कुल 21 प्रजातियां प्राप्त हुई । मैनटीडी कुल में सबसे अधिक संख्या में मैंटिड जोवों ने योगदान दिया। कुल मिलाकर, वर्तमान उत्तर-प्रदेश (राज्य के विभाजन के बाद) राज्य से पहली बार मैंटिस की 10 नई प्रजातियां रिकॉर्ड की गई हैं, जबकि टेनोडेरा कोस्टेलिस (ब्लांकार्ड, 1853) देश में पहली बार उत्तर-प्रदेश से दर्ज की गई है।

Editor: Anonymity requested.

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Author contributions: RSY involved in survey, fauna collection, captured photographs and identification as well as write up of the manuscript. GPP participated in design of the research, supervision of research activities and overview the manuscript.

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INTRODUCTION

Mantids are one of the important groups of predatory insects of different agroecosystems. Mantids are also called preying mantids due to their preying ability. They are sometime confused with the mantisflies of the order Neuroptera. Mantids are grouped in the superorder Dictyoptera because of their more closeness to cockroaches and termites while forelegs of mantids are raptorial type which is not identical to the forelegs of cockroaches and termites. Globally, 2,384 species under 434 genera of 15 families are known (Ehrmann & Roy 2002) while Otte et al (2020) listed 2,400 species from 430 genera; in which more than 169 species, 71 genera, and 11 families are known from India of which 60 species are endemic to the country (Mukherjee et al. 2014). Mantids are a key agent of natural and biological control in most of the terrestrial ecosystems due to their sophisticated behaviour and modifications. They are easily identified by their raptorial forelegs, triangular head, visible eyes, and large cerci.

Probably, first taxonomic work on mantids was initiated by Linnaeus (1758) while in India, remarkable contribution to mantids came in light when the Wood-Mason joined as director of Indian Museum, Kolkata (Yadav 2017) and published a Catalogue of the Mantodea of Indian Museum collections by Wood-Mason (1889 & 1891). Subsequently Bolivar (1899) and Werner (1931, 1933 & 1935) contributed to the Indian mantids. Kirby (1904) has created a synonimic catalogue of the 82 species of mantids from India whereas, Nadkerni (1965) amassed 55 more mantids. Some notable works on the taxonomy and distribution of mantids were done by Mukherjee & Hazra (1983), Mukherjee et al. (1992, 1995, 2014, 2015, 2017), Mukherjee & Shisodia (1999 & 2000), Chaturvedi & Hedge (2000), Rao et al. (2005), Sureshan et al. (2006), Jadhav et al. (2006), Mukherjee & Hazra (2007), Vyjayandi (2007), Jadhav (2008), Chandra (2009), Sureshan (2009), Sureshan & Sambath (2009), Mukherjee & Ghate (2010), Vyjayandi et al. (2010), Ghate et al. (2012), and Chatterjee & Mukherjee (2013). The most remarkable work on Indian mantids was presented by Mukherjee et al. (1995) which was more consolidated account on this group till date. Uttar Pradesh has remained less studied for Mantodea. More recently Yadav et al (2018) have recorded some mantids from this state. More diversity of the mantids remain unexplored. Therefore, we explored the mantid fauna extensively from Uttar Pradesh after the division of Uttarakhand.

Table 1. Coordinates of the survey sites.

	Site	Coordinates
1	Karmahari, Ghazipur	25.3514°N & 82.6481°E
2	Chahaniya, Chandauli	25.4189°N & 83.2118°E
3	Chakka bandh Dam, Ghazipur	25.4204°N & 83.5574°E
4	Rohuna, Ghazipur	25.4159°N & 83.5598°E
5	Maujhi, Chandauli	25.4255°N & 83.5580°E
6	Mohammadabad, Ghazipur	25..6168°N & 83.7531°E
7	Dehariya, Ghazipur	25.2991°N & 83.6562°E

MATERIALS AND METHODS

The present exploration was made from a series of surveys of the several locations in Uttar Pradesh, India from 2017 to 2019. The study sites were located in different areas of eastern Uttar Pradesh (Table 1). The mantids were collected by sweeping net, light trap, and hand-picking methods. After photography, most of the mantids were released to avoid the loss of biodiversity issue. The collections were made during morning and night hours, i.e., 07.00–10.00 h and 20.00–22.00 h, respectively. Some of the collected materials were killed in the killing bottle containing ethyle acetate. Subsequently, materials were cleaned with hair brush, pinned and relaxed (as per need) on the handmade stretching board of thermocol. It was kept for more than 60–72 hours for drying to avoid spoilage of the specimens. The identification was made based on the morphological and genitalic features. The specimens collected were deposited in the Department of Agricultural Entomology, R.M.D. College and Research Station, Ambikapur, Chhattisgarh, India. The classifications were made according to Mukherjee et al. (2014). The coordinates of the survey sites are presented in Table 1.

RESULTS

Biodiversity of surveyed mantids from Uttar Pradesh are presented here in figure 1 and their checklist is as below.

Systematic checklist of the mantids studied from Uttar Pradesh

Systematic account

Class: Insecta

Order: Mantodea Latreille, 1802

A. Family: Hymenopodidae Giglio-Tos, 1915

Subfamily: Acromantinae Giglio-Tos, 1915

Tribe: Anaxarchini Giglio-Tos, 1919

1. *Euantissa pulchra* Fabricius, 1787*

2. *Odontomantis montana* Giglio-Tos, 1915*
Tribe: Hymenpodini Giglio-Tos, 1915
3. *Creobroter apicalis* Saussure, 1869*
Tribe: Acromantini Runner De Wattenwyl, 1893
4. *Ephestiasula pictipes* (Wood-Mason, 1879)**
5. *Hestiasula brunneriana* Saussure, 1871*

B. Family: Liturgusidae Giglio-Tos, 1915
Subfamily: Listurgusinae Giglio-Tos, 1915
Tribe: Humbertiellini Brunner De Wattenwyl, 1893
6. *Humbertiella ceylonica* Saussure, 1869
7. *Humbertiella similis* Giglio-Tos, 1917

C. Family: Tarachodidae Handlirsch, 1930
Subfamily: Schizocephalinae Saussure, 1869
8. *Schizocephala bicornis* (Linné, 1758)**

D. Family: Mantidae Latreille, 1802
Subfamily: Amelinae Westwood, 1889
9. *Amantis saussurei* (Bolivar, 1897)*
10. *Elmantis trincomaliae* (Saussure, 1869)*
Subfamily: Tenoderinae Brunner De Wattenwyl, 1893
11. *Tenodera fasciata* (Oliver,1792)*
12. *Tenodera costalis* (Blanchard, 1853) ¶
13. *Hierodula coarctata Saussure,* 1869
Subfamily: Mantinae Burmeister, 1838
14. *Mantis religiosa religiosa* Linnaeus, 1758**
15. *Statilia maculata continentalis* Werner, 1935
16. *Statilia nemoralis* (Saussure, 1870)

E. Family: Toxoderidae Saussure, 1869
Subfamily: Oxyothespinae Giglio-Tos, 1916
17. *Cheddikulama straminea* Henry, 1932**
Subfamily: Toxoderinae Saussure, 1869
18. *Aethalochroa ashmoliana* (Westwood, 1841)*
19. *Toxoderopsis taurus* Wood-mason, 1889*

F. Family Empusidae Burmeister, 1838;
Subfamily Empusinae Burmeister, 1838
20. *Empusa (Empusa) guttula* (Thunberg, 1815)
21. *Empusa spinosa* Krauss, 1902 *

Note: Asterisk marks (*), (**) and (¶) indications are indicated as species firstly recorded from Uttar Pradesh, probably earlier recorded from Uttar Pradesh and species first time recorded from country respectively.

Family: Hymenopodidae Giglio-Tos, 1915
Subfamily: Hymenopodinae, Giglio-Tos, 1915
Tribe: Anaxarchini Giglio-Tos, 1919

***Euantissa pulchra* Fabricius, 1787 (Image 1)**

1927. *Euantissa pulchra* Gigilio-Tos, Das Tierriech 50 :541.

2002. *Euantissa pulchra* Ehrmann, Mantodea der Welt 244.

2014. *Euantissa pulchra* Mukherjee et al. *Priamus 30: 7.*

Materials examined: RMDCRS 001-002, 1 male, 1 female, 21.x.2017, Udharanpur (Ghazipur) Uttar Pradesh, India; on *Thevetia peruviana*, coll. R.S. Yadav.

Diagnosis: Vertex without protuberance; eyes oblong; pronotum broad, fore femur simple with four sharp-long external and four discoidal spines; mid and hind legs have without lobes; wings brightly coloured, longer than abdomen, with dark line along the outer border (Vyjayandi 2007).

Distribution: India (Andhra Pradesh, Tamil Nadu, West Bengal, & Uttar Pradesh (new record)), China, and Sri Lanka (Mukherjee et al. 2014).

Measurement: Body length 25mm

Remark: The specie is more common in bushes but not frequent in my collection.

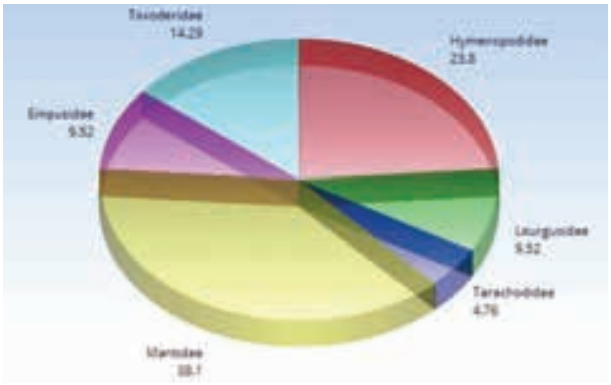

Figure 1. Biodiversity of mantids of Uttar Pradesh. Relative abundance (in percentage)

***Odontomantis montana* Giglio-Tos, 1915 (Image 2 & 3)**

1915. *Odontomantis montana* Giglio-Tos. Bull. Soc. Ent. Ital. 46: *100.*

2002. *Odontomantis montana* Ehrmann. Mantodea der Welt 244.

2014. *Odontomantis montana* Mukherjee et al. Priamus 30: 8.

Materials examined: RMDCRS 003, 1female, 09.ix.2017, Chakka bandh Dam (Ghazipur) Uttar Pradesh, India; on broad leaved shrub, coll. R.S. Yadav.

Diagnosis: Vertex without protuberance; frontal sclerite narrowed in the form of a groove, superior border wavy, a little arched in the middle; inferior border with a slightly elevated ridge; margin of pronotum bearing small tubercular spines. In forelegs external spines of femora blackish near their tips and proximal two of them closer, tibiae with 10

internal spines of same colour (Sureshan et al. 2006).

Distribution: India (Odisha & Uttar Pradesh (new record)), Malayasia, and Sumatra (Mukherjee et al. 2014).

Measurement: Immature mantid (nymph)

Remark: The species was rare in the collection.

Tribe: Hymenpodini Giglio-Tos, 1915

***Creobroter apicalis* Saussure, 1869 (Image 4)**

1869. *Creobroter apicalis* Saussure Mill. Schweiz. Entomol. Ges., 3: 73.

1927. *Creobroter apicalis* Giglio-Tos Das Tierreich., 50: 558.

2014. *Creobroter apicalis:* Mukherjee et al., Priamus, 30: 9.

2017. *Creobroter apicalis* Mukherjee, Iyer & Chatterjee J. Threat. Taxa, 9(2): 9832.

Materials examined: RMDCRS 004-005, 2 female, 16.x.2017, Udharanpur (Ghazipur) Uttar Pradesh, India; on *Thevetia peruviana*, coll. R.S. Yadav.

Diagnosis characters: Female: Body medium to large, body greenish with yellow spot on the fore wing; winged forms; head trapezoidal, vertex of head with a small mid dorsal spine, squarish with prominent lateral lobes; eyes conical, black band with white tips, projecting upwards; antennae slender, filiform; ocelli conspicuous; pronotum saddle shape, shorter than fore coxae, supra coxal dialation well pronounced, prozona laterally denticulated, spatulate with central indistinct carina, metazonal constriction well pronounced; Coxae of fore legs triangular dorsally with eight obtuse marginal spines, middorsal carina with spines, internal apical lobes converging; femur longer than coxa, with four external, four discoidal, (third longest and stoutest,) with six longer internal and seven shorter internal spines, two distal longer internal spines enclose two shorter spines; tibia with 16 smaller, depressed external spines, 14 longer internal closely arranged spines; metatarsus as long as all other tarsal segments together; middle and hind femur twice as long as mid tibia, with semi-circular, distal ventral lobe, with two genicular spines; tibia with three distal genicular spines; wings longer than abdomen; costal and anal areas of forewing transparent, forewing with yellow band bordered by two black semi-circular rings like an eye spot and placed in the middle of the both wings, this eye mark enclosed black dots, usually two; base of forewing with a yellow spot also, the hind wing with pink at base, yellowish in costal area and brownish in discoidal and anal areas.

Distribution: India (Andhra Pradesh, Arunachal Pradesh, Assam, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, West Bengal, & Uttar Pradesh (new record)), Bangladesh, China, Java, Nepal, and Bhutan (Mukherjee et al. 2014, 2017).

Measurement: Body length 34mm

Remark: The species was very attractive and colourful.

Tribe: Acromantini Runner De Wattenwyl, 1893

***Ephestiasula pictipes* (Wood-Mason, 1879) (Image 5)**

1879. *Hestias pitipes* Wood-Mason, Proc. Asiatic Soc. Bengal: 258.

1951. *Ephestiasula pictipes* Roonwal & Bhasin, Indian Forester, 77(5): 313-318.

1995. *Ephestiasula pictipes* Mukherjee et al., Oriental Insects 29(1): 217.

2014. *Ephestiasula pictipes* Mukherjee et al., Priamus, 30: 12.

2015. *Ephestiasula pictipes* Majumder et al. Zool. Surv. India, 115(4): 368

Materials examined: RMDCRS 006, 1 male, 23.ix.2017, Karmahari (Ghazipur) Uttar Pradesh, India; on bushes, coll. R.S. Yadav.

Diagnosis: External edge of fore femur denticulated, internal face of forefemur spines black, inferior internal lobes contain three yellow to white spots encased by black patch; black patch absents at upper border and very thin below near base; tarsi internally black; pronotum dorso-medially black,

Distribution: India (Chhattisgarh, Madhya Pradesh, Maharashtra, Odisha, Uttar Pradesh (earlier record from Dehradun, Uttarakhand) (Mukherjee et al. 1995, 2014), Uttar Pradesh, (new record)) and Nepal.

Measurement: Body length 34mm

Remark: The species was brown in colour.

***Hestiasula brunneriana* Saussure, 1871 (Image 6 & 7)**

1871. *Hestiasula brunneriana* Saussure, Mem. Soc. Phys. Hist. Nat. Geneve, 21: 330.

2001**.** *Hestiasula brunneriana* Ghate, Ranade, Kaur and Marathe, J. Bombay

Nat. Hist. Soc. 98 (3): 473-476.

2007. *Hestiasula brunneriana* Vyjayandi. Zool. Surv. India, Occ. Paper .267: 39.

2014. *Hestiasula brunneriana* Mukherjee et al., Priamus, 30: 12.

Materials examined: RMDCRS 007-009, 1 male, 2 female, 09.ix.2017, Chakka bandh Dam (Ghazipur) Uttar Pradesh, India, on white colour flowering bushes, coll. R.S. Yadav.

Diagnosis: Vertex with protuberance; fore femur arched, foliaceous, external edge smooth with three black spots on superior margin and one near the spine in middle Mukherjee et al. 1995; Ghate et al. 2001; Vyjayandi 2007).

Distribution: India (Andhra Pradesh, Bihar, Maharashtra,

Meghalaya, Odisha, West Bengal, & Uttar Pradesh (New record)), Pakistan, and Sri Lanka (Mukherjee et al. 2014).

Measurement: Body length 29mm

Remark: Inner side of fore femur is orange in colour and ornamented with three inner black spots.

Family: Liturgusidae Giglio-Tos, 1915; Subfamily: Listurgusinae Giglio-Tos, 1915

***Humbertiella ceylonica* Saussure, 1869 (Image 8)**

1869. *Humbertiella ceylonica* Saussure Mitt. Schweiz. Entomol. Ges.,3:62.

1891. *Theopompa sepentrionum* Wood-Mason. A catalogue of Mantblac 2:61.

2007. *Humbertiella ceylonica* Vyjayandi. Zool. Surv. India, Occ. Paper .267: 73.

2014. *Humbertiella ceylonica* Mukherjee et al., Priamus, 30: 14.

Materials examined: RMDCRS 0010-012, 3 female, 09.vi.2017, Zamania (Ghazipur) Uttar Pradesh, India, on light trap, coll. R.S. Yadav.

Diagnosis: Small black species with triangular head having five lobes in vertex and blackish frontal sclerite along with continuous black band; pronotum short and rhomboid in shape; fore femur slightly bulged, externally 4 discoidal and internally 5 large (completely black) and 5 short spines with three blackish band on inner side of femur as well as on tibia black; anal vein of fore wing three branched in female.

Distribution: India (Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh, West Bengal, & Uttar Pradesh (new record)), Myanmar, Nepal, and Sri Lanka (Mukherjee et al. 2014).

Measurement: Body length 34mm

Remark: Wood coloured black species.

***Humbertiella similis* Giglio-Tos, 1917 (Image 9)**

1897. *Humbertiella indica* Bolivar Ann. Soc. Enlolnol. France, 66: 303.

2007. *Humbertiella similis* Vyjayandi. Zool. Surv. India, Occ. Paper .267: 70

1917. *Humbertiella similis* Giglio-tos Bull. Soc. Entomol. Ital., 48: 83.

2014. *Humbertiella similis* Mukherjee et al., Priamus, 30: 15.

Materials examined: RMDCRS 013-015, 1 male, 2 female, 23.vi.2018, Chahaniya, (Chandauli), Uttar Pradesh, India, on light trap, coll. R.S. Yadav.

Diagnosis: Small brown species with frontal sclerite brown with less arched superior edges; pronotum with less prominent protuberances; in fore femur internal spines black at tips only. Irregular veinules in the costal area of fore wing, wings smoky and longer than body.

Distribution: India (Himachal Pradesh, Jammu & Kashmir, Kerala, Madhya Pradesh, Odisha, & Uttar Pradesh), Nepal, and Sri Lanka (Mukherjee et al. 2014).

Measurement: Body length 37mm

Remark: Brown coloured species.

Family: Tarachodidae Handlirsch, 1930; Subfamily: Schizocephalinae Saussure, 1869

***Schizocephala bicornis* (Linné, 1758) (Image 10&11)**

1927. *Schizocephala bicornis* Giglio-Tos, Das Tierreich, 50: 237.

2007. *Schizocephala bicornis* Vyjayandi. Zool. Surv. India, Occ. Paper .267: 121.

2014. *Schizocephala bicornis* Mukherjee et al., Priamus, 30: 16.

Materials examined: RMDCRS 0016, 1 female, 07.vii.2018, Dehariya (Ghazipur), Uttar Pradesh, India, on grasses, coll. R.S. Yadav.

Diagnosis: Long and slender mantid, green coloured. Antenna thickened toward base; eyes anteriorly prolonged forming cone shape. Fore femur with four external and three discoidal in which second is longest one; tibia shortened with six external spines. Forewing very small and opaque in female (Majumder et al. 2015).

Distribution: India (Andhra Pradesh, Bihar, Chhattisgarh (Bilaspur Korba, Raipur, Koriya), Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, West Bengal, & Uttar Pradesh (new record)), Africa, Nepal, Thailand, Sri Lanka, and Sunda Island.

Measurement: Body length 145mm

Remark: Largest mantid in the collection looks like a stick insect**.**

Family: Mantidae Latreille, 1802, Subfamily: Amelinae Westwood, 1889

***Amantis saussurei* (Bolivar, 1897) (Image 12)**

1927. *Amantis saussurei* Giglio-Tos, Das Tierreich, 50: 171.

2014. *Amantis saussurei* Mukherjee et al. Priamus, 30: 25.

2015. *Amantis saussurei* Majumder et al. Zool. Surv. India, 115(4): 376.

Materials examined: RMDCRS 0017-0018, 2 female, 24.iii.2018, Maujhi (Chandauli), Uttar Pradesh, India, on grasses, coll. R.S. Yadav.

Diagnosis: Small in size, brown coloured mantis similar to bark with scattered black spots on vertex, frontal sclerite with two black spots; pronotum with black line. First tarsal

segment brown. Stigma with black spot at either ends (Majumder et al. 2015).

Distribution: India (Andhra Pradesh, Chhattisgarh, Maharashtra, Karnataka, Kerala, Tamil Nadu, & Uttar Pradesh (new record)).

Measurement: Body length 13mm

Remark: Smaller one mantid.

***Elmantis trincomaliae* (Saussure, 1869)**

1869. *Gonypeta trincomaliae* Saussure, Mitt. Schweiz. Entomol. Ges., 3: 63-64.

1915a. *Elmantis trincomaliae* Giglio-Tos, Bull. Soc. Entomol. Ital., 46: 161.

2014. *Elmantis trincomaliae* Mukherjee et al. Priamus, 30: 25.

2015. *Elmantis trincomaliae* Majumder et al. Zool. Surv. India, 115(4): 377.

Materials examined: RMDCRS 0019, 1 male, 24.III.2018, Zamania (Ghazipur), Uttar Pradesh, India, on stones, coll. R.S. Yadav.

Diagnosis: Small brownish insect. In foreleg, proximal two external spines close beset; foretibia with 10 external spines. Hind metatarsus longer than rest segments together (Majumder et al. 2015).

Distribution: India (Andhra Pradesh, Chhattisgarh (Bastar), Karnataka, Kerala, Maharashtra, Tamil Nadu, & Uttar Pradesh (new record)) and Sri Lanka.

Measurement: Body length 14 mm

Remark: Smaller one mantid.

***Tenodera fasciata* (Oliver, 1792) (Image 13)**

1912. *Tenodera fasciata* Giglio-Tos. Bull. Soc. Entomol. Ital., 43: 45.

2009. *Tenodera fasciata* Sureshan, Rec. Zool. Sur. India. Occasional Paper No. 305: 37.

2007. *Tenodera fasciata* Mandal et al. Zoos' Print Journal 22(6): 2719.

2014. *Tenodera fasciata* Mukherjee et al. Priamus, 30: 30.

2017. *Tenodera fasciata* Raut & Gaikwad, J. Threat. Taxa, 9(6): 10351–10354

Materials examined: RMDCRS 0020, 1 male, 10.iv.2018, Zamania (Ghazipur), Uttar Pradesh, India, on grasses, coll. R.S. Yadav.

Diagnosis: Body slender, much elongated; antenna very much elongated, pronotum nearly equal or longer than fore coxae. Fore femora with four discoidal and four external spines, laterally smooth; 1st discoidal spines shorter than 2nd. Both wings well developed; hind femora with apical spine; anal cerci conical and hind wing with reddish transverse veinlets in costal area (Raut & Gaikwad 2017).

Distribution: India (Arunachal Pradesh, Assam, Maharashtra, Manipur, Meghalaya, Odisha, West Bengal, & Uttar Pradesh (new record)), Borneo, China, Flores, Java, Malaysia, Moluccas, Myanmar, Philippines, Sri Lanka, Sumba, Sulawesi, Talaud Islands, and Thailand.

Measurement: Body length 87mm

Remark: Larger one mantid.

***Tenodera costalis* (Blanchard, 1853) (Image 14)**

1853. *Mantis costalis* Blanchard, Voy. Pole Sud, Zool. Iv(I): 353

1904. *Tenodera costalis* Kirby, Syn. Cat. Orth. 1: 238.

1927. *Tenodera costalis* Giglio-Tos, Orthoptera. Mantidae. Das Tierreich/animal kingdom, 414.

Materials examined: RMDCRS 0021-0022, 1 male, 1 female, 10.iv.2018, Karmhari (Ghazipur), Uttar Pradesh, India, on grasses, coll. R.S. Yadav.

Diagnosis: Body slender, soft green in colour, much elongated; frontal sclerite much wider, rather a double curved edge on the upper side; antennae medium-long, brownish to body colored; Fore coxae smooth or partial spines in male, In female finely denticulate, the apex of the femur spines black; fore femora with four discoidal and four external spines, laterally smooth; 1st discoidal spines shorter than 2nd. Both wings well developed, slightly longer than body; hind femora with apical spine. Pronotum little dilated anteriorly keeled in its middle, finely denticulate on its edges, especially in its anterior portion, metazona of the pronotum slightly longer or in similar length to the fore coxae; fore wing long, rather narrow, acuminate, all the anterior part slightly darker, discoidal area of male is hyaline, in female one third the densely veined, the hind wings are adorned with black basal spot, costal area blood-stained, discoidal area transverse venules dark/smoky, anal area dark/smoky, hyaline areas with irregular fenestrae (Giglio-Tos 1912 & 1927).

Distribution: India (Uttar Pradesh (new record)).

Measurement: Body length 89mm, pronotum 33.32mm; pronotum width 4.92mm; metazona 27.20mm; Fore wing 48.38mm.

Remark: First time recorded from India. More detail study and comparison is needed.

***Hierodula coarctata* Saussure, 1869 (Image 15)**

1869. *Hierodula coarctata* Saussure, Mitt. schweiz. ent. Ges. 3:67

1927. *Parahierodula coarctata* Giglio-Tos. Tierreich 50:458 1935. Hierodula coarctata Beier. Genera Insect. 203: 84

2010. *Hierodula coarctata* Mukherjee and Ghate, J. Threat. Taxa, 2(9): 1167-1171.

2014. *Hierodula coarctata* Mukherjee et al. Priamus, 30: 30.

2018b. *Hierodula coarctata* Yadav et al., J. Exp. Zool. India Vol. 21, No. 2, pp. 745-747.

Materials examined: RMDCRS 0023-0025, 1 female, 12.iv.2019, Rohuna (Ghazipur), Uttar Pradesh, India, on light bulb. 2 male, 1 female, 07.ix.2019, Zamania (Ghazipur), on shrub plant, coll. R.S. Yadav.

Diagnosis: The prosternum and mesosternum with red coloured transverse band were found. The supra coxal dilation of pronotum was broader than male and prozonal tubercles on edges were comparatively stronger than the male. The metazona with distinct median carina was there. The forefemur was dark green with dark patches on inner side. The forefemur has black coloured larger spines and discoidal spines also. Wings were mostly similar with male. Male: The body colour of male was green. The head was triangular; eyes were rounded with prominent ocelli. The supra coxal dilation of the pronotum was somewhat wide. The prozona has some finer tubercles. The metazonal carination was not clear. Externally, forefemur was green in colour. Larger spines of forefemur were black in colour. The meso and meta thoracic legs are yellowish green in colour. The forewing was green in colour and veins were green with yellow coloured subcosta. There were yellowish to white colour stigma surrounded by brownish colour patches on the forewing.

Distribution: India (Andhra Pradesh, Bihar, Maharshtra, West Bengal, & Uttar Pradesh), Nepal, Java, Pakistan, & Australia? (Mukherjee et al. 2014; Yadav et al. 2018).

Measurement: Body length 47mm

Remark: Species may show gradual changes in their colouration.

Subfamily: Mantinae Burmeister, 1838

***Mantis religiosa religiosa* Linnaeus, 1758 (Image 16)**

1758. *Gryllus* (*Mantis*) *religiosus* Linnaeus. Sys. Nat. 10: p.426

1927. *Mantis religiosa* Giglio-Tos, 1927. Das Tierreich, 50: 406.

2009. *Mantis religiosa* Sureshan, Rec. Zool. Sur. India. Occasional Paper No. 305: 30.

2014. *Mantis religiosa religiosa* Mukherjee et al. Priamus, 30: 37.

Materials examined: RMDCRS 0026-0027, 1 male, 1 female, 22.viii.2018, Rohuna (Ghazipur), Uttar Pradesh, India, on paddy, coll. R.S. Yadav.

Diagnosis: Pronotum a little longer than fore coxa, prosternum has two small tubercles just to the base; shorter when compared to that of *Statilia* Stal, fore coxa internally with a basal black spot which often encloses an oval yellow spot, fore femora without black spot; a distinct transverse pink line on the vertex, prominent in fresh specimen. Claw groove of femora in the middle; fore wing semi- hyaline and both wings shorter to body.

Distribution: India (Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Odisha, Uttar Pradesh (new record), & West Bengal), Asia, Africa, Europe, North America, Canada, Jordan, Lebanon, and United Arab Emirates (Mukherjee et al. 2014).

Measurement: Body length 57mm

Remark: Species shows aggression when disturbed.

***Statilia maculata* (Thunberg, 1784)**

1985. *Statilia maculata* Mukherjee & Hazra, Rec. zool. Surv. India, 82(1-4): 34.

1927. *Statilia maculata* Giglio-Tos. Das nerreich, 50: 410.

2014. *Statilia maculata* Mukherjee et al., Priamus, 30: 38

Materials examined: RMDCRS 0028-0030, 2 male, 1 female, 23.VI.2018, Chahaniya (Chandauli), Uttar Pradesh, India, on bushes, coll. R.S. Yadav.

Diagnosis: Body brownish, pronotum slender, longer than fore coxa, claw groove of fore femora situated above middle, four external and four discoidal spines, inner disc with pale yellow and black patches; tibiae with seven external spines; femora with shining yellow patch, often bordered by a black patch, larger internal spines of femora not entirely black, wings as long as abdomen.

Distribution: India (Andaman Island, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Madhya Pradesh, Maharashtra, Meghalaya, Kerala, Odisha, Sikkim, Uttar Pradesh, & West Bengal) Annam, Borneo, China, Japan, Java, Labuan, Myanmar, Malaysia, Maluku Islands, Nepal, New Guinea, Palawan, Sri Lanka, and Sumatra, (in Staatliches Museum furNaturkunde, Karlsruhe, Germany (SMNK): Laos, Pakistan, Philippines, Thailand, & Vietnam) (Mukherjee et al. 2014).

Measurement: Body length 55mm

Remark: Brown coloured species, male & female are more or less same size.

***Statilia nemoralis* (Saussure, 1870)**

1927. *Statilia nemoralis* Giglio-Tos. Das nerreich, 50: 411.

2014. *Statilia nemoralis* Mukherjee et al., Priamus, 30: 38

Materials examined: RMDCRS 0031-0032, 1 male,1 female, 23.xi.2017, Rohuna (Ghazipur), Uttar Pradesh, India, on bushes, coll. R.S. Yadav.

Diagnosis: Body Straw yellow with grass green shade, pronotum a shorter than fore coxa, claw groove of fore

femora situated above middle, with yellow and a black patch in front of it, four external and four discoidal spines, inner disc with pale yellow and black patches; tibiae with seven external spines; prosternum without a black patch posteriorly, wings as long as abdomen.

Distribution: India (Arunachal Pradesh, Himachal Pradesh, Maharashtra, Manipur, Kerala, Tamil Nadu, West Bengal, & Uttar Pradesh (new record)), Borneo, China, Japan, Java, Korea, Myanmar, Malayasia, Philippines, Sumatra, Taiwan, and Vietnam (Mukherjee et al. 2014).

Measurement: Body length 58mm

Remark: Male & female were mostly similar.

***Cheddikulama straminea* Henry, 1932 (Image 17)**

1995. *Cheddikulama straminea* Mukherjee et al., Oriental Insects 29(1): 202, 317, 320.

2007. *Cheddikulama straminea* Vyjayandi, (267): IX, 3, 134, 154.

2014. *Cheddikulama straminea* Mukherjee et al., Priamus, 30: 45

Materials examined: RMDCRS 0033-0034, 1 male,1 female, 02.viii.2017, Dehariya (Ghazipur), Uttar Pradesh, India, on logs, coll. R.S. Yadav.

Diagnosis: Body straw yellow coloured, head pentagonal, flattened; occiput produced into two angular lobes; conical eyes with tubercle, pronotum slender as twice longer than fore coxa; hindlegs much longer than middle legs; wings ornate; forewing with parallel venation; hindwing with purple blotch and concentrically arranged purple patches; cerci short.

Distribution: India (Kerala and Uttar Pradesh) and Sri Lanka (Vyjayandi 2007; Mukherjee et al. 2014).

Measurement: Body length 59mm

Remark: Male & female were mostly similar.

***Aethalochroa ashmoliana* (Westwood, 1841) (Image 18)**

1951. *Aethalochroa ashmoliana* Roonwal & Bhasin, Indian Forester, 77(5): 313-318.

1904a. Aethalochroa ashmoliana Kirby, 1904: Brit. Mus. (Nat. Hist.), Vol. 1 1: 308

2014. Aethalochroa ashmoliana syn. As Loxomantis indica Mukherjee et al., Priamus, 30: 2, 3, 47.

2015. *Aethalochroa ashmoliana* Majumder et al. Zool. Surv. India, 115(4): 382.

Materials examined: RMDCRS 0035-0036, 1 male, 23.XI.2017, 1 female, 12.X.2019 Dehariya (Ghazipur), Uttar Pradesh, India, on logs, coll. R.S. Yadav.

Diagnosis: Body dark in coloured middle and hind tibiae dorsally carinated, eyes prominent with a very small dorsal tubercle, upper edge of vertex concave, fore leg external spines and eight internal spines, wing is shorter than abdomen, middle and hind femora without geniuclar spines, cerci foliaceous, longer than wide.

Distribution: India (Andhra Pradesh, Chhattisgarh, Kerala, Maharashtra, Orissa, West Bengal, & Uttar Pradesh (new record)), Iran, Malaysia, and Sri Lanka.

Measurement: Body length 112mm

Remark: One of the larger species**.**

***Toxoderopsis taurus* Wood-mason, 1889**

1927. *Toxoderopsis taurus* Giglio-Tos. Das Tierreich, 50: 569.

2009. *Toxoderopsis taurus* Sureshan, Rec. zool. Surv. India, Occ. Paper (305): 34.

2014. *Toxoderopsis taurus* Mukherjee et al., Priamus, 30: 2, 3, 47.

Materials examined: RMDCRS 0037, 1 female, 12.IX.2019, Dehariya (Ghazipur), Uttar Pradesh, India, on logs, coll. R.S. Yadav.

Diagnosis: Body black brown in colour, middle and hind tibiae not carinate; eyes with a distinctly projecting spine, median lobe of vertex higher than laterals, hind wings hyaline, middle and hind femora with genicular spines; cerci long, flat, crested at tip.

Distribution: India (Andhra Pradesh, Bihar, Maharashtra, Madhya Pradesh, Odisha, & Uttar Pradesh (new record)) and Pakistan (Mukherjee et al. 2014).

Measurement: Body length 88mm

Remark: Sometime confuse with *Aethalochroa ashmoliana*.

Family Empusidae Burmeister, 1838; Subfamily Empusinae Burmeister, 1838

***Empusa* (*Empusa*) *guttula* (Thunberg, 1815) (Image 19)**

1889. *Gongylus guttula* Thunberg, 1815: 5: 294.

2002. *Empusa* (*Empusa*) *guttula* Ehrmann, Mantodea der Welt: 127.

2009. *Empusa guttula* Sureshan, Rec. zool. Surv. India, Occ. Paper (305): 16

2014. *Empusa guttula* Mukherjee et al., Priamus, 30: 2, 3, 51.

Materials examined: RMDCRS 0038-0039, 1 female,1 female, 05.viii.2019, Dehariya (Ghazipur), Uttar Pradesh, India, on paddy, coll. R.S. Yadav.

Diagnosis: Fore femora without lobe and superior edge almost straight; middle and hind femora without dorsal lobes, vertex prolonged into a conical protuberance, armed medially and laterally by triangular sharp spines, apex little expanded and biflog with a median carina extended into sharp point; antennae simple in female and pectinate in male; pronotum slender, slightly spined; forewing little

Image 1. Observed mantids during field surveys in the province of the Uttar Pradesh: 1—*Euantissa pulchra* | 2 & 3—*Odontomantis montana* nymph & adult | 4—*Creobroter apicalis* | 5—forefemur of *Ephestiasula pictipes* | 6 & 7—ootheca of *Hestiasula brunneriana* & adult | 8—*Humbertiella ceylonica* | 9—*Humbertiella similis* | 10 & 11—*Schizocephala bicornis* | 12—*Amantis saussurei* (nymph) | 13—*Tenodera fasciata* | 14—*Tenodera costalis* | 15—*Hierodula coarctata* | 16—*Mantis religiosa religiosa* | 17—*Cheddikulama straminea* | 18—*Aethalochroa ashmoliana* | 19—*Empusa (empusa) guttula* | 20 & 21—*Empusa spinosa*. © R.S. Yadav

longer than body, stigma with two brown spots at corner, costal area green, opaque.

Distribution: India (Andhra Pradesh, Odisha, Rajasthan, & Uttar Pradesh), Algeria, Angola, Cameroon, Egypt, Kenya, Libya, Madagascar, Mauritania, Morocco, Namibia, Senegal, Somalia, Tanzania, Transversal, Tunisia, Gambia, South Africa, and Tanzania (Mukherjee et al. 2014).

Measurement: Body length 58mm

Remark: Species recorded from the state previously.

***Empusa spinosa* Krauss, 1902 (Image 20 & 21)**

1964. *Empusa spinosa* Gupta, Current Sci. 33: 370.

2002. *Empusa spinosa* Ehrmann, Mantodea der Welt, 130.

2014. *Empusa spinosa* Mukherjee et al., Priamus, 30: 2, 3, 51.

2015. *Empusa spinosa* Majumder et al. Zool. Surv. India, 115(4): 382.

Materials examined: RMDCRS 0040-0042, 1 male and 1 female, 15.x.2017, Udharanpur (Ghazipur), Uttar Pradesh, India, on Tectona. 1 female, 05.viii.2019, Dehariya (Ghazipur), coll. R.S. Yadav.

Diagnosis: Longer than *Empusa guttula*, yellowish-green, slender body; vertex of head with a conical protuberance, bifurcated at top; pronotum slender, long with distinct spines, longer than fore coxae; upper edge of fore femur is staright, and simple fore femur (Majumder 2015); wing extended beyond the abdomen; abdominal segments usually expanded laterally.

Distribution: India (Chandigarh, Chhattisgarh, & Uttar Pradesh (new record)) (Mukherjee et al. 2014, Majumder et al. 2015)

Measurement: Body length 59mm

Remark: Very less studied species in the country.

CONCLUSION AND SUMMARY

The 21 species of mantids discussed here, 10 species are firstly recorded from Uttar Pradesh and one species first time reported from the country. Further more intensive field work may enrich mantid fauna of the Uttar Pradesh, India.

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COMMUNICATION

An assessment of genetic variation in vulnerable Borneo Ironwood *Eusideroxylon zwageri* Teijsm. & Binn. in Sarawak using SSR markers

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Abstract: Borneo Ironwood *Eusideroxylon zwageri* Teijsm. & Binn. has high market value for its valuable and durable timber, which has put it at risk due to illegal logging. This study analysed *E. zwageri* genetic variation using four microsatellite markers in populations at Nirwana Rehabilitation Forest (NRF), and Tatau, Sarawak. We found that 20.1% of total genetic variation corresponded to differences between populations, while 79.9% was attributed to differences among individuals from the same population. The Tatau population had lower genetic diversity compared to NRF, and both populations showed depressed heterozygosity indicative of inbreeding. Allelic data were also used to confirm variety level differences proposed by earlier workers, and three informal varieties: *zwageri, grandis*, and *exilis* were recognized in the study area. It is expected that the results from this study could serve as baseline data for conservation of this vulnerable species.

Keywords: Allelic data, Belian, DARwin, GenAlex, IUCN Red List, Malaysia.

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Author contributions: MISF collected, performed the experiments, analyzed data and contributed in giving ideas. CSYY, MNS-assisted in analyzing the data, reviewed and suggested some comments on the article. RG-Principal investigator of the research grant and assisted in designing and planning the research. MISF, RG-Wrote the manuscript. All authors gave final approval for publication.

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INTRODUCTION

The Borneo Ironwood *Eusideroxylon zwageri* Teijsm. & Binn. is one of the most treasured and crucial commercial timber trees endemic to the Asian forest (Malaysia, Indonesia, Brunei, and The Philippines). It is known locally as 'Belian' in Malaysia, 'Ulin' in Indonesia, and 'Tambulan' in The Philippines. The species belongs to the Lauraceae family that includes the avocado, bay laurel and cinnamon tree. It has been listed as 'Vulnerable' on the IUCN Red List of Threatened Species due to over-exploitation and habitat destruction (Asian Regional Workshop 1998). This species will remain endangered unless circumstances threatening its survival and reproduction improve. Slow growth rates (mean radial growth rate is 0.058cm per year; Kurokawa et al. 2003) and slow regeneration in logging areas also contribute to lower numbers of forest trees.

Many taxonomists have reported variety level morphological differences in *E. zwageri* (Teijsmann 1858; Teijsmann & Binnendijk 1863; Koopman & Verhoef 1938; Kostermans et al. 1994;), however, no valid taxonomic treatment for these varieties has been proposed so far. Some of the vernacular names given to the varieties were 'Belian telor', 'Belian kapur', 'Belian sirap', 'Belian tanduk', 'Belian tembaga', and 'Belian lilin'. Nevertheless, Irawan et al. (2016) tried to confirm the presence of these varieties using amplified fragment length polymorphism (AFLPs) studies. The study showed promising results, with 98% out of a total of 50 samples clustered according to the varieties recognized by the local people in Indonesia. The four varieties were informally recognized as var. *zwageri*, var. *exilis*, var. *grandis*, and var. *ovoidus* (Irawan 2005a,b). Local people in Sarawak also recognized these varieties based on the differences in fruit's form, bark or wood structure (Marzuki pers. comm. 18.ix.2017), however, no valid taxonomic treatment has been published.

This tree can reach a height of up to 50m and may live over 1,000 years (Global Trees Campaign 2020). Mature trees produce large fruits that, although poisonous to humans, are important food sources for foraging animals. The species is also valued for cultural reasons. The wood is dense (0.85–1.1 g/cm^3) (Irawan 2016), strong and resistant to decay, making it preferred by indigenous people of Borneo for building houses. The *Dayak* people of Borneo believe the tree protects them from dangerous animals, while 'Murut' (Borneo headhunter) use it to make blowpipes and *Dusun* ancestors used it to create coffins. The black pepper industry in Borneo has traditionally used Belian wood as a support to the creeping herbs. In the famous Murut Cultural Center of Malaysia, Belian wood pillars are used.

The revised status of *E. zwageri* in Sarawak under Criteria B of IUCN Red List (Md-Isa et al. 2021) indicates the need to formulate conservation plans to protect this species from extinction. In addition to economic or social information, occurrences and distribution patterns of species, genetic information of the species is another important aspect that needs to be considered in conservation action plans. Habitat fragmentation can contribute to the reduction of genetic diversity of this species. Although transplantation of *E. zwageri* from other locations is a practical conservation strategy, an accurate understanding of the genetic structure of natural population of *E. zwageri* is necessary for conserving them. This is because relocation of the species or reduction in size for other reasons will cause the loss of genetic diversity in the new population through genetic drift (Lowe et al. 2005; Finlay et al. 2017).

Little is known about the genetics of *E. zwageri,* especially in Sarawak. Two studies in Indonesia using randomized amplified polymorphic DNA (RAPD) markers revealed 96% genetic diversity of *E. zwageri* within populations, and the remaining attributed to population differences (Harkingto et al. 2006; Rimbawanto et al. 2006). This was probably due to the samples that originated from the same population. Nurtjahjaningsih et al. (2017a,b) showed high genetic diversity for *E. zwageri* in Indonesia, and suggested transplantation among different populations should be conducted with careful consideration. A few studies on genotyping of *E. zwageri* using direct amplified minisatellite DNA (DAMD) marker (Yoon 2006), M13 universal marker (Siew 2005) and RAPD marker (Hong 2005) were mainly aimed at identifying and genotyping the two genera (*Eusideroxylon* and *Potoxylon*) known by similar common names Belian in Sarawak.

In this study, two different habitats were chosen to study the genetic variation of *E. zwageri* in Sarawak. One was a restoration forest, Nirwana Rehabilitation Forest (NRF) located in Universiti Putra Malaysia (UPM) Bintulu Campus. The other was a fragmented forest in Tatau, Bintulu, Sarawak. This study was conducted to assess the genetic variation of *E. zwageri* by using four highly polymorphic microsatellite markers recently developed for the species (Kurokochi et al. 2014). We compared genetic variation between the two populations and within each population, and determined the level and pattern of genetic variation in both areas. Allelic data were also analyzed for the presence of variety level

differences in collected samples.

MATERIALS AND METHODS

Sample collection

Two sampling sites were selected as model habitats for this study; 1) Nirwana Rehabilitation Forest (NRF) in UPM Bintulu Campus, and 2) fragmented forest area in Tatau, Bintulu, Sarawak (Figure 1). Samplings were conducted in April 2016, August 2016, and September 2017, over the periods of two weeks each. Leaves were collected from 52 trees, of which 39 from NRF and 13 from Tatau forest. A single leaf was collected per tree. The leaf materials were kept in silica gel prior to DNA extraction.

DNA extraction

Total genomic DNA was isolated using conventional Cetyl-Trimethyl Ammonium Bromide (CTAB) method (Doyle & Doyle 1987) with some modifications. The leaf materials were ground with CTAB buffer until fine paste and transferred into sterilized 1.5mL micro-centrifuge tube. In the fume hood, 500µL of 2X preheated (at 65°C) CTAB extraction buffer [2% (w/v) hexadecyltrimethylammonium bromide (CTAB); 1.4 M sodium chloride (NaCl); 100 mM Tris-HCl, pH 8.0; 20 mM ethylenediamine tetra-acetic acid (EDTA), pH 8.0; 1–2% (w/v) polyvinyl-pyrrolidone (PVP-40T)] and 2µL of 1% β-mercaptoethanol were added to each sample in the 1.5mL micro-centrifuge tube and vortex gently until mixed well. The homogenized mixture was then incubated for 20–30 minutes at 50°C in a water bath and inverted every five minutes (Md-Isa 2020). The tubes were then transferred to another water bath and incubated at 65°C for another 15 minutes. The samples were allowed to cool slightly before adding 500µL of chloroform: isoamyl alcohol (24 : 1) and inverted to mix. At room temperature, the samples were gently shaken for 15 minutes and centrifuged for 10 minutes at 12,500rpm. About 400µL of supernatant was transferred into a new sterile 2.0mL screw cap micro-centrifuge tube (Md-Isa 2020).

The DNA was precipitated by adding 800–1,000 µL of 95% cold ethanol and inverted gently, and allowed to precipitate up to three hours or longer in -20°C freezer. The tubes were then centrifuged for 10 minutes at 12,500rpm to pellet the DNA. The supernatant was

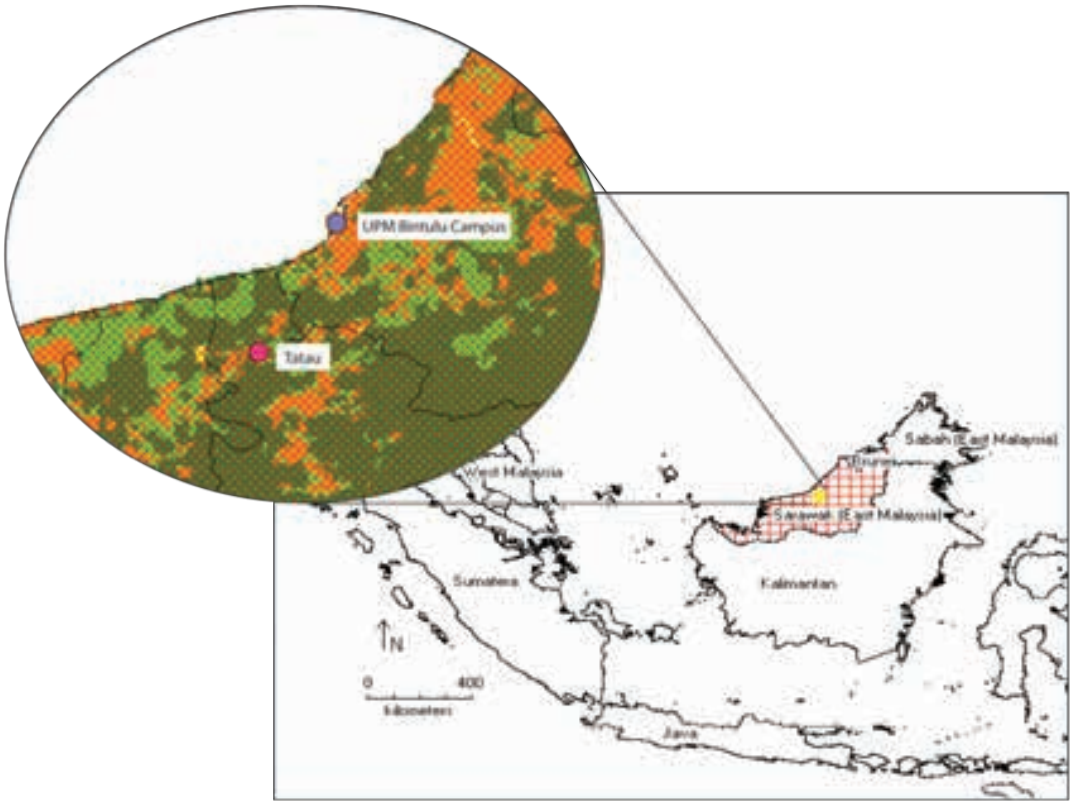

Figure 1. The locations of the sampling sites in Sarawak, Malaysia.

discarded and the pellet was washed with 500µL of 80% cold ethanol and gently mixed for 10 minutes. Then, the pellet was centrifuged for five minutes at 12,500rpm and the supernatant was discarded again. The DNA pellet was allowed to air dry at room temperature before re-suspending with 100µL of TE buffer or distilled water. The DNA samples were then kept at -20°C for further usage.

Afterward, the DNA quantity was estimated through electrophoresis on 1.0% (w/v) agarose gel. The gel was run in tris-boric acid-EDTA (TBE) buffer with EtBr "Out" Staining Solution (YEASTERN BIOTECH Co. Ltd) at 90V for 30–45 minutes and quantified in comparison to the 1kb DNA ladder (Promega, Madison, WI, USA) with known concentrations. The band was visualized using UV transilluminator. The band intensity of the DNA product was quantified to the intensity in the ladder (Promega 2020). The images were captured with DOC PRINT system (Vilber Lourmat, USA).

Polymerase chain reaction (PCR)

Polymerase chain reactions (PCR) were performed in a volume of 25µL using 2µL of DNA template (5–10 ng), 10µM of each primer, 5X GoTaq buffer, 10mM dNTPs, and 25mM MgCl using an Eppendort AG 22331 Mastercycler. PCR cycling conditions were as follows: a single cycle of pre-denaturation for two min a 95°C, followed by 40 cycles, each consisting of 30 sec denaturing at 95°C, 30 sec at annealing temperature 50°C, and 30 sec elongation at 72°C, the last cycle ending with a single cycle of final extension at 72°C for five min.

The PCR amplification of the DNA sample was carried out using four highly polymorphic microsatellites developed for *E. zwageri* (Kurokochi et al. 2014). Forward primer of each marker was labeled with fluorescent dye (Table 1). One representative of PCR product from each primer was subjected to one direction sequencing done by First Base Laboratories Sdn. Bhd. (Seri Kembangan, Selangor, Malaysia) to confirm the amplification of the microsatellite repeat region. The products were then subjected to bi-directional sequencing for fragment analysis (FA). FA were carried out to detect changes in the length of a specific DNA sequence to indicate the presence or absence of the microsatellite marker through detection of fluorescent label in the PCR product. The size standard (500-ROX) was combined with the sample of interest and co-injected on the capillary electrophoresis system (ABI3730XL Applied Biosystems Genetic Analyzer).

Data analysis

For data analysis, a total of 52 leaves samples were distributed into two populations with Tatau (13 samples) as one population and NRF (39 samples) as one population. The scoring of allele sizes were performed using GeneMapper® version 4.0 analysis software using the service provided by First Base Laboratories Sdn. Bhd. The alleles nearest to the expected PCR product size were recorded; while the non-specific products, which were out of range, were ignored. Allele frequencies per locus and per population were analyzed by FSTAT version 2.9.3 (Goudet 1995). Number of alleles (Na), expected heterozygosity (He), observed heterozygosity (Ho) and polymorphism information content (PIC) were also estimated using Cervus version 3.0. F-statistics, including inbreeding coefficient of an individual relative to the subpopulations (F_{IS}), inbreeding coefficient of an individual relative to the total population (F_{IT}), and genetic differentiation index between population (F_{ST}) were calculated using GenAlex version 6.501 (Peakall & Smouse 2012). The software was also employed to determine genetic diversity within each population (Na, Ho, He, and F_{IS}).

Further, the allelic data of the 52 samples were subjected to estimation of genetic distance among genotypes using simple matching coefficients by bootstrapping 1,000 times and then were clustered using unweighted neighbor-joining method by using

Table 1. Characteristics of four polymorphic microsatellite loci in *Eusideroxylon zwageri* (Kurokochi et al. 2014) used in the current study.

Marker	Sequence 5' – 3' with fluorescent label	(Repeat motif)$_n$	Size range (bp)	Na	Ho	He	Tm (ºC)
Ez-04	F04 (56FAM) TTGAAGTGGACGTCCTCTAG R04 CCAAAGAAGCGAAGTAAGG	$(AC)_{16}$	205–234	10	0.74	0.74	58
Ez-05	F05 (5HEX) TCCTCTTGGTGAAATCTTCTC R05 CAGTTTTCTTCTCCTCCCATTC	$(GA)_{15}$	255–282	14	0.86	0.91	58
Ez-07	F07 (5HEX) CTTGCGGAATCAATGAGAACT R07 GTAGGTAGGTCCAACTGGAAG	$(TC)_{12}$	132–177	19	0.69	0.90	58
Ez-09	F09 (5HEX) CGCTAAATTTAAGAAAACCGTCTC R09 CCAGTCCTGCAGTAGGCTC	$(TAC)_{12}$	275–299	10	0.74	0.76	58

Na—number of allele | Ho—observed heterozygosity | He—expected heterozygosity | Tm—melting temperature.

Dissimilarity Analysis and Representation for Windows (DARwin) version 6.0.21 (Perrier & Jacquemoud-Collet 2006). This analysis was done to see if there are any variety level differences in the collected samples. The names of varieties used in the present study were adopted based on earlier studies (Irawan 2005a,b; Irawan et al. 2016).

RESULTS

The 52 samples from *E. zwageri* trees were scored for all four microsatellite DNA loci. The amplification of the microsatellite repeats was confirmed by sequencing, where specific repeat motifs were successfully identified. The PCR reactions which failed to produce sufficient product for genotyping were recorded as missing data for all analyses, however, locus Ez-04 yielded less than 20% amplification and was discarded for the subsequent analysis.

Genetic variations among three markers tested for all 52 individuals are summarized in Table 2. In total, 25 alleles were detected at these three loci in 52 individuals, with the number of alleles per locus ranging from 3 (Ez-09) to 12 (Ez-05), with an average of 8.33 alleles per locus. Ez-09 showed lowest number of alleles being amplified but it was detected in 50 individuals with 38 individuals from NRF and 12 individuals from Tatau compared to Ez-05 detected in 42 individuals with 35 individuals from NRF and seven individuals from Tatau (Appendix 1).

Meanwhile, observed and expected heterozygosity values of all three loci ranged 0.511–0.720 and 0.664–0.867, respectively. Whereas, the average observed heterozygosity for both populations (Ho= 0.593) was lower than the average expected heterozygosity (He= 0.791), which may indicate moderate levels of genetic variation in the Belian populations studied. While, the polymorphic information content (PIC) value for all three loci were higher than 0.5 ranging from 0.583 to 0.841, which suggested all three loci used in this study were highly polymorphic.

Besides, locus Ez-05 showed the highest value of allelic richness (A_R= 7.117) among the three markers with total of 12 alleles being amplified from both populations; however, among the 12 alleles amplified, only six alleles were identified in Tatau compared to 10 alleles in NRF. The distributions and allele frequencies of the three loci in both populations are shown in Figure 2A–2C and listed in Appendix 1.

Furthermore, F-statistics were estimated in a fixation index as shown in Table 2. The average inbreeding coefficient of the individuals to the total population (F_{IT}) was 0.295 while the average inbreeding coefficient of the individuals to the subpopulation (F_{IS}) was 0.048. Whereas, the average genetic differentiation (F_{ST}) of the subpopulation compared to the total populations was 0.201. The average value of F_{ST} indicated that about 20.1% of total genetic variation corresponded to differences between populations, while 79.9% was explained by differences between individuals of the same populations. And the lower F_{ST} value, which is less than 0.25, may suggest that there is gene flow between the two populations.

The genetic indicators within each population are summarized in Table 3. The data showed higher number of alleles (Na= 7.333) being amplified in 36 individuals in NRF populations. The observed heterozygosity value (Ho= 0.659), however, was lower than the expected heterozygosity (He= 0.739), which indicated moderate level of genetic variation in NRF populations. Comparatively, in Tatau, lower number of alleles (Na= 4.000) was found in nine individuals. Moderate level of genetic variation was also observed in Tatau population by the lower number of observed heterozygosity (Ho= 3.99) than the expected heterozygosity (He= 0.563).

Generally, the lower number of observed heterozygosity than the expected heterozygosity was

Table 2. Genetic diversity analyses over all three loci and populations based on number of alleles per locus (Na), observed (Ho) and expected heterozygosity (He), allelic richness (A_R), polymorphism information content (PIC), and F-statistic (F_{IT}, F_{IS} and F_{ST}).

Locus	Na	N	Ho	He	A_R	PIC	F_{IT}	F_{IS}	F_{ST}	Nm
Ez-05	12	42	0.548	0.867	7.117	0.841	0.299	0.242	0.076	3.054
Ez-07	10	45	0.511	0.842	6.618	0.815	0.438	0.371	0.107	2.078
Ez-09	3	50	0.720	0.664	2.988	0.583	0.146	-0.470	0.419	0.346
Total	25									
Average	8.333		0.593	0.791	5.574	0.746	0.295	0.048	0.201	1.826

N—number of individuals | F_{IT}—global heterozygote deficit among populations | F_{IS}—heterozygote deficit within populations | F_{ST}—fixation index as genetic differentiation | Nm—gene flow.

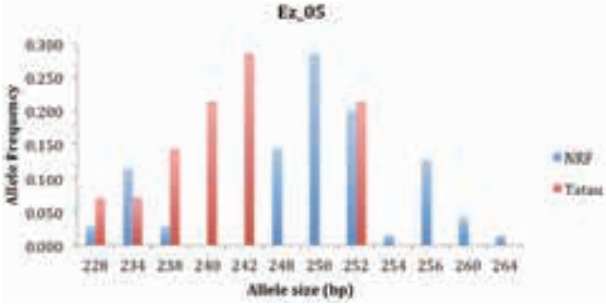

Figure 2A. Allele frequencies for locus Ez-05 in Nirwana Rehabilitation Forest and Tatau.

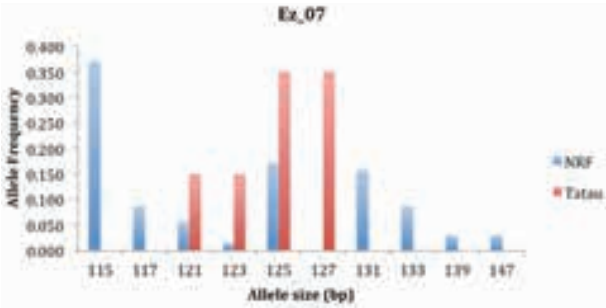

Figure 2B. Allele frequencies for locus Ez-07 in Nirwana Rehabilitation Forest and Tatau.

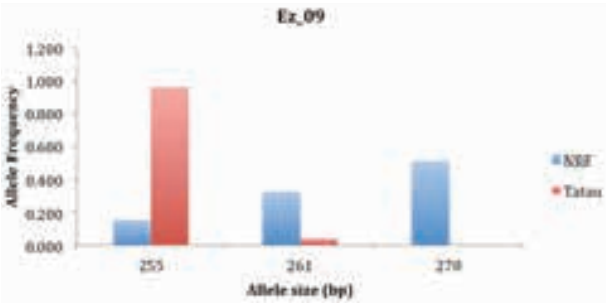

Figure 2C. Allele frequencies for locus Ez-09 in Nirwana Rehabilitation Forest and Tatau.

Table 3. Genetic diversity analyses within populations.

Population	N	Na	Ho	He	F_{IS}
NRF	36	7.333	0.659	0.739	0.054
Tatau	9	4.000	0.399	0.563	0.165
Average		4.759	0.529	1.020	0.109

N—number of individuals analyzed | Na—number of alleles | Ho—observed heterozygosity | He—expected heterozygosity | F_{IS}—heterozygote deficit within populations.

also evidence that both populations deviated from Hardy-Weinberg equilibrium. Both populations also showed a deficiency of heterozygosity, indicated by positive F_{IS} values (NRF= 0.054; Tatau= 0.165).

Additionally, the allelic data for 52 samples were analyzed based on the estimation of genetic distance among genotypes to segregate the individuals according to their varieties. The unweighted neighbor-joining dendogram grouped the 52 samples of the two populations into three varieties (Figure 3). Of the 52 samples, 15 samples were grouped together as variety *exilis*, 16 samples as variety *grandis* and 21 samples as variety *zwageri*.

DISCUSSION

The informativeness of observed loci across the two populations was measured based on polymorphic information content (PIC). Theoretically, PIC values range 0–1 (Hilderbrand et al. 1994). At a PIC of 0, the marker has only one allele, and at a PIC of 1 the marker would have an infinite number of alleles. Thus values of PIC greater than 0.5 are considered to be highly informative. Data from the current study resulted in an average value of PIC= 0.746. Therefore, all the three loci used in this study can be classified as highly informative loci (PIC >0.5) and appropriate for assessing genetic variation.

Based on the average value of expected heterozygosity (He= 0.791), a moderate level of genetic variation among the 52 individuals studied was obtained. Nevertheless, when compared the genetic variation between NRF and Tatau, NRF showed higher genetic variation within population compared to Tatau, where theoretically, the wild population should have higher genetic variation (Pandey et al. 2004; Gauli et al. 2009). This may be due to the source of NRF trees, which originated from several places. It may not only limit to Bintulu area but from several places, which contribute to the high level of genetic variation in the populations, However, inbreeding depression may still occur because of the small size population. As for wild population of Tatau, the genetic variation was lower than expected, probably due to the small population size in an island forest fragment within palm oil plantation, which may contribute to the low genetic variation in the population.

In addition, heterozygote deficiency was detected, which was depicted by the lower average value of observed compared to expected heterozygosity (Ho < He). It suggested that both populations might be inbred. This was also evidenced by the positive average value of F_{IS} (Table 2), which observed a stronger inbreeding in the Tatau population than the NRF population. Heterozygote deficit can be explained by various factors such as

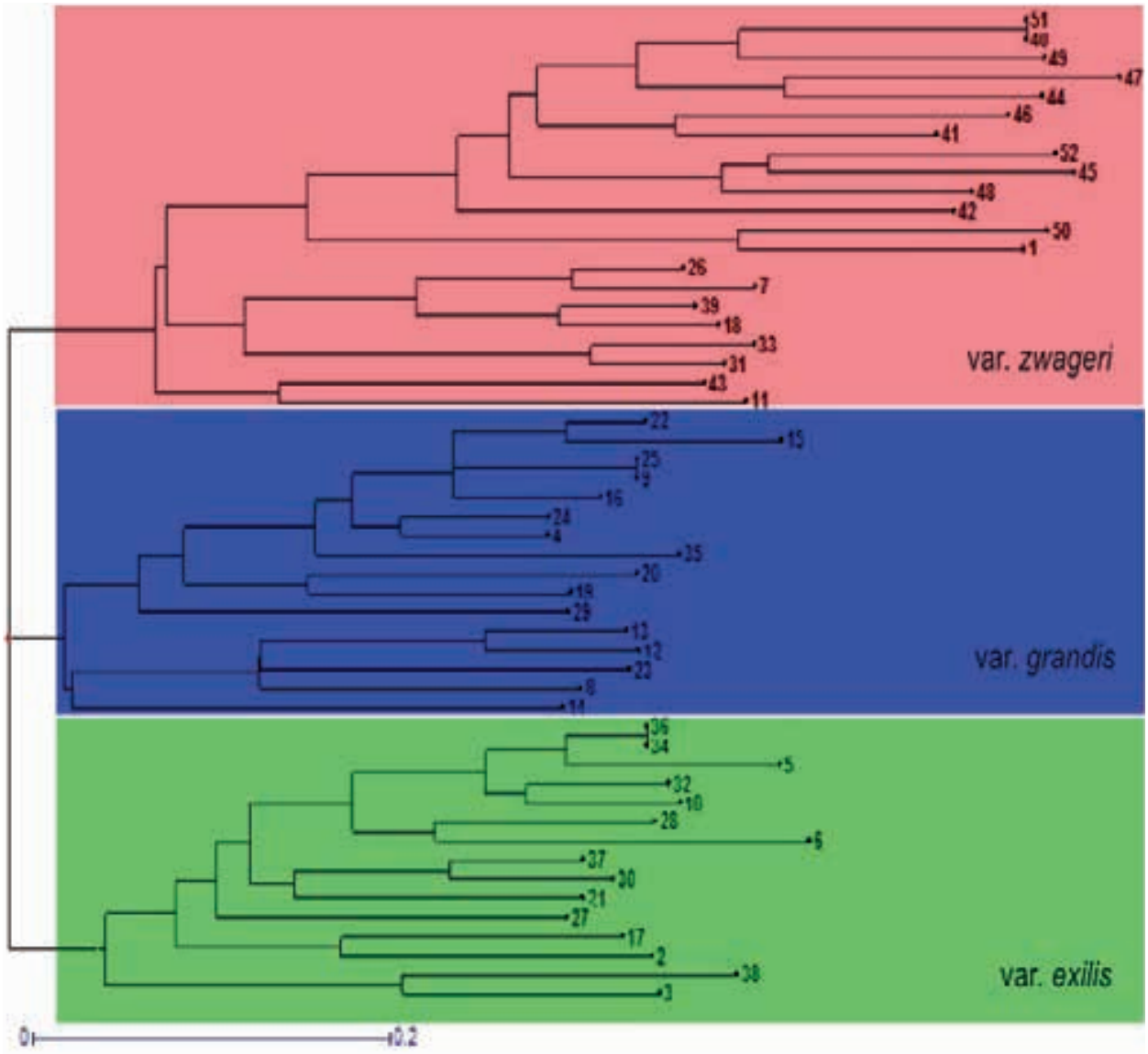

Figure 3. Unweighted Neighbor-joining trees using simple matching similarity coefficient based on three microsatellite markers for the 52 individuals of *Eusideroxylon zwageri* from Nirwana Rehabilitation Forest and Tatau, Bintulu. The tree shows the clustering pattern of three varieties of *E. zwageri* namely; variety *exilis,* variety *grandis* and variety *zwageri*. The scale bar (0–0.2) represents the level of dissimilarity.

non-random mating, unamplified alleles (null alleles) and inappropriate sampling (population admixture Wahlund's effects) (Borsa et al. 1991; Castric et al. 2002; Dharmarajan et al. 2012; Waples 2015).

Inbreeding often results from a population bottleneck (genetic drift) due to anthropogenic or environmental events. In this study, higher inbreeding depression was observed in Tatau. The small population size and limited number of standing trees in the area might be the main cause of the inbreeding depression. Other factors could be founder events, where a population has reduced genetic variation compared to the original population and thus produces an apparent high level of inbreeding. This phenomenon may happen in the NRF population where seeds from several unknown populations in Bintulu and outside Bintulu added the small size of the NRF population. The different source of seeds, however, may contribute to the high genetic variation in NRF compared to Tatau.

Furthermore, based on Wright (1978), F_{ST}= 0–0.05 indicates little population differentiation, F_{ST}= 0.05–0.15 indicates moderate differentiation, F_{ST}= 0.15–0.25 indicates high differentiation, and F_{ST} >0.25 indicates highest differentiation. Current study revealed high genetic differentiation between the two populations (F_{ST}= 0.201). The genetic differences might be due to the

extensive geographic range (population isolation) of the species and the small population size.

This fixation index (F_{ST}) may also provide approach for estimating inter-population gene flow (Nm) (Avise 2004). Average gene flow (Nm= 1.826, Table 2) in the current study may indicate one incoming migrant per generation in each population when F_{ST}= 0.201 (Wright 1931). This indicates some migration (gene flow) at low rate between the two populations and low levels of interbreeding.

Additionally, both populations showed a possible deviation from Hardy-Weinberg equilibrium (HWE), which can be observed through the lower number of observed heterozygosity (Ho) than expected heterozygosity (He). Another possible parameter to look for the deviation from HWE in this study is the F-statistics. Populations are in Hardy-Weinberg equilibrium if F_{IS}= 0 and F_{IT}= F_{ST} (Guries & Ledig 1981). The value of F_{IS} ranges between -1 and +1. Negative F_{IS} values indicate heterozygote excess (outbreeding) and positive values indicate heterozygote deficiency (inbreeding) compared with HWE expectations. Result from this study showed a positive F_{IS} value, (NRF= 0.054; Tatau= 0.165) which indicates deficiency of heterozygosity, hence, a possible deviation from HWE.

The deviation from HWE can be caused by several factors such as mutation, migration, random mating, selection and small size population (Keats & Sherman 2013; Johnston et al. 2019). In this study, the disequilibrium was probably caused by the small population size of both study sites. Consequently, sampling error is unavoidable in this study. Small sample size contributes to the violations of the HWE principles. Other factors such as migration or seed dispersal by human or animal were observed in NRF, which also contribute to the deviation from HWE. While in Tatau, dispersal of seed was observed mainly through the river where the population is situated. Inbreeding and population isolation as discussed above may also contribute to the deviation from HWE.

Overall, results from this study should be used with caution, as the number of marker and samples tested in this particular study are not sufficient to make any conclusive statement. The PIC of all the three markers, however, is very high, in this case the average is 0.746, which is more than 0.5 and suitable to use for the analysis. Nonetheless, future study where more samples and more markers can be included should be carried out to have more comprehensive understanding on the genetic variation of *E. zwageri* especially in Sarawak.

The allelic data obtained in this study were also used to segregate the samples according to their varieties based on estimation of genetic distance among genotypes. The result showed that the 52 samples were grouped into three varieties. Morphological study conducted in the same sampling area documented similar variations (Md-Isa 2020). The present result demonstrates the existence of variety level differences in *E. zwageri*. Nevertheless, further study on using more markers, samples and DNA barcoding will verify and give more concrete answer for this finding. Thorough work on taxonomy classification is ongoing to validate the taxonomic status of the varieties in *E. zwageri*.

CONCLUSION

Genetic analysis of the two populations of *E. zwageri* in Bintulu, Sarawak shows that 20.1% of total genetic variation corresponded to differences between populations. The Tatau population was observed to have relatively lower genetic diversity compared to NRF area. Therefore, it was suggested that establishment of the restored population (NRF) from a limited number of individuals originated from unknown places has higher level of genetic variation compared to the wild population (Tatau). This occurrence, however, resulted in the inbreeding due to genetic drift (population bottleneck and founder effect). Furthermore, inbreeding can lead to fixation of deleterious alleles and may lead to a decrease in the genetic variation of the population.

Consequently, it is important to obtain more detailed information on the genetic variation of this species in order to form an effective conservation strategy. We suggest further conservation efforts focused on ensuring suitable habitat for the continued recovery of this species. Effort can be made to identify locations of *E. zwageri* as protected forest areas. This will facilitate natural regeneration without disturbance. Alternatively, sprouting and cutting techniques can be proposed, as the sprouts tend to grow faster and may reach mature stage faster than regenerating them from seedling (Mostacedo et al. 2009).

In addition, the findings on the segregation of the species into three varieties based on the allelic data are promising. Validation of the names of the varieties can now be proposed with effective taxonomic publication. It would also be interesting to establish DNA barcodes for this species to confirm our observations. More samples from different locations and different genetic markers are suggested to be included to support future study on this topic.

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Appendix 1. Weighted (W) and unweighted (UW) allele frequencies per locus and per population. N is allele size (base pair).

Locus	Pop	NRF, UPM	Tatau, Bintulu	All_W	All_UW
	N	35	7		
Ez-05	228	0.029	0.071	0.036	0.050
	234	0.114	0.071	0.107	0.093
	238	0.029	0.143	0.048	0.086
	240		0.214	0.036	0.107
	242	-	0.286	0.048	0.143
	248	0.143	-	0.119	0.071
	250	0.286	-	0.238	0.143
	252	0.200	0.214	0.202	0.207
	254	0.014	-	0.012	0.007
	256	0.129	-	0.107	0.064
	260	0.043	-	0.036	0.021
	264	0.014	-	0.012	0.007
Locus	**Pop**	**NRF, UPM**	**Tatau, Bintulu**	**All_W**	**All_UW**
	N	35	10		
Ez-07	115	0.371	-	0.289	0.186
	117	0.086	-	0.067	0.043
	121	0.057	0.150	0.078	0.104
	123	0.014	0.150	0.044	0.082
	125	0.171	0.350	0.211	0.261
	127	-	0.350	0.078	0.175
	131	0.157	-	0.122	0.079
	133	0.086	-	0.067	0.043
	139	0.029	-	0.022	0.014
	147	0.029	-	0.022	0.014
Locus	**Pop**	**NRF, UPM**	**Tatau, Bintulu**	**All_W**	**All_UW**
	N	38	12		
Ez-09	255	0.158	0.958	0.350	0.558
	261	0.329	0.042	0.260	0.185
	270	0.513	-	0.390	0.257

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REVIEW

Termites (Blattodea: Isoptera) of southern India: current knowledge on distribution and systematic checklist

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Abstract: A checklist of termites (Blattodea: Isoptera) of southern India with their distribution is presented in this paper. In total, 132 species from five families are listed, of which Termitidae Latreille, 1802 is the dominant family comprising 101 species from 27 genera and four subfamilies. The recent additions of species to the regional termite diversity are *Krishnacapritermes dineshan* Amina & Rajmohana, 2020, *K. manikandan* Amina & Rajmohana, 2020, and *Pseudocapritermes kunjepu* Mathew, 2020. Out of 132 species recorded from southern India, 60 species and five genera are endemic to the region, and the subfamily Termitinae Latreille, 1802 accounts for maximum endemism.

Keywords: Endemism, taxonomy, Termitidae, white ants.

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INTRODUCTION

Termites, also called "white ants" are considered soil engineers and structural pests. Interestingly, they are known as eusocial cockroaches in the order Blattodea Brunner von Wattenwyl, 1882. Molecular phylogenetic data obtained from termites revealed that, Isoptera is not a separate order, and can be considered under Blattodea along with cockroaches (Inward et al. 2007). Krishna et al. (2013) estimated about 2,933 species of extant termites in the world. India has a high diversity of termites, but the Indian termite fauna shares a very small portion of the global fauna, i.e., approximately 295 species, 52 genera, and six families (Krishna et al. 2013; Rajmohana et al. 2019). The first ever taxonomic work on Indian termites was carried out in southern India by König (1779) and the last comprehensive work was by Bose (1984) who reported 95 species from the region. This comprehensive taxonomic work is made to list all the termites recorded so far from the southern Indian region, which should serve as a base for further taxonomic research.

MATERIALS AND METHODS

Southern India comprises five states of India—Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, and Telangana. This region is composed of various climatic conditions ranging from tropical to sub-tropical zones and lies between 8-20°N and 74-85°E. Most of these regions lie between the Western Ghats and Eastern Ghats and the coastal region. The Western Ghats is the hotspot of diversity; climate is hot and arid in some regions whereas in other parts it is hot and humid, or cold with 25–32 °C temperature during hot season and 23–30 °C in the cool season.

The checklist has been mainly based on available literature rather than extensive taxonomic work. The classification is based on Krishna et al. (2013). This list has been compiled based on Roonwal & Chhotani (1989), Chhotani (1997), Krishna et al. (2013), and original descriptions. The literature published until date is considered for making the checklist of termites and their distribution in southern India.

RESULTS AND DISCUSSION

The checklist for the five families and 132 species reported from southern India along with their distribution are provided here. Among the reported, Termitidae Latreille, 1802 is the dominant family comprising of 101 species from four subfamilies. The family Termitidae accounts maximum generic diversity also (27 genera) followed by Kalotermitidae Froggatt, 1897 (five genera), and Rhinotermitidae Froggatt, 1897 (three genera). The genus *Odontotermes* Holmgren, 1910b (25 species) in the family Termitidae have high species diversity followed by genus *Neotermes* Holmgren, 1911b from family Kalotermitidae with 10 species.

Endemism of termites to the region is high, out of the 132 species, 60 species (45.45%) (denoted by *) and five genera (denoted by **) are endemic to southern India. Subfamily Termitinae Latreille, 1802 of family Temitidae accounts for maximum endemism with 20 species out of 43 endemic species of the family. Three genera of subfamily Termitinae, viz., *Indocapritermes* Chhotani, 1997, *Krishnacapritermes* Chhotani, 1997, and *Labiocapritermes* Krishna, 1968 and two genera of subfamily Nasutitermitinae Hare, 1937, viz., *Ampoulitermes* Mathur & Thapa, 1962a and *Emersonitermes* Mathur & Sen-Sarma, 1959 are endemic to southern India.

Check list of termites of southern India

Family Hodotermitidae Desneux, 1904

Subfamily Hodotermitinae Desneux, 1904

Genus *Anacanthotermes* Jacobson, 1905

1. *Anacanthotermes viarum* (König, 1779)

Synonyms: *Termes viarum* König, 1779; *Hodotermes* (*Anacanthotermes*) *koenigi* Holmgren & Holmgren, 1917; *Anacanthotermes rugifrons* Mathur & Sen-Sarma, 1958.

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Tamil Nadu (König 1779; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013).

Family Kalotermitidae Froggatt, 1897

Genus *Cryptotermes* Banks, 1906

2. *Cryptotermes bengalensis* (Snyder, 1934)

Synonyms: *Kalotermes* (*Cryptotermes*) *bengalensis* Snyder, 1934; *Calotermes* (*Cryptotermes*) *brachygnathus* Jepson, 1931; *Calotermes* (*Cryptotermes*) *ceylonicus* Jepson, 1931; *Cryptotermes angulatus* Pinto, 1941.

Type locality: India: West Bengal: Sunderbans.

Distribution: Andhra Pradesh; Karnataka (Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

3. *Cryptotermes domesticus* (Haviland, 1898)

Synonyms: *Calotermes domesticus* Haviland, 1898;

Calotermes (*Cryptotermes*) *ogasawaraensis* Oshima, 1913; *Calotermes* (*Cryptotermes*) *dentatus* Oshima, 1914; *Cryptotermes campbelli* Light, 1924; *Cryptotermes hermsi* Kirby, 1925; *Calotermes* (*Cryptotermes*) *buxtoni* Hill, 1926; *Kalotermes* (*Cryptotermes*) *breviarticulatus* Snyder, 1926; *Calotermes* (*Cryptotermes*) *gulosus* Hill, 1927a; *Calotermes* (*Cryptotermes*) *repentinus* Hill, 1927a; *Calotermes* (*Cryptotermes*) *torresi* Hill, 1927b; *Calotermes* (*Cryptotermes*) *lignarius* Jepson, 1931; *Calotermes* (*Cryptotermes*) *tectus* Jepson, 1931.

Type locality: Malaysia: Borneo: Sarawak.

Distribution: Kerala (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

4. *Cryptotermes dudleyi* Banks, 1918

Synonyms: *Calotermes havilandi parasita* Wasmann, 1910; *Calotermes* (*Cryptotermes*) *jacobsoni* Holmgren, 1913c; *Planocryptotermes nocens* Light, 1921b; *Cryptotermes thompsonae* Snyder, 1922; *Cryptotermes* (*Planocryptotermes*) *primus* Kemner, 1932; *Cryptotermes* (*Planocryptotermes*) *javanicus* Kemner, 1934; *Cryptotermes melloi* Chhotani, 1970.

Type locality: Central America: Panama.

Distribution: Kerala; Karnataka (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

5. *Cryptotermes roonwali* Chhotani, 1970*

Type locality: India: Kerala: Beliapatam.

Distribution: Karnataka; Kerala (Chhotani 1970; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Genus *Glyptotermes* Froggatt, 1897

6. *Glyptotermes chiraharitae* Amina & Rajmohana, 2016*

Type locality: India: Kerala: Kakkayam.

Distribution: Kerala (Amina & Rajmohana 2016).

7. *Glyptotermes coorgensis* (Holmgren & Holmgren, 1917)*

Synonym: *Calotermes* (*Glyptotermes*) *coorgensis* Holmgren & Holmgren, 1917.

Type locality: India: Karanataka: Coorg: Sidapur.

Distribution: Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Genus *Neotermes* Holmgren, 1911

8. *Neotermes assmuthi* (Holmgren, 1913)

Synonym: *Calotermes* (*Neotermes*) *assmuthi* Holmgren, 1913b.

Type locality: India: Karnataka: Bangalore.

Distribution: Karnataka (Holmgren 1913b; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

9. *Neotermes dhirendrai* Bose, 1984*

Type locality: India: Tamil Nadu: Salem.

Distribution: Tamil Nadu (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

10. *Neotermes eleanorae* Bose, 1984*

Type locality: India: Karnataka: Mangalore.

Distribution: Karnataka (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013).

11. *Neotermes fletcheri* (Holmgren & Holmgren, 1917)

Synonym: *Calotermes* (*Neotermes*) *fletcheri* Holmgren & Holmgren, 1917.

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Mathew 2015).

12. *Neotermes greeni* (Desneux, 1908)

Synonym: *Calotermes greeni* Desneux, 1908.

Type locality: Sri Lanka.

Distribution: Tamil Nadu (Shanbhag & Sundararaj 2013).

13. *Neotermes keralai* Roonwal & Verma, 1972*

Type locality: India: Kerala: Trivandrum: Chackai.

Distribution: Kerala (Roonwal & Verma 1972; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

14. *Neotermes krishnai* Bose, 1984*

Type locality: India: Tamil Nadu: Salem.

Distribution: Tamil Nadu (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013).

15. *Neotermes nilamburensis* Thakur, 1978*

Type locality: India: Kerala: Nilambur.

Distribution: Kerala (Thakur 1978; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Mathew 2015).

16. *Neotermes shimogensis* Thakur, 1975*

Type locality: India: Karnataka: Shimoga.

Distribution: Karnataka (Sen-Sarma et al. 1975; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

17. *Neotermes venkateshwara* Bose, 1984*

Type locality: India: Tamil Nadu: Topslip.

Distribution: Tamil Nadu (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013).

Genus *Postelectrotermes* Krishna, 1961

18. *Postelectrotermes bhimi* Roonwal & Maiti, 1965*

Type locality: India: Kerala: Kottayam: Vandiperiyar.

Distribution: Kerala (Roonwal & Maiti 1965; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

19. *Postelectrotermes nayari* Roonwal & Verma, 1971*

Type locality: India: Kerala State: Trivandrum: Chackai.

Distribution: Kerala (Roonwal & Verma 1971; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Genus *Procryptotermes* Holmgren, 1910

20. *Procryptotermes dhari* Roonwal & Chhotani, 1963*

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Tamil Nadu (Roonwal & Chhotani 1963; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

21. *Procryptotermes hunsurensis* Thakur, 1975*

Type locality: India: Mysore: Kalbetta, Hunsur.

Distribution: Karnataka (Thakur 1975; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

22. *Procryptotermes valeriae* Bose, 1979*

Type locality: India: Tamil Nadu: Nagercoil.

Distribution: Tamil Nadu (Bose 1979, 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

Family Rhinotermitidae Froggatt, 1897
Subfamily Coptotermitinae Holmgren, 1910
Genus *Coptotermes* Wasmann, 1896

23. *Coptotermes beckeri* Mathur & Chhotani, 1969*

Type locality: India: Tamil Nadu: Chennai.

Distribution: Kerala; Tamil Nadu (Mathur & Chhotani 1969; Bose 1984; Roonwal & Chhotani 1989; Maiti 2006; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Amina et al. 2016c).

24. *Coptotermes ceylonicus* Holmgren, 1911

Type Localities: Sri Lanka: Peradeniya; Heneratgoda; Seenigoda Estate.

Distribution: Andhra Pradesh; Kerala; Tamil Nadu (Bose 1984; Roonwal & Chhotani 1989; Maiti 2006; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

25. *Coptotermes heimi* (Wasmann, 1902)

Synonyms: *Arrhinotermes heimi* Wasmann, 1902; *Coptotermes parvulus* Holmgren, 1913b.

Type locality: India: Maharashtra: Ahmadnagar: Wallon.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Roonwal & Chhotani 1989; Maiti 2006; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

26. *Coptotermes kishori* Roonwal & Chhotani, 1962

Type locality: India: West Bengal: Murshidabad: Berhampur.

Distribution: Kerala (Roonwal & Chhotani 1989; Maiti 2006; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Subfamily Heterotermitinae Froggatt, 1897
Genus *Heterotermes* Froggatt, 1897

27. *Heterotermes balwanti* Mathur & Chhotani, 1969

Type locality: India: Orissa: Balukhand Forest Range.

Distribution: Karnataka (Roonwal & Chhotani 1989; Maiti 2006; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Vidyashree et al. 2018).

28. *Heterotermes indicola* (Wasmann, 1902)

Synonym: *Leucotermes indicola* Wasmann, 1902.

Type locality: India: Maharashtra: Bombay.

Distribution: Andhra Pradesh; Kerala (Rao et al. 2012; Amina & Rajmohana 2013a).

29. *Heterotermes malabaricus* Snyder, 1933

Type locality: India: Karnataka: Mangalore.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Snyder 1933b; Bose 1984; Roonwal & Chhotani 1989; Maiti 2006; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Subfamily Prorhinotermitinae Quennedey & Deligne, 1975

Genus *Prorhinotermes* Silvestri, 1909

30. *Prorhinotermes flavus* (Bugnion & Popoft, 1910)

Synonyms: *Coptotermes flavus* Bugnion & Popoff, 1910; *Arrhinotermes japonicus* Holmgren, 1912c; *Arrhinotermes krakataui* Holmgren, 1913c; *Termitogetonella tibiaoensis* Oshima, 1920; *Prorhinotermes luzonensis* Light, 1921; *Prorhinotermes gracilis* Light, 1921b; *Prorhinotermes shiva* Roonwal & Thakur, 1963; *Prorhinotermes tibiaoensiformis* Ahmad, 1965; *Prorhinotermes ravani* Roonwal & Maiti, 1966; *Prorhinotermes panaitanensis* Thakur & Thakur, 1992.

Type locality: Sri Lanka: Ambalangoda.

Distribution: Karnataka (Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

Family Stylotermitidae Holmgren & Holmgren, 1917

Subfamily Stylotermitinae Holmgren & Holmgren, 1917

Genus *Stylotermes* Holmgren & Holmgren, 1917

31. *Stylotermes fletcheri* Holmgren & Holmgren, 1917*

Type localities: India: Tamil Nadu: Coimbatore, Shevaroy Hills.

Distribution: Karnataka; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Roonwal & Chhotani 1989; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

Family Termitidae Latreille, 1802

Subfamily Apicotermitinae Grassé & Noirot, 1955

Genus *Euhamitermes* Holmgren, 1912

32. *Euhamitermes dentatus* Thakur & Chatterjee, 1974*

Type locality: India: Andhra Pradesh: Khammam: Annapradipalli Range: Lankapalli Block: Satpalli.

Distribution: Andhra Pradesh (Thakur & Chatterjee 1974; Bose 1984; Chhotani 1997; Krishna et al. 2013).

33. *Euhamitermes indicus* (Holmgren & Holmgren, 1917)*

Synonym: *Hamitermes* (*Euhamitermes*) *indicus* Holmgren & Holmgren, 1917.

Type locality: India: Tamil Nadu: Shevaroy Hills.

Distribution: Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

34. *Euhamitermes karnatakensis* Roonwal & Chhotani, 1965

Type locality: India: Karnataka: Dharwar.

Distribution: Karanataka (Roonwal & Chhotani 1965; Bose 1984; Chhotani 1997; Krishna et al. 2013).

Genus *Eurytermes* Wasmann, 1902

35. *Eurytermes assmuthi* Wasmann, 1902

Type locality: India: Maharashtra: Khandala.

Distribution: Karnataka; Tamil Nadu (Chhotani 1997; Krishna et al. 2013).

36. *Eurytermes buddha* Bose & Maiti, 1966

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Karnataka; Tamil Nadu (Bose & Maiti 1966; Bose 1984; Chhotani 1997; Krishna et al. 2013).

37. *Eurytermes topslipensis* (Chatterjee & Thapa, 1963)*

Synonym: *Beesonitermes topslipensis* Chatterjee & Thapa, 1963.

Type locality: India: Tamil Nadu: Topslip: Mount Stuart.

Distribution: Kerala; Tamil Nadu (Chatterjee & Thapa 1963; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Speculitermes* Wasmann, 1902

38. *Speculitermes chadaensis* Chatterjee & Thapa, 1964*

Type locality: India: Madhya Pradesh: South Mandala Forest Division: Karanjia.

Distribution: Kerala (Amina et al. 2016a).

39. *Speculitermes cyclops* Wasmann, 1902

Type locality: India: Maharashtra: Bombay: Khandala.

Distribution: Andhra Pradesh; Karnataka (Chhotani 1997; Krishna et al. 2013).

40. *Speculitermes deccanensis* Roonwal & Chhotani, 1962*

Type locality: India: Karnataka: Bababudin Hills.

Distribution: Karnataka (Roonwal & Chhotani 1962b; Bose 1984; Chhotani 1997; Krishna et al. 2013).

41. *Speculitermes dharwarensis* Roonwal & Chhotani, 1964

Type locality: India: Karnataka: Dharwar.

Distribution: Andhra Pradesh; Karanataka (Roonwal

& Chhotani 1964b; Bose 1984; Chhotani 1997; Krishna et al. 2013).

42. *Speculitermes emersoni* Bose, 1984*

Type locality: India: Kerala: Thekkadi.

Distribution: Karnataka; Kerala (Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

43. *Speculitermes goesswaldi* Roonwal & Chhotani, 1964

Type locality: India: Karnataka: Dharwar.

Distribution: Karnataka (Roonwal & Chhotani 1964; Bose 1984; Chhotani 1997; Krishna et al. 2013).

44. *Speculitermes sinhalensis* Roonwal & Sen-Sarma, 1960

Synonym: *Speculitermes cyclops sinhalensis* Roonwal & Sen-Sarma, 1960.

Type locality: Sri Lanka: Vavuniya.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Kalleshwaraswamy et al. 2018; Mathew 2015).

Subfamily Termitinae Latreille, 1802

Genus *Angulitermes* Sjöstedt, 1924

45. *Angulitermes acutus* Mathur & Sen-Sarma, 1961

Type locality: India: Tamil Nadu: Tirunelveli: Palayankottai.

Distribution: Tamil Nadu (Mathur & Sen-Sarma 1961; Bose 1984; Chhotani 1997; Krishna et al. 2013).

46. *Angulitermes fletcheri* (Holmgren & Holmgren, 1917)*

Synonym: *Mirotermes* (*Mirotermes*) *fletcheri* Holmgren & Holmgren, 1917.

Type locality: India: Karnataka: Bellary District: Hadagalli.

Distribution: Karnataka (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

47. *Angulitermes keralai* Verma, 1984*

Type locality: India: Kerala: Kondazhi.

Distribution: Kerala (Verma 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

48. *Angulitermes obtusus* (Holmgren & Holmgren, 1917)*

Synonyms: *Mirotermes* (*Mirotermes*) *obtusus* Holmgren & Holmgren, 1917.

Type locality: India: Karnataka: Bellary District: Hospet.

Distribution: Karnataka (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

Genus *Dicuspiditermes* Krishna, 1968

49. *Dicuspiditermes achankovili* Verma, 1985*

Type locality: India: Kerala: Achankovil.

Distribution: Kerala; Tamil Nadu (Verma 1985b; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

50. *Dicuspiditermes boseae* Chhotani, 1997*

Type locality: India: Tamil Nadu: Kulasekaram Forest Range: Mylar.

Distribution: Tamil Nadu (Chhotani 1997; Krishna et al. 2013).

51. *Dicuspiditermes gravelyi* (Silvestri, 1922)

Synonyms: *Capritermes gravelyi* Silvestri, 1922.

Type localities: India: Maharashtra: Satara: Koyna Valley: Helvak.

Distribution: Karnataka; Kerala (Bose 1984; Chhotani 1997; Krishna et al. 2013; Amina et al. 2016b; Kalleshwaraswamy et al. 2018).

52. *Dicuspiditermes incola* (Wasmann, 1893)

Synomnyms: *Eutermes incola* Wasmann, 1893; *Capritermes longicornis* Wasmann, 1902; *Dicuspiditermes fletcheri* (Holmgren & Holmgren, 1917); *Dicuspiditermes pername* Thakur & Chatterjee, 1971.

Type locality: Sri Lanka: Colombo.

Distribution: Karnataka; Kerala; Tamil Nadu (Chhotani 1997; Krishna et al. 2013; Mathew 2015).

53. *Dicuspiditermes obtusus* (Silvestri, 1923)

Synonyms: *Capritermes obtusus* Silvestri, 1923; *Capritermes obtusus abbreviatus* Silvestri, 1923.

Type locality: India: Orissa: Chilika lake: Barkuda Island.

Distribution: Karnataka (Chhotani 1997; Krishna et al. 2013).

54. *Dicuspiditermes sisiri* Chhotani, 1997*

Type locality: India: Kerala: Silent Valley.

Distribution: Kerala (Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Eremotermes* Silvestri, 1911

55. *Eremotermes fletcheri* Holmgren & Holmgren, 1917

Synonyms: *Eremotermes maliki* Ahmad, 1955.

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

56. *Eremotermes madrasicus* Roonwal & Sen-Sarma, 1960*

Type locality: India: Tamil Nadu: Villivakkam.

Distribution: Tamil Nadu (Roonwal & Sen-Sarma 1960; Bose 1984; Chhotani 1997; Krishna et al. 2013).

57. *Eremotermes paradoxalis* Holmgren, 1912

Type locality: India: Karnataka: Bangalore.

Distribution: Karnataka; Tamil Nadu (Holmgren 1912; Bose 1984; Chhotani 1997; Krishna et al. 2013).

Genus *Homallotermes* John, 1925

58. *Homallotermes pilosus* (Mathur & Thapa, 1962)*

Synonym: *Microcapritermes pilosus* Mathur & Thapa, 1962b.

Type locality: India: Tamil Nadu: Coimbatore: Topslip.

Distribution: Tamil Nadu; Kerala (Mathur & Thapa 1962b; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Indocapritermes* Chhotani, 1997**

59. *Indocapritermes aruni* Chhotani, 1997*

Type locality: India: Kerala: Silent Valley.

Distribution: Kerala (Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Krishnacapritermes* Chhotani, 1997**

60. *Krishnacapritermes dineshan* Amina & Rajmohana, 2020*

Type locality: India: Kerala: Idukki; Kurunjimala Shola.

Distribution: Kerala (Amina et al. 2020).

61. *Krishnacapritermes maitii* Chhotani, 1997*

Type locality: India: Tamil Nadu: Pumbarai: Palni Hills.

Distribution: Kerala; Tamil Nadu (Chhotani 1997; Krishna et al. 2013; Amina et al. 2020).

62. *Krishnacapritermes manikandan* Amina & Rajmohana, 2020*

Type locality: India: Kerala: Idukki: Amar Shola-Munnar.

Distribution: Kerala (Amina et al. 2020).

63. *Krishnacapritermes thakuri* Chhotani, 1997*

Synonym: *Pericapritermes travancorensis* Mathew & Ipe, 2018.

Type locality: India: Kerala: Silent Valley.

Distribution: Kerala (Chhotani 1997; Krishna et al. 2013; Mathew 2015; Amina et al. 2020).

Genus *Labiocapritermes* Krishna, 1968**

64. *Labiocapritermes distortus* (Silvestri, 1922)*

Synonyms: *Capritermes distortus* Silvestri, 1922; *Pericapritermes vythirii* Verma, 1983.

Type locality: India: Kerala: Kavalai.

Distribution: Karnataka; Kerala; Tamil Nadu (Silvestri 1922; Verma 1983; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Microcerotermes* Silvestri, 1901

65. *Microcerotermes beesoni* Snyder, 1933

Synonyms: *Microcerotermes championi* Snyder, 1933b; *Microcerotermes lanceolatus* Mathur & Thapa, 1965.

Type locality: India: Uttarakhand: Haldwani: Chakrata Range.

Distribution: Andhra Pradesh; Kerala (Rao et al. 2012; Mathew 2015).

66. *Microcerotermes cameroni* Snyder, 1934

Type locality: India: Tamil Nadu: Madras: North Vellore District.

Distribution: Andhra Pradesh; Kerala; Tamil Nadu (Snyder 1934; Bo 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj, 2013; Mathew 2015).

67. *Microcerotermes fletcheri* Holmgren & Holmgren, 1917

Type locality: India: Karnataka: Mysore: Bababudin Hills.

Distribution: Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew et al. 2013; Kalleshwaraswamy et al. 2018, 2015; Vidyashree et al. 2018).

68. *Microcerotermes ganeshi* Bose, 1984*

Type locality: India: Tamil Nadu: Salem: Karambapatty Reserve Forest.

Distribution: Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013).

69. *Microcerotermes heimi* Wasmann, 1902

Type locality: India: Maharashtra: Ahmednagar: Wallon.

Distribution: Karnataka; Kerala (Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

70. *Microcerotermes kudremukhae* Chhotani, 1997*

Type locality: India: Karnataka: Kudremukh: Koppa Division: Kalasa Forest Range.

Distribution: Karnataka (Chhotani 1997; Krishna et al. 2013).

71. *Microcerotermes labioangulatus* Sen-Sarma & Thakur, 1975

Type locality: India: Tripura: Ambasa; Zoelchara.

Distribution: Andhra Pradesh (Krishna et al. 2013; Shanbhag & Sundararaj 2013).

72. *Microcerotermes minor* Holmgren, 1914

Type locality: Sri Lanka: Maha Iluppalama.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Amina et al. 2016b).

73. *Microcerotermes pakistanicus* Akhtar, 1974

Type locality: Pakistan: North West Frontier Province: Parachinar.

Distribution: Kerala; Karnataka (Chhotani 1997; Krishna et al. 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

Genus *Pericapritermes* Silvestri, 1914

74. *Pericapritermes topslipensis* Thakur, 1976*

Type locality: India: Tamil Nadu: South Coimbatore Forest Division: Topslip.

Distribution: Karnataka; Tamil Nadu (Thakur 1976a; Bose 1984; Chhotani 1997; Krishna et al. 2013).

Genus *Procapritermes* Holmgren, 1912

75. *Procapritermes dakshinae* (Chhotani & Ferry, 1995)*

Synonym: *Malaysiocapritermes dakshinae* Chhotani & Ferry, 1995.

Type locality: India: Kerala: on road from Kolattupuzha to Nedumangad: near Arippal.

Distribution: Kerala (Chhotani & Ferry 1995; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

76. *Procapritermes keralai* (Chhotani & Ferry, 1995)#

Synonym: *Malaysiocapritermes keralai* Chhotani & Ferry, 1995.

Type locality: India: Kerala: 5 km from road from Kothamangalam to Munnar.

Distribution: Kerala (Chhotani & Ferry 1995; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Pseudocapritermes* Kemner, 1934

77. *Pseudocapritermes fletcheri* (Holmgren & Holmgren, 1917)

Synonyms: *Capritermes fletcheri* Holmgren & Holmgren, 1917; *Pseudocapritermes fontanellus* Mathur & Thapa, 1961; *Pseudocapritermes goanicus* Thakur & Chatterjee, 1969; *Pseudocapritermes roonwali* Verma, 1985a.

Type locality: India: Tamil Nadu: Anamalai Hills.

Distribution: Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

78. *Pseudocapritermes kunjepu* Mathew, 2020*

Type locality: India: Kerala: Kottayam: Pinnakkanadu.

Distribution: Kerala (Ipe et al. 2020).

Genus *Synhamitermes* Holmgren, 1912

79. *Synhamitermes quadriceps* (Wasmann, 1902)

Synonyms: *Amitermes quadriceps* Wasmann, 1902.

Type locality: India: Maharashtra: Khandala.

Distribution: Karnataka; Kerala (Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

Subfamily Macrotermitinae Kemner, 1934

Genus *Hypotermes* Holmgren, 1913

80. *Hypotermes obscuriceps* (Wasmann, 1902)

Synonyms: *Termes obscuriceps* Wasmann, 1902; *Odontotermes* (*Hypotermes*) *marshalli* Kemner, 1926.

Type locality: Sri Lanka: Trincomali.

Distribution: Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

81. *Hypotermes xenotermitis* (Wasmann, 1896)

Synonyms: *Termes xenotermitis* Wasmann, 1896; *Hypotermes nongpriangi* Roonwal & Sen-Sarma, 1956.

Type locality: Myanmar: Palon.

Distribution: Kerala (Poovoli & Rajmohana 2019).

Genus *Macrotermes* Holmgren, 1909

82. *Macrotermes convulsionarius* (König, 1779)

Synonyms: *Termes convulsionarii* König, 1779; *Termes estherae* Desneux, 1908.

Type locality: Tamil Nadu: Tanjore.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (König 1779; Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Mathew 2015).

Genus *Microtermes* Wasmann, 1902

83. *Microtermes incertoides* Holmgren, 1913

Type locality: India: Maharashtra: Ahmednager: Wallon.

Distribution: Andhra Pradesh; Karnataka; Tamil Nadu (Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

84. *Microtermes obesi* Holmgren, 1912

Synonyms: *Microtermes anandi* Holmgren, 1913b; *Microtermes anandi curvignathus* Holmgren, 1913b.

Type locality: India: Maharashtra: Khandala.

Distribution: Andhra Pradesh; Kerala; Tamil Nadu; Karnataka (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

85. *Microtermes unicolor* Snyder, 1933

Synonyms: *Microtermes pubescens* Snyder, 1933b.

Type locality: India: Uttarakhand: Dehra Dun.

Distribution: Kerala (Amina et al. 2016).

Genus *Odontotermes* Holmgren, 1910

86. *Odontotermes adampurensis* Akhtar, 1975

Type locality: Bangladesh: Adampur.

Distribution: Karnataka (Kalleshwaraswamy et al. 2018).

87. *Odontotermes anamallensis* Holmgren & Holmgren, 1917

Synonyms: *Odontotermes* (*Odontotermes*) *anamallensis* Holmgren & Holmgren, 1917.

Type localities: India: Tamil Nadu: Anamalai Hills.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018).

88. *Odontotermes assmuthi* Holmgren, 1913

Synonym: *Odontotermes* (*Odontotermes*) *assmuthi* Holmgren, 1913b.

Type locality: India: Maharashtra: Borivali Jungle.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

89. *Odontotermes bellahunisensis* Holmgren & Holmgren, 1917

Synonyms: *Odontotermes* (*Cyclotermes*) *bellahunisensis* Holmgren & Holmgren, 1917.

Type locality: India: Karnataka: Bellary: Bellahunisi.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

90. *Odontotermes bhagwatii* Chatterjee & Thakur, 1967

Type locality: India: Punjab: Pathankot.

Distribution: Karnataka (Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Kalleshwaraswamy et al. 2018).

91. *Odontotermes boveni* Thakur, 1981

Type locality: India: Uttarakhand: Garhwal: Gwaldam.

Distribution: Karnataka (Kalleshwaraswamy et al. 2018).

92. *Odontotermes brunneus* (Hagen, 1858)

Synonyms: *Termes* (*Termes*) *brunneus* Hagen, 1858; *Odontotermes mathadi* Roonwal & Chhotani, 1964a.

Type locality: India: Bengal.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

93. *Odontotermes ceylonicus* (Wasmann, 1902)

Synonyms: *Termes ceylonicus* Wasmann, 1902; *Odontotermes meturensis* Roonwal & Chhotani, 1959.

Type locality: Sri Lanka: Nalanda.

Distribution: Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

94. *Odontotermes distans* Holmgren & Holmgren, 1917

Synonym: *Odontotermes* (*Cyclotermes*) *distans* Holmgren & Holmgren, 1917.

Type locality: India: Tamil Nadu: Shevaroy Hills.

Distribution: Tamil Nadu (Holmgren &

Holmgren,1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

95. *Odontotermes escherichi* (Holmgren, 1911)

Synonym: *Termes escherichi* Holmgren, 1911a.

Type locality: Sri Lanka: Peradeniya: Hantana.

Distribution: Karnataka; Kerala (Chhotani 1997; Krishna et al. 2013; Mathew 2015).

96. *Odontotermes feae* (Wasmann, 1896)

Synonyms: *Termes feae* Wasmann, 1896; *Odontotermes indicus* Thakur, 1981.

Type locality: Myanmar: Carin Chebà.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Vidyashree et al. 2018).

97. *Odontotermes feaeoides* Holmgren & Holmgren, 1917*

Synonyms: *Odontotermes* (*Odontotermes*) *feaeoides* Holmgren & Holmgren, 1917.

Type locality: India: Karnataka: Coorg: Margalli.

Distribution: Karnataka (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

98. *Odontotermes globicola* (Wasmann, 1902)

Synonyms *Microtermes globicola* Wasmann, 1902; *Termes* (*Termes*) *dehraduni* Snyder, 1933b; *Odontotermes roonwali* Bose, 1975.

Type locality: Sri Lanka: Anurhadhapura.

Distribution: Karnataka; Kerala; Tamil Nadu (Bose 1975; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

99. *Odontotermes guptai* Roonwal & Bose, 1961

Synonyms: *Odontotermes bellahunisensis guptai* Roonwal & Bose, 1961; *Odontotermes lokanandi* Chatterjee & Thakur, 1967.

Type locality: India: Rajasthan: Nagaur, near Gudha Village.

Distribution: Kerala (Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Mathew 2015).

100. *Odontotermes horni* (Wasmann, 1902)

Synonyms: *Termes horni* Wasmann, 1902; *Termes peradeniyae* Holmgren, 1911b; *Odontotermes horni hutsoni* Kemner, 1926; *Odontotermes horni minor* Kemner, 1926.

Type locality: Sri Lanka: Nalanda.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

101. *Odontotermes kulkarnii* Roonwal & Chhotani, 1959*

Type locality: India: Karnataka: Bijapur.

Distribution: Karnataka (Roonwal & Chhotani 1959; Bose 1984; Chhotani 1997; Krishna et al. 2013).

102. *Odontotermes latiguloides* Roonwal & Verma, 1973

Type locality: India: Rajasthan: Bhilwara: Mandalgarh.

Distribution: Karnataka (Chhotani 1997; Krishna et al. 2013).

103. *Odontotermes malabaricus* Holmgren & Holmgren, 1917

Synonym: *Odontotermes* (*Odontotermes*) *malabaricus* Holmgren & Holmgren, 1917.

Type localities: India: Kerala: Malabar: Poovanur.

Distribution: Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

104. *Odontotermes microdentatus* Roonwal & Sen-Sarma, 1960

Type locality: India: Uttarakhand: Dehradun: Dobhalwala.

Distribution: Andhra Pradesh; Karnataka (Chhotani 1997; Krishna et al. 2013; Mathew 2015).

105. *Odontotermes obesus* (Rambur, 1842)

Synonyms: *Termes obesus* Rambur, 1842; *Termes fatalis* König, 1779; *Odontotermes* (*Cyclotermes*) *bengalensis* Holmgren, 1912a; *Odontotermes* (*Cyclotermes*) *assamensis* Holmgren, 1913c; *Odontotermes* (*Cyclotermes*) *bangalorensis* Holmgren, 1913c; *Odontotermes* (*Cyclotermes*) *flavomaculatus* Holmgren & Holmgren, 1917; *Odontotermes* (*Cyclotermes*) *obesus oculatus* Silvestri, 1923b; *Termes* (*Cyclotermes*) *orissae* Snyder, 1934; *Termes obesus assmuthi* Van Boven, 1969.

Type locality: India: Bombay.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

106. *Odontotermes parvidens* Holmgren & Holmgren, 1917

Synonyms: *Odontotermes* (*Odontotermes*) *parvidens* Holmgren & Holmgren, 1917; *Odontotermes microdens* Silvestri, 1914b; *Termes* (*Cyclotermes*) *almorensis* Snyder, 1933b.

Type localities: India: Karnataka.

Distribution: Karnataka (Holmgren & Holmgren 1917; Chhotani 1997; Krishna et al. 2013).

107. *Odontotermes redemanni* (Wasmann, 1893)

Synonym: *Termes redemanni* Wasmann, 1893

Type locality: Sri Lanka: Colombo.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

108. *Odontotermes vaishno* Bose, 1975*

Type locality: India: Kerala: Malabar: Kannoth Forest Range: Wayanad Division.

Distribution: Karnataka; Kerala (Bose 1975, 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

109. *Odontotermes wallonensis* (Wasmann, 1902)

Synonyms: *Termes obesus wallonensis* Wasmann, 1902; *Odontotermes brunneus kushwahai* Roonwal & Bose, 1964.

Type locality: India: Maharashtra: Ahmadnagar: Sangamner: Wallon.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Rao et al. 2012; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

110. *Odontotermes yadevi* Thakur, 1981*

Type locality: India: Karnataka: Siddapur.

Distribution: Karnataka; Kerala (Thakur 1981; Chhotani 1997; Krishna et al. 2013; Amina et al. 2016b; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

Subfamily Nasutitermitinae Hare, 1937

Genus *Ampoulitermes* Mathur & Thapa, 1962**

111. *Ampoulitermes wynaadensis* Mathur & Thapa, 1962*

Type locality: India: Kerala: Wynaad: Periyar Forest Range.

Distribution: Kerala (Mathur & Thapa 1962a; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Ceylonitermellus* Emerson, 1960

112. *Ceylonitermellus periyarensis* Amina & Rajmohana, 2013b*

Type locality: Kerala: Idukki: Thekkady: Anchuruli.

Distribution: Kerala (Amina & Rajmohana 2013b).

Genus *Ceylonitermes* Holmgren, 1912

113. *Ceylonitermes indicola* Thakur, 1976

Type locality: India: Kerala: Nilambur.

Distribution: Kerala (Thakur 1976b; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

114. *Ceylonitermes paulosus* Ipe & Mathew, 2019*

Type locality: India: Kerala: Kottayam.

Distribution: Kerala (Ipe & Mathew 2019).

Genus *Emersonitermes* Mathur & Sen-Sarma, 1959**

115. *Emersonitermes thekadensis* Mathur & Sen-Sarma, 1959*

Type locality: India: Kerala: Travancore: Thekkady.

Distribution: Kerala; Karnataka (Mathur & Sen-Sarma 1959; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015).

Genus *Grallatotermes* Holmgren, 1912

116. *Grallatotermes grallatoriformis* (Holmgren & Holmgren, 1917)*

Synonym: *Eutermes* (*Grallatotermes*) *grallatoriformis* Holmgren and Holmgren, 1917.

Type localities: India: Tamil Nadu: Anamalai Hills: Tellkadi.

Distribution: Karnataka; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Kalleshwaraswamy et al. 2018).

117. *Grallatotermes niger* Chatterjee & Thapa, 1964*

Type locality: India: Tamil Nadu: Tunacadur Range: Topslip: Mt. Stuart Block.

Distribution: Kerala; Tamil Nadu (Chatterjee & Thapa 1964b; Bose 1984; Chhotani 1997; Krishna et al. 2013; Amina et al. 2016b).

Genus *Hospitalitermes* Holmgren, 1912

118. *Hospitalitermes madrasi* (Snyder, 1934)*

Synonym: *Nasutitermes* (*Hospitalitermes*) *madrasi* Snyder, 1934.

Type locality: India: Tamil Nadu: North Vellore.

Distribution: Tamil Nadu (Snyder 1934; Bose 1984; Chhotani 1997; Krishna et al. 2013).

119. *Hospitalitermes monocers* (König, 1779)

Synonym: *Termes monoceros atrum* König, 1779.

Type locality: Sri Lanka.

Distribution: Kerala (Amina et al. 2013; Mathew 2015).

Genus *Nasutitermes* Dudley, 1890

120. *Nasutitermes anamalaiensis* Snyder, 1933*

Synonyms: *Nasutitermes* (*Rotunditermes*) *anamalaiensis* Snyder, 1933b; *Alstonitermes flavescens* Thakur, 1976c.

Type locality: India: Tamil Nadu: Anamalai Hills.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Snyder 1933; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

121. *Nasutitermes brunneus* Snyder, 1934*

Synonym: *Nasutitermes* (*Nasutitermes*) *brunneus* Snyder, 1934.

Type locality: India: Tamil Nadu: Anamalai Hills.

Distribution: Karnataka; Kerala; Tamil Nadu (Snyder 1934; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013; Mathew 2015).

122. *Nasutitermes crassicornis* (Holmgren & Holmgren, 1917)*

Synonym: *Eutermes* (*Eutermes*) *crassicornis* Holmgren & Holmgren, 1917.

Type locality: India: Karnataka: Bababudin Hills.

Distribution: Karnataka; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Shanbhag & Sundararaj 2013).

123. *Nasutitermes fletcheri* (Holmgren & Holmgren, 1917)

Synonym: *Eutermes* (*Eutermes*) *fletcheri* Holmgren & Holmgren, 1917.

Type locality: India: Tamil Nadu: Shevaroy Hills.

Distribution: Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013).

124. *Nasutitermes indicola* (Holmgren & Holmgren, 1917)*

Synonyms: *Eutermes* (*Eutermes*) *indicola* Holmgren & Holmgren, 1917; *Eutermes* (*Eutermes*) *processionarius* Schmitz, 1924; *Nasutitermes beckeri* Prashad & Sen-Sarma, 1959.

Type locality: India: Tamil Nadu: Anamali Hills.

Distribution: Karnataka; Kerala; Tamil Nadu (Holmgren & Holmgren 1917; Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015; Kalleshwaraswamy et al. 2018; Vidyashree et al. 2018).

125. *Nasutitermes krishna* Roonwal & Bose, 1970

Type locality: India: Andaman Islands: Little Andaman: Kwate-tu-Kwage.

Distribution: Karnataka (Kalleshwaraswamy et al. 2018).

126. *Nasutitermes matangensis matangensis* (Haviland, 1898)

Synonyms: *Termes matangensis* Haviland, 1898; *Eutermes* (*Eutermes*) *matangensiformis* Holmgren, 1913c; *Eutermes djemberensis* Kemner, 1934.

Type locality: Malaysia: Borneo: Sarawak: Matang.

Distribution: Kerala (Amina et al. 2016b).

127. *Nasutitermes vishnu* Bose, 1984*

Type locality: India: Karnataka: Coorg: Makut.

Distribution: Karnataka (Bose 1984; Chhotani 1997; Krishna et al. 2013).

Genus *Trinervitermes* Holmgren, 1912

128. *Trinervitermes biformis* (Wasmann, 1902)

Synonyms: *Eutermes biformis* Wasmann, 1902; *Eutermes heimi* Wasmann, 1902; *Nasutitermes* (*Trinervitermes*) *longinotus* Snyder, 1934.

Type locality: Sri Lanka: Bandarawella.

Distribution: Andhra Pradesh; Karnataka; Kerala; Tamil Nadu (Bose 1984; Chhotani 1997; Krishna et al. 2013; Mathew 2015; Vidyashree et al. 2018).

129. *Trinervitermes fletcheri* Chatterjee & Thakur, 1965

Type locality: India: Tamil Nadu: Coimbatore.

Distribution: Tamil Nadu (Chatterjee & Thakur 1965; Bose 1984; Chhotani 1997; Krishna et al. 2013).

130. *Trinervitermes nigrirostris* Mathur & Sen-Sarma, 1959*

Type locality: India: Tamil Nadu: Mandapam.

Distribution: Karnataka; Tamil Nadu (Mathur & Sen-Sarma 1959; Bose 1984; Chhotani 1997; Krishna et al. 2013).

131. *Trinervitermes rabidus* (Hagen, 1859)

Synonym: *Termes rabidus* Hagen, 1859.

Type locality: Sri Lanka: Colombo.

Distribution: Tamil Nadu (Chhotani 1997).

132. *Trinervitermes sensarmai* Bose, 1984*

Type locality: India: Andhra Pradesh: North Vijayapuri.

Distribution: Andhra Pradesh (Bose 1984; Chhotani 1997; Krishna et al. 2013).

DISCUSSION

Checklist of species from a defined locality serves as a base for further research. Southern Indian termites comprise 132 species from five families, viz., Hodotermitidae, Kalotermitidae, Rhinotermitidae, Stylotermitidae, and Termitidae. The distribution of few of these species is still uncertain. There is a need to systematically study and identify the voucher specimens of the uncertain records to confirm their presence in the region. Among the reported, Termitidae is the dominant family comprising 106 species from four subfamilies. This indicates that an addition to fauna of termites has occurred in the region after a comprehensive work by Bose (1984), who reported a total of 70 species from 23 genera in the subfamily Termitinae. Five genera and 36 species of the subfamily were added later on. Endemism of termites fauna of the region is high, out of the 138 species, 59 species (42.75%) reported are endemic to southern India. Subfamily Termitinae of family Termitidae accounts for a maximum endemism with 19 species out of 42 endemic species of the family. Among the 37 genera reported from southern India, five genera are endemic to the region with eight species. Three genera of subfamily Termitinae, viz., *Indocapritermes*, *Krishnacapritermes*, and *Labiocapritermes* with one species each in *Indocapritermes* and *Labiocapritermes* and four in *Krishnacapritermes* are endemic to the region. Two genera of subfamily Nasutitermitinae, viz., *Ampoulitermes* and *Emersonitermes* with one species each are endemic to southern India. The latest additions of species to the regional termite diversity are *Krishnacapritermes dineshan* Amina & Rajmohana, 2020 and *Krishnacapritermes manikandan* Amina & Rajmohana, 2020 are endemic to the Western Ghats of southern India (Amina et al. 2020). Families such as Hodotermitidae and Stylotermitidae have only one representative species in the region; *Anacanthotermes viarum* and *Stylotermes fletcheri*, respectively. Hence, this provides an update to the termite fauna of southern India, which, in turn, help termitologist's to look forward for the additions to the termite fauna in the region and direct them towards conservation of endemic species.

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SHORT COMMUNICATION

Population status and distribution of Ibisbill *Ibidorhyncha struthersii* (Vigors, 1832) (Aves: Charadriiformes: Ibidorhynchidae) in Kashmir Valley, India

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Abstract: A field study was carried out for the first time in Kashmir Valley to investigate the population status and distribution of Ibisbill. The initial reconnaissance surveys conducted across Kashmir Valley, indicated that the Lidder River in district Anantnag and Sindh River in district Ganderbal harbor populations of Ibisbill. During the intensive study carried out in the river Sindh from September 2017 to August 2018, the mean population size was maximum (36±8.63) at Stretch I and minimum (3±1.35) at stretch II. The seasonal population of Ibisbill was maximum (25.66±18.44) in the autumn and minimum (10±9.35) in the winter. The present study indicated that river Sindh provides an ideal habitat for Ibisbill, and was most widely used by the bird. We recommend further intensive research studies on the lesser known aspects of ecology and biology of this enigmatic species for long term conservation planning in the region.

Keywords: Distribution, Ibisbill, Kashmir, population status, Sindh.

Ibisbill *Ibidorhyncha struthersii* is a large wader inhabiting the shingle bed rivers of central Asia and Himalaya. It is distributed from the Pamirs and the Himalaya to the Tibetan Plateau with some populations occurring west to Turkistan and east of northern Myanmar (Ali & Ripley 1969; Pierce 1986). The ideal breeding habitat of the Ibisbill comprises rivers with shingle beds on either side at the altitudinal range of 1,700–3,400 m with intermittent stretches of sand and silt, boulders, cobbles, and pebbles (Ye et al. 2013). The Ibisbill is a resident bird of the Himalayan rivers and migrates to lower altitudes in winter. Until now there is very limited scientific information available on the global population status, distribution pattern, and general behavior of Ibisbill (BirdLife International 2020). In the Indian subcontinent, few natural history records mention that the distribution of Ibisbill is restricted to a few places in the Himalaya with localised records of its sightings (Grimmett et al. 2011).

Ibisbill occurs in small flocks occupying small islands and river beds in the Himalaya. The population size has not been quantified globally, however, China is known to have a population of less than 100 breeding pairs (Brazil 2009) and in Nepal Ibisbill population is estimated to be between 100–250 (Inskipp et al. 2016). There are no population estimates available for India, therefore the present study has been a pioneer attempt to understand, assess and generate baseline data on the current population status and distribution of the Ibisbill in Kashmir Valley.

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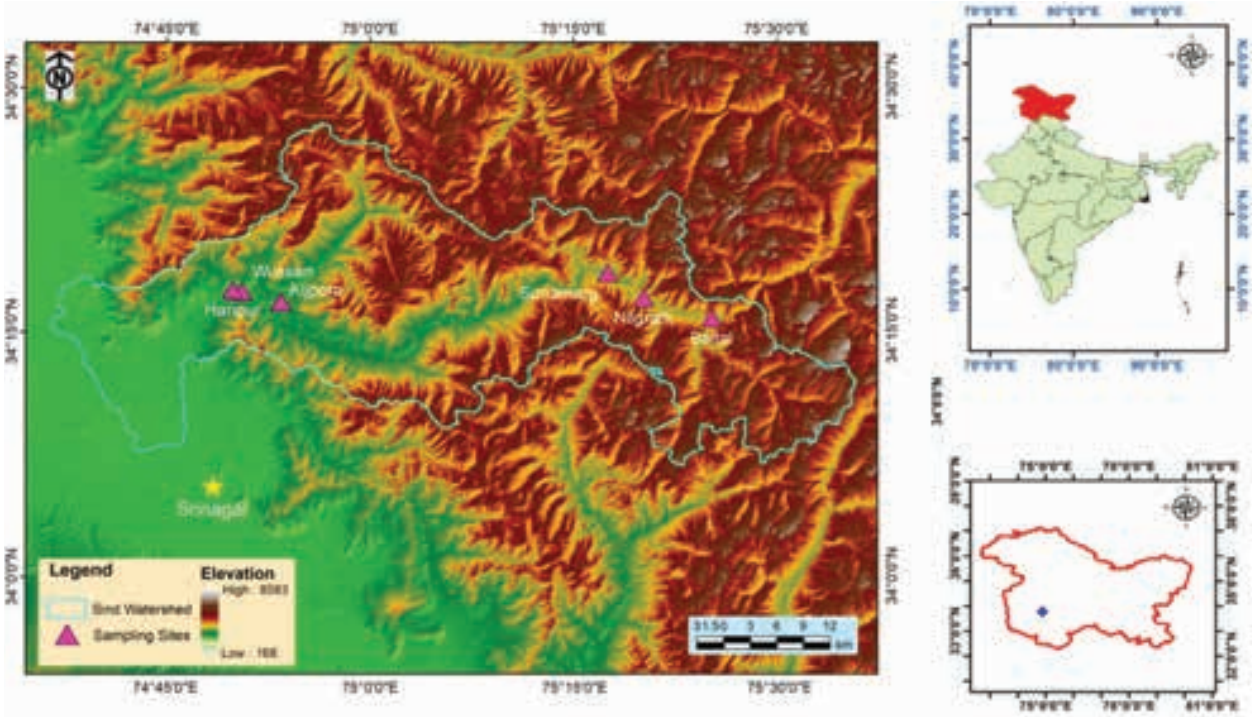

Image 1. Map of the study area.

Methods

Study area

River Sindh, located in district Ganderbal of Jammu & Kashmir at an average elevation of 1,619m is spread across a basin area exceeding 1,559km^2 (Dada et al. 2013). The river originates from Panjtarni snowfields (4,250m) and is further substantiated by the water flow from the Amarnath (5,003m), Kolahoi (5,425m), and Thajwas Glacier (3,000m) (Image 1). In the upper and middle reaches, river Sindh is a fast-flowing torrential river whereas in the lower reaches the river is calmer (Siraj 2018). The river comprises of small islands all along its course dominated by the presence of huge stones in the upper stretches and mainly of cobbles, pebbles, sand, and silt at lower reaches which serve as an ideal habitat for riverine birds including the Ibisbill.

Population monitoring

Preliminary surveys were conducted in all the major rivers of Kashmir Valley, viz., river Lidder (district Anantnag), river Sindh (district Ganderbal), river Vishew (district Kulgam), Madhumatti stream (district Bandipora) to assess the occurrence and distribution of Ibisbill in the valley following survey methodology by Shrubb et al. (1991) and Wilson et al. (2001). Ibisbills were detected in only two rivers; Sindh River and Lidder River with a very few sightings (n= 4 individuals) from the latter. Therefore, subsequent surveys were concentrated only on river Sindh from September 2017 to August 2018.

For the purpose of this study, river Sindh was divided into three stretches, viz., stretch I (Wayuil to Mammar), stretch II (Mammar to Kullan), and stretch III (Kullan to Baltal). For understanding the distribution pattern of Ibisbill in Sindh river, nine transects were laid randomly covering a total length of nearly 60km along the entire riverbank across the three stretches. For accomplishing the status assessment, six study locations (Appendix 1) were delineated along the entire riverbank based on the presence of Ibisbill and they were surveyed on regular basis (Image 1). A total of 72 surveys were conducted in all the four seasons; autumn (September to November), winter (December to February), spring (March to May), and summer (June to August). Observations were made using a pair of binoculars (Nikon Aculon A211 10x50) in the morning hours. During the surveys, individuals were counted at each location following the widely used line transects (Burnham et al. 1980; Bibby et al. 2000).

Results

Ibisbills were sparsely distributed in river Sindh from 34.287–34.258 N and 75.828–75.412 E. The bird occupied only the shingle river bed areas with small pebbles and cobbles, small boulders and moderate flow of water. It was generally present in flocks of 2 to

Table 1. Population status of Ibisbill during the year 2017–2018 in Sindh River.

Study site	Elevation (m)	Year	Autumn	Winter	Spring	Summer	Mean± SE
Stretch I	1,680–1,930	2017–2018	62	29	24	31	36.5±8.63
Stretch II	1,930–2,257	2017–2018	2	1	2	7	3±1.35
Stretch III	2,257–2,859	2017–2018	13	0	7	32	13±6.87

SE—Standard error

Table 2. Encounter rate of Ibisbill during the year 2017–2018 in Sindh River.

Study site	Year	Autumn	Winter	Spring	Summer	Mean± SE
Stretch I	2017–2018	1.47	0.69	0.57	0.73	0.86±0.20
Stretch II	2017–2018	0.04	0.02	0.04	0.16	0.07±0.03
Stretch III	2017–2018	0.30	0	0.16	0.76	0.30±0.16

SE—Standard error

Image 2. Ibisbill adult in Sindh River.

Image 3. Ibisbill juvenile in Sindh River.

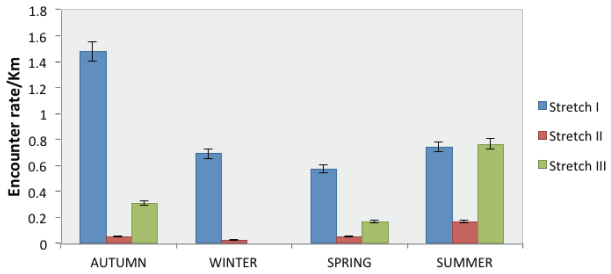

Image 4. Encounter rate in different seasons at all the three stretches in Sindh River.

5, however, in autumn season they were found in larger flock size (>10 birds). On the onset of breeding season, Ibisbill dispersed and the bird became territorial, with a single pair occupying a patch (ca. 50x100 m; n= 8) of the river.

The mean (±SE) population size of Ibisbill was found to be highest (36±8.63) at stretch I and lowest (3±1.35) at stretch II (Table 1). The maximum number (25.66±18.44 SE) of Ibisbill was documented in the autumn season, whereas least (10.33±9.35 SE) in the winter season in Sindh River. Representative images of adult and juvenile are provided in Image 2 and 3, respectively.

The Ibisbill encounter rate was higher (0.86 ± 0.20 individuals/km) at stretch I and lower (0.07 ± 0.03 individuals/km) at stretch II among all the four seasons (Table 2).

The seasonal encounter rate was higher (1.47 detections/km) in autumn at stretch I and lower (0.02 detections/km) at stretch II in winter (Image 4). As the bird does not exhibit sexual dimorphism, we were not able to calculate the male-female ratio in any of the seasons.

Discussion

Ibisbill typically inhabit freshwater shingle bed high altitude rivers of Himalaya (Ali & Ripley 1969) and central Asia (Knystautas 1996). The distribution of Ibisbill is sparse along the river Sindh, such pattern of distribution

can be attributed to the habitat specificity of the bird. Shingle banks with cobbles, pebbles and moderate flow of water appear to be the ideal habitat for birds as these habitat conditions provide the most suitable feeding and breeding grounds (Knystautas 1996). Similar observations have also been recorded by Pierce (1986) while observing the Ibisbill in Nepal. Moreover, Ibisbill can also be also found in agricultural fields near the river for feeding during summer (Haq et al. 2021).

In river Sindh, the average population of Ibisbill was highest at stretch I, as it had the ideal habitat characteristics best suited for the bird. The population of Ibisbill was lowest at stretch II due to the reason that stretch II had areas covered with large stones and increased flow of water and boulder pattern not perfectly suitable for the bird. Besides having large range in central Asia, the population of Ibisbill is low and the bird occurs only at restricted places owing to its special habitat requirement (Ye et al. 2013).

The size of flocks was differing according to the season and the altitude. The size of flocks ranged 2–5 individuals in nonbreeding season except for autumn in which the bird was found to occur in flock size of more than 10 individuals. In breeding season, the bird became territorial, with a single pair occupying a patch of the river. This possibly might be an ecological strategy used by the birds for their survival.

The congregation of the birds in autumn season at lower altitudes firmly indicates the altitudinal migration of the bird, presumably, due to limited availability of food resources and harsh weather conditions at higher elevations as they remain frozen or snow-covered during winter. The altitudinal migration of the Ibisbill in also supported by Shreshta & Lakhay (2000) who studied Ibisbill in Rapti River, Nepal. Kirby & Lack (1993) observed similar patterns of movement in other waders, viz., Golden Plovers *Pluvialis dominica* and Northern Lapwings *Vanellus vanellus*.

Our findings reveal that the river sustains a resident population of Ibisbill and provides baseline information on the status, distribution and occupancy of the bird in a limited number of study sites in the Kashmir Valley. The study also reports congregational behavior in Ibisbill for the first time which occurs in autumn season. We, therefore, recommend a more advanced and intensive studies on the ecology of Ibisbill in the region including use of satellite telemetry or geo tagging to better understand its movement patterns and behavioral aspects.

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Appendix 1. GPS coordinates of the six sites along the Sindh River.

	Study site	GPS coordinates
1	Haripur	34.287^{0}N, 75.828^{0}E
2	Wussan	34.281^{0}N, 74.853^{0}E
3	Kijpora	34.268^{0}N, 74.885^{0}E
4	Sonamarg	34.304^{0}N, 75.291^{0}E
5	Nilgrath	34.289^{0}N, 75.323^{0}E
6	Baltal	34.258^{0}N, 75.412^{0}E

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SHORT COMMUNICATION

A new fish species of genus *Garra* (Teleostei: Cyprinidae) from Nagaland, India

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Abstract: A species of the genus *Garra* is described from the Langlung River, Brahmaputra basin, Nagaland, India. The new species is distinguished from its congeners in having weakly-developed unilobed proboscis, a distinct transverse lobe with 8–12 small sized unicuspid acanthoid tubercles, 30–32 lateral line scales, and 13–15 circumpeduncular scales.

Keywords: *Garra langlungensis* sp. nov., new species, northeastern India.

The members of the labeonine genus *Garra* Hamilton, 1822 are elongated fish that live in torrential rivers and streams. They are widely distributed from Sub-Saharan Africa to Borneo through the Arabian Peninsula, southern Asia, and southern China (Zhang & Chen 2002). The species of *Garra* are diagnosed by the presence of a labial fold forming a gular disc that displays variations in the snout (Kottelat 2020). Nebeshwar & Vishwanath (2017) divided the genus found in southern and southeastern Asia into five groups based on snout morphology: smooth, transverse lobe, proboscis, rostral flap, and the rostral lobe.

The Langlung River, also known as Atu Ghoki (meaning-stone River) is an important tributary of Dhansiri River in Nagaland. It originates near New Jalukie, Peren District and flows through Zutovi Village, Dimapur, and joins with Dhansiri River and finally confluences into the Brahmaputra. The river forms an ideal habitat for *Garra*. There are no prior reports of ichthyological explorations of this river.

A field survey in the Langlung River, a tributary of Brahmaputra drainage in Nagaland, India included the collection of seven undescribed *Garra* with a weakly-developed proboscis and a transverse lobe on the snout. The present paper deals with the formal description of this species as *Garra langlungensis* sp. nov.

Material and Methods

Samples were fixed in 10% formaldehyde and then kept in 70% ethanol. All measurements were made using digital callipers, point to point on the left side of the specimen closest to 0.1mm. Counts, measurements and terminology follow Nebeshwar & Vishwanath (2013). Gular disc terminology follows (Kottelat 2020). Dorsal and anal fin rays follow Kottelat (2001). Lateral line scales were counted from the anterior-most scale in contact with the shoulder girdle to the posterior-most scale on the caudal

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fin. Fin rays and number of scales were counted using Huvitz stereo zoom microscope. Numbers in parentheses following meristic data indicate the number of specimens with that count. Head length and measurements of body are expressed in percentage of standard length (%SL); pelvic-anal distance in the percentage of vent-anal distance; subunits of the head in the percentage of head length (%HL); caudal peduncle depth in the percent of caudal peduncle length. Examined specimens are deposited in the Zoological Survey of India (ZSI), Kolkata.

Results

Garra langlungensis sp. nov. (Images 1 & 2)

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Holotype: ZSI FF7152, 13.i.2017, 54.9mm SL, India, Nagaland, Langlung River near Zutovi Village, Dimapur District, Brahmaputra Basin; 25.716^{0}N, 93.650^{0}E, collected by Ezung et al.

Paratypes: ZSI FF 8859, 6 exs, 54.8–70.2 mm SL, same data as holotype.

Diagnosis

Garra langlungensis sp. nov., a member of the snout with proboscis species group, can be distinguished from other members of this group in having the following combination of characters: weakly-developed unilobed proboscis, a distinct transverse lobe with 8–12 small sized unicuspid acanthoid tubercles, 8–9 pre-dorsal scales, 30–32 lateral line scales and 13–15 circumpeduncular scales. Vent closed to the anal-fin origin than pelvic-fin origin.

Description

Table 1 depicts morphometric and meristic data. Body elongate, laterally compressed, more towards the caudal peduncle. Dorsal head profile rising gently over the snout, slightly convex, more or less continuous with dorsal body profile to dorsal-fin origin, then gently sloping towards caudal peduncle. Ventral profile from head to chest straight and profile from chest to anal-fin origin more or less convex. Head moderately large, depressed with slightly convex inter-orbital area; height less than length; width greater than height. Eyes dorso-laterally located, closer to posterior margin of opercle than to snout tip.

Snout rounded, with a distinct transverse lobe covered with 8–12 small-sized unicuspid acanthoid tubercles, demarcated posteriorly by a narrow moderately deep transverse groove. Proboscis weakly developed, unilobed with small tubercles on its margin (Image 2). Barbels two pairs; rostral barbel anteroventrally located, shorter than eye diameter; maxillary barbel at the corner of the mouth, shorter than rostral barbel. Rostral cap well–developed, its distal margin highly fimbriate, papillate ventral surface moderately wide; separated from upper jaw by deep groove and laterally continuous with the lower lip. Upper jaw entirely covered by the rostral cap. Disc elliptical, shorter than wide and narrower than head width through roots of maxillary barbel; labellum of lower lip distinct; torus well developed with papillae, not covered by the rostral cap; toral groove between the posterior torus and pulvinus deep; papillae on inner half of the whole length of labrum larger and coarsely arranged; anterior marginal surface of pulvinus with coarsely arranged fleshy papillae; posterior most margin of labrum extending vertical to eye.

Dorsal fin with two simple and 8½ branched rays; distal margin concave; origin nearer to snout tip than to caudal-fin base, inserted anterior to vertical through pelvic-fin origin. Pectoral fin with 1 simple and 11 (4) or 12 (3) branched rays, reaching beyond midway to pelvic-fin origin; margin subacuminate. Pelvic fin with 1 simple and 7½ branched rays; second branched ray longest, reaching beyond midway to anal-fin origin, surpassing anus; origin closer to anal-fin origin than to pectoral-fin origin. Anal fin with 2 simple and 5½ branched rays; first branched ray longest, not reaching base of caudal fin; distal posterior margin slightly concave, origin closer to caudal-fin base than to pelvic-fin origin. Vent closer to the anal-fin origin than to pelvic-fin origin. Caudal fin forked with 10+9 principal caudal rays; upper lobe slightly longer; tip of lobes pointed.

Lateral line complete, scales along lateral line 28 (3), 29 (2) or 30 (2) + 2 (7) on caudal-fin base. Transverse scale rows above lateral line scale 3½ (7); between lateral line and pelvic-fin origin 3 (7); between the lateral line to anal-fin origin 3½ (7). Circumpeduncular scales 13 (3), 14 (2) or 15 (2). Pre-dorsal scales 8 (4) or 9 (3); scales regularly arranged. Chest and belly with well-developed scales. One long axillary scale at the base of the pelvic fin, its tip reaching the posterior end of pelvic-fin origin. Dorsal-fin base scales 7 of which last three to four connected to the base of the dorsal fin. Anal-fin base scales 4 of which last three to four connected to the base of the anal fin. Scales between the vent and anal-fin origin 2 (3) or 3 (4).

Coloration: In fresh specimens, head and body greenish-brown dorsally and laterally. Mouth, chest and abdomen white. Dorsal, pectoral, pelvic, anal and caudal fins orange yellowish, fin rays moderately spotted. In preservative, head, dorsal and lateral side dark grey. Mouth, chest and abdomen yellowish white. A black spot at upper angle of gill opening. Dorsal, pectoral, and

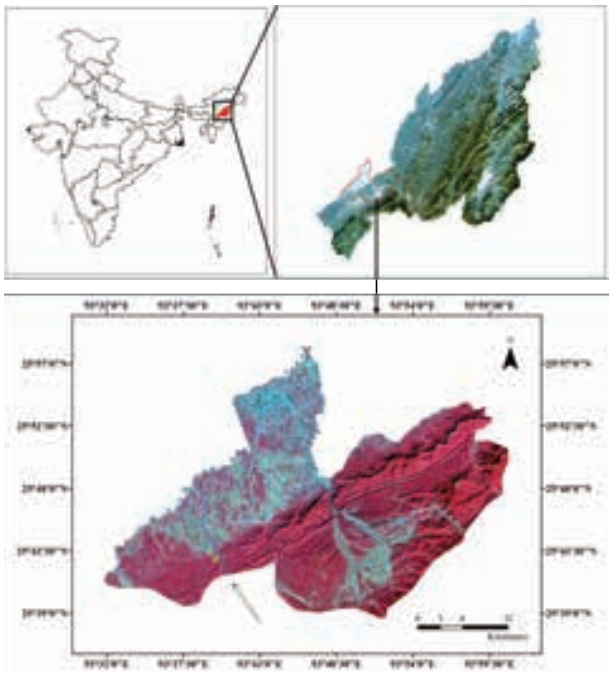

Figure 1. Type locality of *Garra langlungensis* sp. nov.

Image 1. *Garra langlungensis* sp. nov. holotype. ZSI FF7152: A—dorsal view | B—ventral view | C—lateral view. © Sophiya Ezung.

Image 2. *Garra langlungensis* sp. nov. holotype. ZSI FF7152: A—Dorsal view of head | B—Ventral view of oromandibular structures. © Sophiya Ezung.

pelvic fins with thin melanophores. Anal and caudal fins greyish-yellow. Six narrow black stripes on lateral side more prominent towards caudal peduncle. Median rays and tips of upper and lower lobe of caudal fin dark brown.

Etymology: Named after its type locality, Langlung River.

Distribution: *Garra langlungensis* is known only from the type locality, Langlung River near Zutovi Village, Dimapur District, Nagaland, India (Image 3, Figure 1).

Discussion

There are currently 32 valid species of *Garra* belonging to the members of snout with proboscis species group of Nebeshwar & Vishwanath (2017). *Garra langlungensis* belongs to the proboscis species group, and is compared with its congeners of the group, viz., *Garra dengba* Deng et al., 2018, *G. kalpangi* Nebeshwar et al., 2012, *G. gravelyi* Annandale, 1919, *G. bimaculacauda* Thoni et al., 2016, *G. clavirostris* Roni et al., 2017, *G. kangrae* Prashad, 1919, *G. montisalsi* Hora, 1921, *G. parastenorhynchus* Thoni et al., 2016, *G. simbalbaraensis* Rath et al., 2019, *G. stenorhynchus* Jerdon, 1849, *G. substrictorostris* Roni & Vishwanath, 2018, *G. arunachalensis* Nebeshwar & Vishwanath, 2013, *G. biloborostris* Roni & Vishwanath, 2017, *G. birostris* Nebeshwar & Vishwanath, 2013, *G. bispinosa* Zhang, 2005, *G. chindwinensis* Premananda et al., 2017, *G. cornigera* Shangningam & Vishwanath, 2015, *G. gotyla* Gray, 1830, *G. litanansis* Vishwanath, 1993, *G. motuoensis Gong* et al., 2018, *G. quadratirostris* Nebeshwar & Vishwanath, 2013, *G. qiaojiensis* Wu, 1977, *G. rotundinasus* Zhang, 2006, *G. yajiangensis* Gong et al., 2018, *G. bicornuta* Rao, 1920, *G. koladynensis* Nebeshwar & Vishwanath, 2017, *G. nasuta* M'Clelland, 1838, *G. paratrilobata* Roni et al., 2019, *G. surgifrons* Sun et al., 2018, *G. tamangi* Gurumayum & Kosygin, 2016, and *G. trilobata* Shangningam & Vishwanath, 2015.

Garra langlungensis is distinguished from *G. dengba* in having fewer pre-dorsal scales (8–9 vs. 14–16), fewer lateral-line scales (30–32 vs. 42–44), more branched anal-fin rays (5½ vs. 4), branched dorsal-fin rays (8½ vs. 6), more circumpeduncular scales (13–15 vs. 12) and shorter disc width (46–54 vs. 57–73%HL). It differs from *Garra kalpangi* in the absence (vs. presence) of black spot at the base of branched dorsal-fin rays, fewer pre-dorsal scales (8–9 vs. 10–11), fewer transverse row below lateral line (3 vs. 3½–4), fewer circumpeduncular scales (13–15 vs. 16), longer pulvinus length (5.7–6.6 vs. 4.8–5.5 %SL) and greater pulvinus width (8.6–9.5 vs. 7.3–8.1 %SL). It differs from *Garra gravelyi* in the absence (vs. presence) of black spots along dorsal-fin base, more branched dorsal-fin rays (8½ vs. 7), fewer branched pectoral-fin rays (11–12 vs.

Table 1. Morphometric data of *Garra langlungensis* sp. nov. range includes value of holotype. n= number of specimens; SD= standard deviation.

	***Garra langlungensis*- (n=7 including holotype)**			
	holotype	**range**	**mean**	**SD**
Standard length (mm)	54.9	54.8–70.2		
Percent of standard length (% SL)				
Head length	26.2	24.9–27.9	26.4	1
Body depth at dorsal-fin origin	23.5	20.9–25.9	23.5	1.6
Predorsal length	48.7	47.1–49.8	48.7	0.9
Preanus length	67.9	66.6–69.6	67.7	1
Preanal length	74.1	74.1–77.4	75.5	1.1
Prepectoral length	22.4	21.4–22.6	22.1	0.5
Prepelvic length	50.9	50.9–53.9	52	1
Dorsal-fin base length	16.4	16.3–19.0	17.3	0.9
Dorsalfin length	25.1	23.2–25.4	24.1	0.9
Pectoral fin length	23.2	18.4–23.9	22.3	1.8
Pelvic fin length	19.7	18.5–20.3	19.6	0.6
Anal-fin base length	7.1	6.4–7.6	7	0.4
Analfin length	19.5	16.9–20.1	19.1	1.1
Distance from vent to anal fin	5.5	4.8–7.8	6.4	1.2
Caudal peduncle length	16.3	16.3–19.8	18	1.2
Caudal peduncle depth	15.2	14.2–15.7	14.8	0.6
Disc length	8.5	8.5–9.8	9.4	0.5
Disc width	13	12.5–13.7	13	0.4
Pulvinus length	5.7	5.7–6.6	6.1	0.3
Pulvinus width	9.5	8.6–9.5	9.1	0.3
Percent of pelvic-anal distance (% pelvic-anal distance)				
Distance from vent to anal fin	23	19–31	25	4
Percent of head length (% HL)				
Head depth at occiput	75	68–77	72	3
Snout length	55	50–56	53	1
Interorbital distance	45	43–49	46	2
Eye diameter	26	20–26	23	2
Disc length	32	32–38	35	2
Disc width	49	46–54	49	2
Pulvinus length	21	21–25	23	1
Pulvinus width	36	33–36	34	1
Percent of caudal peduncle length (%caudal peduncle length)				
Caudal peduncle depth	93	77–93	82	5
Meristic count				
Dorsal fin rays	ii8½	ii8½		
Pectoral fin rays	i11	i11–12		
Pelvic fin rays	i7½	i7½		
Anal fin rays	ii5½	ii5½		
Caudal fin rays	10+9	10+9		
Pre-dorsal scales	9	8–9		
Lateral line scales	28+2	28–30+2		
Transverse scales	3½/1/3	3½/1/3		
Circumpeduncular scale rows	15	13–15		

14–15), fewer predorsal scales (8–9 vs. 10–11) and more circumpeduncular scales (13–15 vs. 12).

Garra langlungensis is distinguished from *G. bimaculacauda* in the absence (vs. presence) of two distinct black spot in the caudal fin, lesser branched pectoral-fin rays (11–12 vs. 14), fewer pre-dorsal scales (8–9 vs. 11–12), transverse scale rows from dorsal-fin origin to lateral line (3½ vs. 6), more circumpeduncular scales (13–15 vs. 12), shorter disc length (32–38 vs. 40–44 %HL). It differs from *G. clavirostris* in having weakly-developed proboscis (vs. clubbed proboscis), lesser branched pectoral fin rays (11–12 vs. 14–15), transverse scale rows from dorsal origin to lateral line (3½ vs. 5½) and smaller disc length (32–38 vs. 50–65 % HL); from *G. kangrae* in having weakly-developed proboscis (vs. prominent quadrate proboscis), fewer branched pectoral-fin rays (11–12 vs. 15) and fewer lateral line scales (30–32 vs. 34). It differs from *G. montisalsi* in having weakly-developed proboscis (vs. prominent unilobed proboscis projecting upward above the transverse lobe), longer disc length (32–38 vs. 28 %HL), pulvinus length (21–25 vs. 18 %HL) and pulvinus width (33–36 vs. 22 %HL).

Garra langlungensis is distinguished from *G. parastenorhynchus* in having weakly-developed proboscis (vs. club-shaped overhanging proboscis), fewer pre-dorsal scales (8–9 vs. 10–11), circumpeduncular scales (13–15 vs. 16), more head length (24.9–27.9 vs. 28.5–30.7 %SL), lesser pre-anus length (66.6–69.6 vs. 70.1-74.2 %SL) and more interorbital width (43–49 vs. 34–39 %HL). It differs from *G. simbalbaraensis* in having weakly-developed proboscis (vs. prominent unilobed rounded proboscis), fewer circumpeduncular (13–15 vs. 16) and more pulvinus width (33–36 vs. 26–29 %HL). It differs from *G. stenorhynchus* in having weakly-developed proboscis (vs. prominent quadrate proboscis) and fewer lateral line scales (30–32 vs. 34). It differs from *G. substrictorostris* in having weakly-developed proboscis (vs. narrow antrorse unilobed proboscis), fewer branched pectoral-fin rays (11–12 vs. 15), fewer pre-dorsal scales (8–9 vs. 10), transverse scale rows from dorsal origin to lateral line (3½ vs. 5½), circumpeduncular (13–15 vs. 16), shorter pre-anus length (66.6–69.6 vs. 70.3–77.7 %SL), disc length (32–38 vs. 44–55 %HL) and disc width (46– 54 vs. 53–66 %HL).

Garra langlungensis can be differentiated from *G. arunachalensis*, *G. biloborostris*, *G. birostris*, *G. bispinosa, G.chindwinensis, G. cornigera*, *G. gotyla*, *G. litanansis, G. motuoensis, G. quadratirostris*, *G. qiaojiensis*, *G. rotundinasus G. yajiangensis* in having weakly-developed unilobed proboscis (vs. prominent bilobed or slightly bilobed) proboscis on the snout. It can be differentiated from *G. bicornuta, G. koladynensis, G. nasuta*, *G. paratrilobata*, *G. surgifrons, G. tamangi*, and *G. trilobata* in having weakly-developed unilobed (vs. prominent trilobed) proboscis on the snout.

Image 3. Langlung River, Nagaland, India; type locality of *Garra langlungensis* sp. nov. © Sophiya Ezung.

Comparative material and sources

Garra arunachalensis: Data from Nebeshwar & Vishwanath (2013)

Garra bicornuta: Data from Rao (1920)

Garra biloborostris: ZSI FF 7928, 2 paratypes, 69.1–75.6 mm; India, Assam, Chirang District, Kanamakra River, Brahmaputra basin, Sewali and Paraty.

Garra bimaculacauda: Data from Thoni et al. (2016)

Garra birostris: Data from Nebeshwar & Vishwanath (2013)

Garra bispinosa: Zhang (2005)

Garra chindwinensis: ZSI FF 5906, holotype, 120mm SL, India, Manipur, Senapati District, Laniye River nearLaii, Premananda.

Garra clavirostris: ZSI FF 6062, 2 paratypes, 71.2–83.0 mm SL; India, Assam, Dima Hasao District, DilaimaRiver at Boro Chenam village below the confluence of Dilaima and Dihandi Brahmaputra drainage.

Garra cornigera: ZSI FF 5995, 2 paratypes, 72.19–46.82 mm SL; India, Manipur, Ukhrul District, Sanalok River, Chindwin basin.

Garra dengba: Data from Deng et al. (2018)

Garra gotyla: Data from Gray (1830)

Garra gravelyi: ZSI F 9694/1, type, 60.9mm SL; Myanmar, S. Shan States, he-ho stream, Annandale (1919)

Garra kalpangi: Data from Nebeshwar et al. (2012)

Garra kangrae: Data from Prashad (1919)

Garra koladynensis: Data from Nebeshwar &Vishwanath (2017)

Garra litanensis: Data from Vishwanath (1993)

Garra magnacavus: Data from Shangningam et al.

(2019)

Garra montisalsi: ZSI F 9953/1, type, 100.8mm. SL; India, Punjab, Nilwan ravine near the Shapur salt ranges.

Garra mutuoensis: Data from Gong et al. (2018)

Garra nasuta: Data from Menon (1964)

Garra parastenorhynchus: Data from Thoni et al. (2016)

Garra paratrilobata: Data from Roni et al. (2019)

Garra qiaojiensis: Data from Gong et al. (2018)

Garra quadratirostris: Data from Nebeshwar & Vishwanath (2013)

Garra rotundinasus: Data from Zhang (2006)

Garra simbalbaraensis: ZSI FF 8003, 60.8mm SL; India: Himachal Pradesh, Sirmaur District, Simbalbara River, Yamuna River Basin.

Garra stenorhynchus: ZSI F 9957, 64.5mm SL; India, Mysore, hillstream, Coorg,

Garra substrictorostris: Data from Roni & Vishwanath (2018)

Garra surgifrons: Data from Gong et al. (2018)

Garra tamangi: ZSI FF 5423, paratypes, 102.4mm SL; India, Arunachal Pradesh, Dikrong River at Hoj, Brahmaputra drainage.

Garratrilobata: ZSI FF 5994, 2 paratypes, 95.78–119.14 mm SL; India, Manipur, Ukhrul District, Sanalok River.

Garra yajiangensis: Data from Gong et al. (2018)

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SHORT COMMUNICATION

Occurrence of Tamdil Leaf-litter Frog *Leptobrachella tamdil* (Sengupta et al., 2010) (Amphibia: Megophryidae) from Manipur, India and its phylogenetic position

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Abstract: We present a new state record of *Leptobrachella tamdil* from Manipur State, northeastern India based on three individuals collected from Chakpi stream, Chandel District. This record represents the range extension of the species as well as the easternmost distribution record. We also provide additional morphological data as well as the first time genetic data for the species and inferred its phylogenetic position using mitochondrial 16S rRNA marker gene sequence.

Keywords: 16S rRNA, morphology, northeastern India, phylogeny, range extension.

Leptobrachid frogs are one of the most speciose groups comprising 166 species with four genera namely *Leptobrachella* Smith, 1925, *Leptobrachium* Tschudi, 1838, *Oreolalax* Myers and Leviton, 1962, and *Scutiger* Theobald, 1868. The Tamdil Leaf-litter Frog belongs to the genus *Leptobrachella* which consists of 86 congeners that are presently known from southern China, northeastern India, Myanmar through Thailand, Vietnam to Malaysia, Borneo, and Natuna Island (Frost 2021). *Leptobrachella tamdil* was originally described as *Leptolalax tamdil* based on two specimens collected from the Tamdil National Wetland, Mizoram, India (Sengupta et al. 2010). It had been known only from its type locality for about a decade. An additional specimen was reported from Dampa Tiger Reserve (DTR) (23.387–23.705N; 92.273–92.431E), Mamit District, Mizoram near the Bangladesh international boundary by Vanlalsiammawii et al. (2020). Herein, we report the occurrence of *L. tamdil* from Chakpi Stream, Chandel District, Manipur State with comments on the taxon's phylogenetic position inferred using partial sequences of mitochondrial 16S rRNA gene.

Methods

Herpetological surveys were carried out in two different bouts. The first trip was conducted during 16 December 2020 to 5 January 2021, and the second trip during 18 January 2021 to 24 January 2021, with a total

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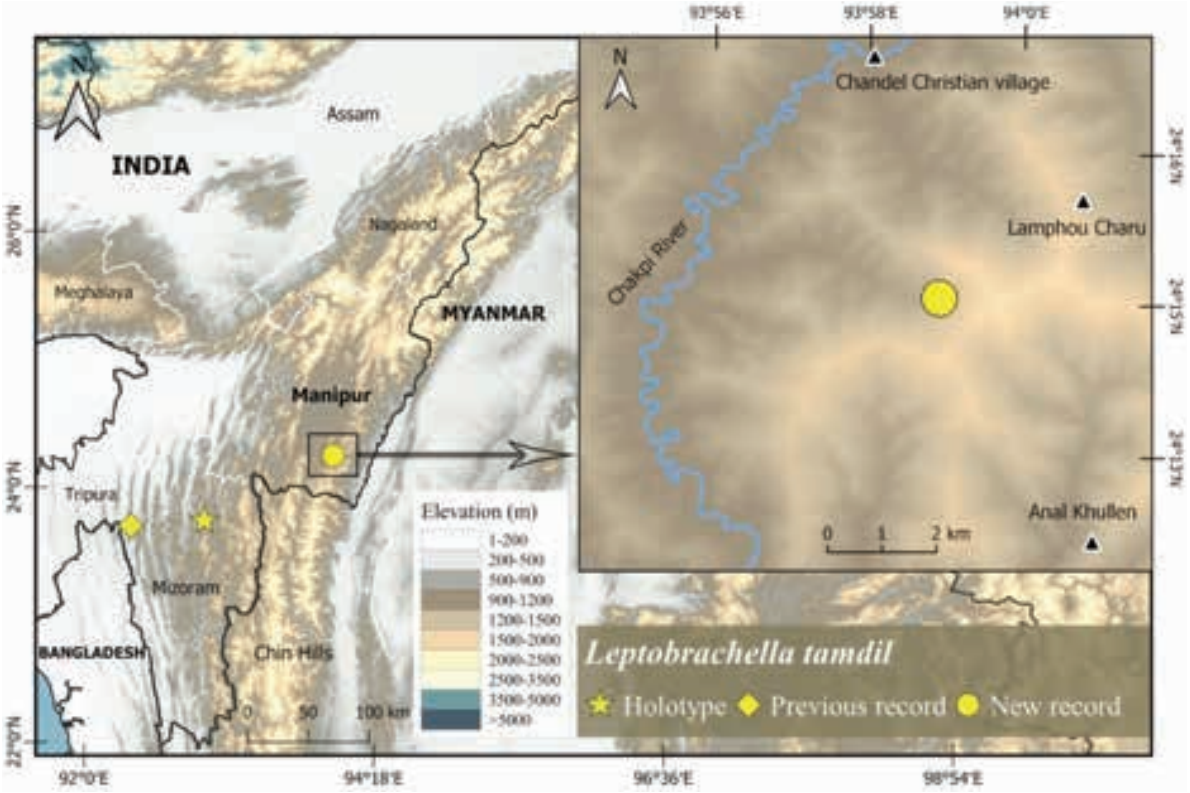

Figure 1. Map showing the type locality (in yellow star), previous record (in yellow diamond), and new record (in yellow dot) of *Leptobrachella tamdil* at Chakpi Stream, Chandel District, Manipur, India.

of 27-days field trip, and covering a total distance of ca. 120km. On 16 December 2020, we encountered the first two adult male individual frogs (MZMU 2224 and MZMU 2225) from the Chakpi Stream bed (24.1454N, 93.5856E; 1,122m) at around 17.40h, the sampling site is located ca. 30km south from Chandel Town, Chandel District, Manipur (Figure 1). The nearest village from the collection site is the Lamphou Charu located at ca. 4km. After a month, on 23 January 2021 at 19.59h, we encountered an adult female (MZMU 2226) at the upper stream bed (24.1453N, 93.5857E; 1,228m) ca. 7m away from the previous collection site. During the present work, the sampling sites were visited four times at day time, dusk, and night time.

Specimens of *L. tamdil* collected in this study were photographed by using Sony DSC-HX400V (50x optical zoom) digital camera. Specimens (MZMU 2224, MZMU 2225, and MZMU 2226) were fixed in 4% formalin, later preserved in 70% ethyl alcohol, liver tissues were stored in 95% ethyl alcohol for molecular processing, and deposited in Museum of Zoology, Mizoram University (MZMU), India. The altitude with the geo-locations was recorded by using global positioning system device (Garmin Montana 650-GPS navigator). A digital thermo hygrometer (Kusam Meco KM 918) was used for measurement of temperature and relative humidity. The morphometric parameters of the specimens were measured by using Mitutoyo™ (505–730) dial calipers and are given to the nearest 0.1mm. The sex was determined through dissection. The parameters from Sengupta et al. (2010) and Vanlalsiammawii et al. (2020) were followed to measure the frog specimens (Table 1).

Genomic DNA was extracted from the 95% ethanol preserved liver tissues of the frog specimens using QIAamp DNA Mini Kit (Cat No.ID:51306) following the manufacturer protocol. PCR reaction was prepared for 20µL reaction mixture contained 1X amplification buffer, 2.5 mM$MgCl_2$, 0.25 mM dNTPs, 0.2 pM each forward and reverse primer, 1µL genomic DNA, and 1U Taq DNA polymerase with a pair of partial 16*S* rRNA primers: forward (L02510- CGC CTG TTT ATC AAA AAC AT) (Palumbi 1996) and reverse (H03063- CTC CGG TTT GAA CTC AGA TC) (Rassmann 1997). The PCR thermal regime for amplification was 5 min at 95°C for initial denaturation, followed by 35 cycles of 1 min at 95°C for denaturation, 30s for annealing at 50.3°C, elongation for 1 min at 72°C, and a final elongation for 5 min at 72°C. PCR products were checked by gel electrophoresis on a 1.5% agarose gel

Table 1. Detailed morphological (in mm) and eggs data of *Leptobrachella tamdil* from Chandel District, Manipur, India.

Voucher number	MZMU2224	MZMU2225	MZMU2226	Vanlalsiammawii et al. (2020)	Sengupta et al. (2010)	
				MZMU 1631	ZSI A10962 (Holotype)	ZSI A10963 (Paratype)
Sex	Male	Male	Female	Male	Male	Female
Locality	Chandel, Manipur			Dampa Tiger Reserve, Mizoram	Tamdil National Wetland, Mizoram	
SVL	28.7	27.8	33.2	31.3	32.3	31.8
IN	2.7	2.7	2.9	3.2	3.2	3.1
HL	9.8	9.9	11.4	9.2	8.7	8.8
HW	9.6	9.2	11	10.5	12.0	12.0
HD	4.2	4	4.3	4.4	5.2	4.8
ED	4	4.2	4.8	4.3	4.5	4.6
IO	3.9	3.8	4	4.8	5.1	5.8
E-S	3.5	3.9	4.4	4.6	4.7	4.7
E-N	2.1	1.7	2.2	2.5	2.8	2.7
UE	3	3.2	3.8	3.1	3.4	3.5
TL	12.6	12.7	15	14.2	16.0	15.7
IMT	1.8	1.5	1.8	1.8	1.9	1.8
IPT	1.8	1.5	2	2.1	2.2	1.8
A-G	14	13.6	16.3	13.7	13.8	13.8
BW	9.9	8.3	10.5	9.8	9.7	11.9
No. of eggs			n= 105			
Diameter of eggs			1.4–1.5			

containing ethidium bromide. Samples were sequenced using Sanger's dideoxy method and sequencing reactions were carried out in both directions on a sequencer (Agrigenome Labs Pvt Ltd., Kochin, India). The generated partial 16S rRNA sequences were deposited in the GenBank repository (accession numbers: MW665130.1; MW665131.1; MW665132.1). In our dataset of 16S rRNA, we included 34 congeneric sequences obtained from National Centre for Biotechnology Information (NCBI) database and our generated sequence of *Duttaphrynus melanostictus* (MW165455.1) sample was used as an outgroup. All sequences were aligned by using Muscle algorithm in MEGA 7 (Kumar et al. 2016), the Kimura 2 (K2P) and genetic distances (Kimura, 1980) were calculated using MEGA 7 (Kumar et al., 2016). The Bayesian Inference (BI) phylogenetic tree (Figure 2) was constructed in MrBayes 3.2.5 using GTR+I+G model. The MCMC (one cold and three hot chains) was run for one million generations by sampling every 1,000 generations and set the burn-in to 25%. The analysis was terminated when the standard deviation of split frequencies was less than 0.001. The percentage of trees in which the associated taxa clustered together is shown next to the branches (Ronquist & Huelsenbeck 2003). The generated phylogenetic tree was further illustrated using Figtree 1.44v (Rambaut 2014).

Results

The collected specimens are identified as *L. tamdil* based on the original morphological diagnostic features (Sengupta et al. 2010), and the new specimens showed genetic homogeneity on the phylogenetic tree with the mean intra-species K2P genetic distance of 0.0%. Our recently collected specimens are diagnosed in showing the following combination of characters: SVL between 27.8–28.7 mm in males and 33.2mm in the only female; dorsum tuberculate; eyelids with tubercles; tympanum and supratympanic fold distinct; supratympanic fold extending to posterior edge of tympanum; macroglands, including preaxillary, pectoral, femoral and ventrolateral glands present; Finger II > I; toe tips not dilated, bearing dermal fringes; relatively long hind limbs, with heels in contact when limbs are held perpendicular to body; dorsum with dark blotches; flanks with small dark blotches; dark tympanic mask present; venter pale; labial bars present and limbs with dark cross-bars (Sengupta et al. 2010). Current location extends the range of the species by ca. 122km aerial distance northeast from the

Table 2. Genetic distance among *Leptobrachella* species using 16S rRNA partial gene sequence. Only the species showing low genetic distances with *L. tamdil* are provided in the table.

	Species	K2P distance																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	*L. tamdil* MW665131.1																				
2	*L. tamdil* MW665132.1	0.00																			
3	*L. tamdil* MW665130.1	0.00	0.00																		
4	*L. laui* MH406903.1	0.09	0.09	0.09																	
5	*L. liui* MH923370.1	0.09	0.09	0.09	0.04																
6	*L. puhoatensis* KY849587.1	0.09	0.09	0.09	0.07	0.09															
7	*L. wulingensis* MT530316.1	0.10	0.10	0.10	0.08	0.06	0.08														
8	*L. petrops* MH055903.1	0.09	0.09	0.09	0.07	0.09	0.00	0.08													
9	*L. bourreti* KR018124.1	0.10	0.10	0.10	0.09	0.07	0.09	0.02	0.09												
10	*L. minimus* JN848369.1	0.11	0.11	0.11	0.07	0.08	0.09	0.08	0.09	0.09											
11	*L. mangshanensis* MH277365.1	0.10	0.10	0.10	0.05	0.02	0.09	0.08	0.09	0.08	0.08										
12	*L. dorsospina* MW046194.1	0.10	0.10	0.10	0.09	0.07	0.09	0.03	0.09	0.03	0.09	0.08									
13	*L. nyx* MH055818.1	0.10	0.10	0.10	0.08	0.07	0.09	0.07	0.09	0.08	0.06	0.07	0.08								
14	*L. pluvialis* MT644610.1	0.10	0.10	0.10	0.07	0.07	0.09	0.08	0.09	0.08	0.05	0.07	0.09	0.04							
15	*L. purpuraventra* MK414531.1	0.11	0.11	0.11	0.10	0.07	0.09	0.04	0.09	0.03	0.10	0.08	0.03	0.08	0.08						
16	*L. suiyangensis* MK829650.1	0.12	0.12	0.12	0.10	0.09	0.10	0.05	0.10	0.04	0.11	0.10	0.04	0.10	0.10	0.04					
17	*L. alpinus* MH406905.1	0.12	0.12	0.12	0.10	0.09	0.11	0.05	0.11	0.05	0.11	0.09	0.05	0.10	0.10	0.05	0.06				
18	*L. shangsiensis* MK095461.1	0.12	0.12	0.12	0.08	0.08	0.10	0.09	0.10	0.10	0.06	0.09	0.09	0.05	0.05	0.09	0.11	0.11			
19	*L. aspera* MW046202.1	0.12	0.12	0.12	0.10	0.10	0.10	0.08	0.10	0.09	0.08	0.10	0.10	0.06	0.06	0.10	0.11	0.11	0.06		
20	*L. bijie* MK414539.1	0.12	0.12	0.12	0.09	0.08	0.10	0.05	0.10	0.05	0.10	0.09	0.04	0.10	0.10	0.03	0.04	0.06	0.10	0.11	

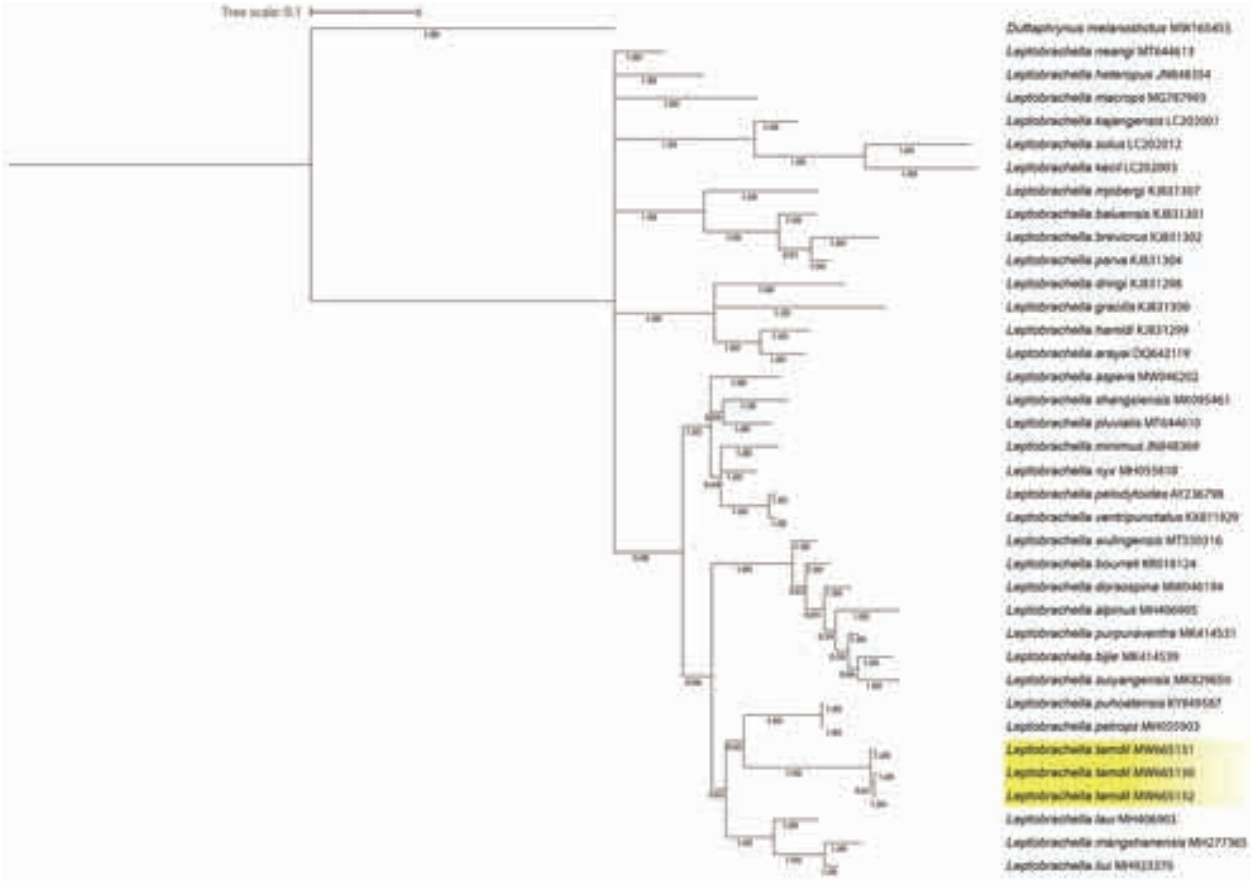

Figure 2. Bayesian inference phylogenetic relationship among *Leptobrachella* species using partial 16S rRNA gene sequences. The numbers at nodes represent Bayesian posterior probabilities.

type locality at Tamdil National Wetland, Mizoram, India.

Our generated partial 16S rRNA gene sequences of *L. tamdil* (MW665130.1; MW665131.1; MW665132.1) were compared with the congeners sequences obtained from NCBI database. From the estimated K2P genetic distances (Table 2), we infered that *L. laui* (MH406903.1) to be the closest species by showing 9% genetic distance with the sequences of *L. tamdil* (MW665130.1; MW665131.1; MW665132.1). Moreover, the phylogenetic relationship revealed that *L. tamdil* formed a distinct lineage within the monophyletic clade comprising *L. puhoatensis* + *L. petrops* (Figure 2); the former taxon (*L. puhoatensis*) is known only from its type locality in Pu Hoat Nature Reserve, Vietnam, and the later (*L. petrops*) is recorded only from four Provinces (Tuyen Quang, Lai Chau, Thanh Hoa, and Phu Tho) in Vietnam (Frost 2021).

Discussion

Live individuals of *Leptobrachella tamdil* were found in the secondary forests, ca. 30km south of Chandel Town. Chandel District is surrounded by tropical semi-evergreen and moist deciduous/secondary forest, subjugated by *Schima wallichii*, *Albizzia* sp. and *Macaranga denticulata*. The forest in the moist valleys is lofty, while steep slopes are covered with canopy (Singh et al. 2000; Forest Survey of India 2019). Chakpi's slow-flowing streams where sampling was carried out, is surrounded by the subtropical semi-evergreen and the sub-tropical hill forests, predominantly subjugated by *Juglans* sp., *Albizzia chinensis, Quercus* sp., *Macaranga denticulata*, and *Schima wallichi* based on the classification of Champion & Seth (1968). Specimens were collected from beneath weathered sedimentary rocks and on the exposed sand stones in the vicinity close to slow-flowing stream. This is quite similar to the previous collection site of the species from Dampa Tiger Reserve, Mizoram State by Vanlalsiammawii et al. (2020). During the collection period, atmospheric temperature and relative humidity were 12.9°C and 83.6 %, respectively. Chakpi offshoots offer a unique ecosystem and congenial breeding grounds for many rare amphibian species especially near stagnant and flowing water. In Chakpi, streams were bounded by sedimentary rocks and weathered huge boulders and logs which provide suitable breeding spot for several

Image 1. *Leptobrachella tamdil* from Chandel District, Manipur State, India: A—Three adult individuals, left to right – (Male, MZMU2224; Male, MZMU 2225; Female, MZMU 2226) | B—Microhabitat at Chakpi Stream | C—Adult female individual MZMU 2226.

anuran species. Sympatric frog species includes *Amolops* cf. *indoburmanensis* and *Sylvirana* cf. *lacrima* that were observed at the upper reaches of the elevated stream bed. The present study found a gravid female (MZMU 2226) with 105 eggs. We suggest that the breeding season is likely to start during dry season (December to January) as hinted by the presence of gravid females and deposition of eggs. The egg diameter of *L. tamdil* range between 1.4–1.5 mm (N= 10). The conservation status for the species remains unclear. Deuti (2013) categorized this species as data deficient (DD), but later Dinesh et al. (2020) corrected that to not assessed (NA). Thus, the proper assessment of its conservation status is lacking. The microhabitat of *L. tamdil* consisted primarily of intermediate-flowing stream within tropical semi-evergreen forest (Sengupta et al. 2010; Vanlalsiammawii et al. 2020). Other aspects of *L. tamdil* such as the breeding biology, tadpole morphology, diet, and general life history remain largely unknown and considerable works are needed to shed more light on this species. Legitimately, the present record of *L. tamdil* from northeastern part of India represents the northeastern-most locality with the highest altitude (1,220–1,228 m), against the records in Mizoram at 745 m (Sengupta et al. 2010) and 449 m (Vanlalsiammawii et al. 2020). This study provides a range extension of *L. tamdil* away from the type locality in Mizoram, north-east towards Manipur, and it is likely present in the adjacent country of Myanmar and possibly in Assam, Nagaland, and Tripura states. The new individuals represent the latest range of SVL (27.8–33.2 mm), and the breeding season might be commencing from late winter as indicated by the presence of gravid female. Further observations are necessary to know more information about the biology of *L. tamdil*.

The loss of forest canopy and natural streams were

noted to directly threaten the habitats of the anuran species. Jhum cultivation, forestry effluents, and forest fires are also attributed to it (see Gupta 2000; Shimray 2004; Maithani 2005; Bhattacharya & Nanda 2005; Kerkhoff et al. 2006; Sastry et al. 2007; Jamir & Lianchawii 2013; Reimeingam 2017). The first step towards ensuring the long-term persistence of such anurans is addressing the lack of understanding of range, population trends, ecology, and potential threats. Mitigation measures must be put in place to stop the unchecked depletion of the resources of such little-known species, failing which *L. tamdil* and other such taxa will regrettably be wiped out from Manipur, to say the least (Banita & Bordoloi 2007). Overall, amphibian studies in the northeastern India is the least when compared to rest of the regions of the country and especially amphibian faunal inventorying is scanty in Manipur State. Safeguarding the ecological diversity of the existing areas is most likely to protect viable populations of such fragile wildlife. Surroundings of the Chandel Village include some intact habitats that are suitable for anurans where probable discovery of unique amphibians are reasonably high. Thus, extensive explorations can ascertain the true amphibian richness in the present study area.

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SHORT COMMUNICATION

Further additions to the Odonata (Insecta) fauna of Asansol-Durgapur Industrial Area, Paschim Bardhaman, India

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Abstract: In this present communication we report the occurrence of additional 13 Odonate species from the Asansol-Durgapur Industrial Area, West Bengal, India, making the total 76. This paper reports the first record of *Libellago indica* (Fraser, 1928) and first photographic records of *Macromia flavicincta* Selys, 1874 from West Bengal. It also reports the range extension of *Macromia cingulata* Rambur, 1842 from the Purulia District to Paschim Bardhaman District.

Keywords: Damselfly, dragonfly, Odonata, Paschim Bardhaman.

The first peer reviewed work on the Odonata fauna of Asansol-Durgapur Industrial Area, Paschim Bardhaman, West Bengal, India was conducted by Nayak & Roy (2016), which reported a total number of 57 species. Nayak (2020) added six more species to the list, thereby increasing the total species to 63. In this communication, we report an additional 13 species found from the same region, however, the aim of the present study is to update the checklist of the Odonata fauna of Asansol-Durgapur industrial area.

Materials and Methods

Study area: The present study is conducted at all 13 study sites along with six new study points which are situated in Asansol-Durgapur (23.689–23.520^{0}N and 86.966–87.312^{0}E) area, an important industrial urban agglomeration of Paschim Bardhaman District of West Bengal, India (Figure 1). The details of 19 study points are given in the Table 1.

Data collection: The present work has been conducted by both the authors from October 2019 to October 2020 in different selected study sites of the region. We also examined our previously (January 2013 to September 2019) captured images during the present study and some species were identified which are new records for the study region. A combination of direct search technique (Sutherland 1996) and opportunistic sighting methods were applied during the entire study (January 2013 to October 2020) to record Odonata diversity. Individual species were photo-documented from the study area (Figure 1). Images (Images 1–13) were cross-checked and identified using standard field guides (Fraser 1933, 1934, 1936; Subramanian 2009; Nair 2011). Canon Power Shot SX40 HS, Nikon Coolpix P600 and Nikon D5300 camera with Nikkor Af-P 70–

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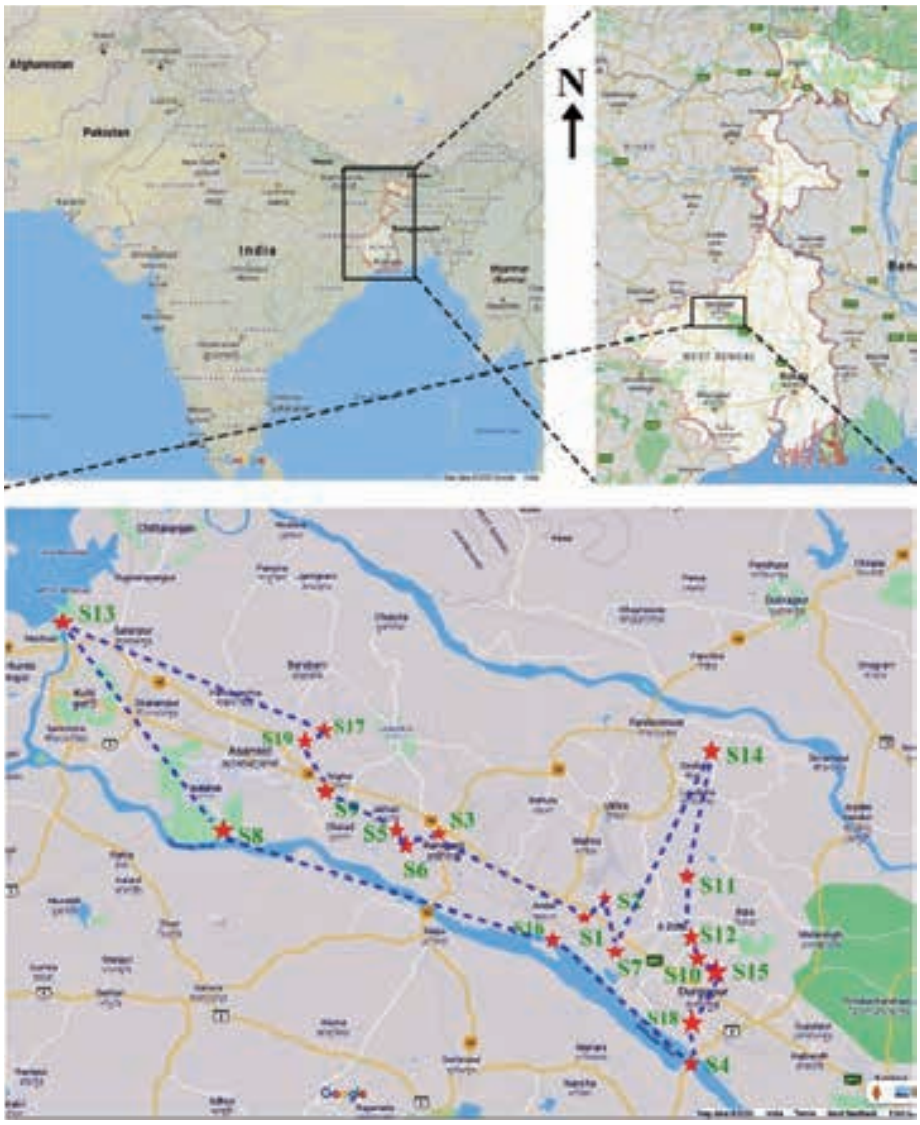

Figure 1. Study sites (S1–S19) under present investigation from Asansol-Durgapur area of Paschim Bardhaman District from West Bengal, India. Source – Google Maps.

300mm lens were used for photo documentation of the odonates.

Results

A total of 13 different Odonata species were recorded including both dragonflies (Anisoptera) and damselflies (Zygoptera) (Figure 2), which were represented by 12 genera from seven families. Among these, three families were represented by damselflies (Zygoptera), viz., Lestidae (One species and one genus), Chlorocyphidae (One species and one genus), and Coenagrionidae (two species and two genera) (Figure 3). Rest of the families was represented by dragonflies (Anisoptera), viz., Aeshnidae (two species and two genera), Gomphidae (one species and one genus), Macromiidae (two species and one genus), and Libellulidae (four species and four genera) (Figure 4). Comparison of the previously reported and the new reports of Anisoptera and Zygoptera sub-order from the study region are represented by Figures 5 & 6, respectively. All these 13 species found in Ajay-Damodar River basin area are new reports for the entire district. Systematic arrangement of the species follows Subramanian & Babu (2017). A detailed account of the species is given below:

Suborder Anisoptera Selys, 1854
Family Aeshnidae Leach, 1815
1. *Anax indicus* Lieftinck, 1942
IUCN status: Least Concern (Mitra 2010)
Sighted on: 18.x.2016, 02.xi.2018, 18.x.2019, 05.ix.2020,

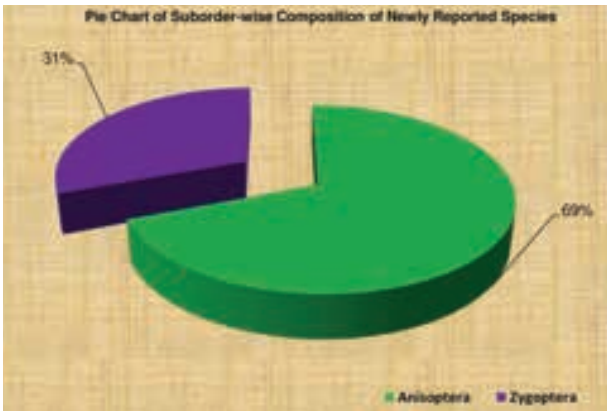

Figure 2. Percentage of newly recorded species of Anisoptera and Zygoptera from Asansol-Durgapur Industrial Area.

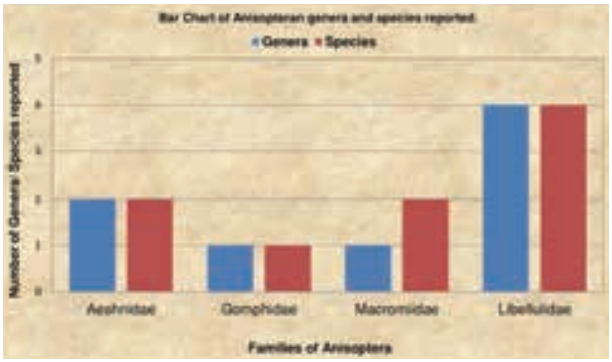

Figure 3. Family-wise numbers of anisopteran genera and species reported during the present study.

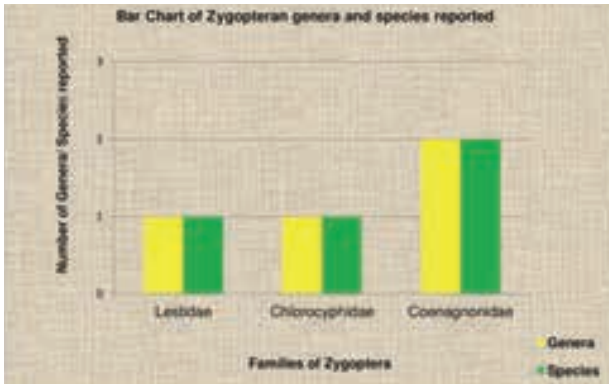

Figure 4. Family-wise numbers of zygopteran genera and species reported during the present study.

28.x.2020; Study sites: S1, S12, S14

Comments: This species is commonly seen in the study region. It hovers above wetlands and water bodies. We found two individual females in different place and time, hanging vertically inside the scrub during day time.

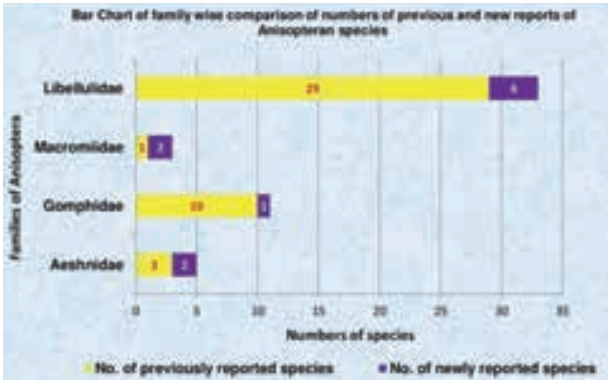

Figure 5. Family-wise comparison of numbers of previous and new reports of anisopteran species.

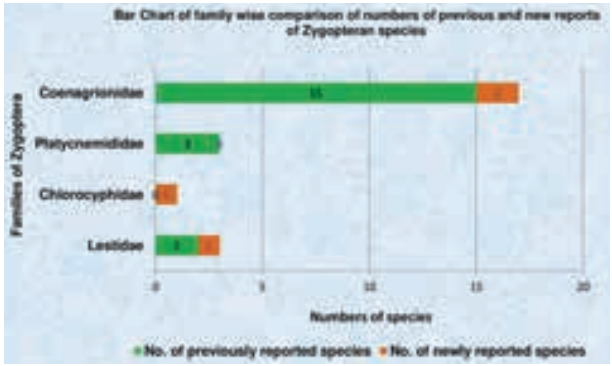

Figure 6. Family-wise comparison of numbers of previous and new reports of zygopteran species.

AKN found this species frequently from S1. From S12 & S14 each, single female individuals have been sighted by Sagar Adhurya & SR, respectively.

2. *Gynacantha* cf. *subinterrupta* Rambur, 1842

IUCN status: Least Concern (Dow 2011)

Sighted on: 18.i.2013, 24.vi.2013, 11.vii.2013; Study sites: S3, S5

Comments: This species was confused with similar other *Gynacantha* species. With the help of the description given by Khan (2015) and by the images of the 'Odonata of India' website (Joshi et al. 2020), author found similarities with *Gynacantha subinterrupta* species but due to lack of a specimen authors cannot confirm the photograph as *Gynacantha subinterrupta* without matching secondary genitalia. So we decided to report this observation as *Gynacantha* cf. *subinterrupta*. This species prefers shaded area. From S3, AKN found one male and one female and a single male individual were sighted by AKN from S5.

Table 1. Brief description with altitude, latitude, and longitude of the selected study sites.

Study site	Location name	Altitude (meters)	Latitude (N)	Longitude (E)	Habitat type
S1	Dubchururia Village, Andal, Durgapur	93	23.576°	87.227°	Remnants of dry deciduous forests with more than 20 large water bodies.
S2	Andal old aerodrome, Andal, Durgapur	84	23.588°	87.230°	Open grassland and agricultural land with a slow flowing perennial stream.
S3	Searsole Junior Basic School, Raniganj, Asansol	113	23.630°	87.109°	Planted trees with four large water bodies surrounded by agriculture land.
S4	Durgapur Barrage, Durgapur	70	23.475°	87.302°	Wetland dependent mixed vegetation with a perennial river.
S5	Nimcha village, Raniganj, Asansol	114	23.638°	87.089°	Remnants of dry deciduous forests with eight large water bodies, interspersed with agricultural land.
S6	Nimcha Coal Mine area, Raniganj, Asansol	95	23.636°	87.093°	Mixed forest with a slow flowing perennial stream and open coal pits.
S7	Gopalmath Rail Colony, Durgapur	71	23.569°	87.229°	Open grassland and agricultural land with more than 10 large water bodies.
S8	Nehru Park, Burnpur, Asansol	104	23.634°	86.947°	Remnants of dry deciduous forests with a slow flowing perennial stream and a river.
S9	Gunjan Ecological Park, Nigha, Asansol	98	23.664°	87.028°	Wetland dependent, mixed vegetation with an abandoned open-cast coal mine converted into a large water body.
S10	Ambuja Wetland, City Centre, Durgapur	104	23.540°	87.306°	Wetland dependent mixed vegetation with a large water body.
S11	Rana Pratap, A–Zone, Durgapur	97	23.601°	87.295°	Remnants of dry deciduous forests with a slow flowing perennial stream.
S12	Mohan Kumarmangalam Park, B-Zone, Durgapur	109	23.564°	87.301°	The study area is covered by mixed vegetation with a large water body.
S13	Kalyaneshwari Temple, Kalyaneshwari, Asansol	110	23.777°	86.829°	The study area situated beside the temple and the habitat is remnant of dry deciduous forests with a slow flowing perennial stream.
S14	Tumni River, Balijuri village, Faridpur-Durgapur	71	23.688°	87.321°	This place is situated at the bank of Ajay River. The Tumni river is a slow flowing perennial stream. Natural marshes and bushes at the study point.
S15	Uttar Pally, M.A.M.C., Durgapur	92	23.540°	87.326°	The study area is a pond. The pond is located with hamlet to its west and south, forest on the north and paddy fields to the east and south.
S16	Damodar River Bank, Srirampur Village, Durgapur	71	23.561°	87.197°	The area has been covered by trees, marshes, bushes, paddy fields and other crop yielding fields.
S17	Girmint Colliery, Kankhaya, Asansol	115	23.707°	87.029°	An underground colliery abandoned after a fire, it is now overgrown with secondary vegetation of shrubs and bushes and surrounded by rural grasslands. A small rectangular cemented manmade water tank, previously used to supply water to the boiler, is the only water body.
S18	Durgapur Projects Limited Township, Gammon Bridge, Durgapur	91	23.499°	87.304°	Backyard of an urban bungalow with both ornamental garden plants, trees bearing edible fruits and natural shrubs facing a tiny remnant of primary *Shorea robusta* forest on the opposite side of the road. No water bodies around.
S19	Garui River, Satpukuria village, Asansol	104	23.700°	87.009°	Densely forested, almost impenetrable sacred grove of remnant primary vegetation around a temple on one bank of the Garui River, and agricultural fields on the opposite bank. The riverbed, home to diverse emergent and submerged aquatic macrophytes interspersed with rocky boulder formations.

Family Gomphidae Rambur, 1842

3. *Cyclogomphus heterostylus* Selys, 1854

IUCN status: Data Deficient (Dow 2009)

Sighted on: 19.vii.2015; Study site: S4

Comments: This species is not commonly seen in this region. Only a single male was sighted in the field by AKN. The diagnostic characteristics of *Cyclogomphus heterostylus* Selys, 1854 are - thorax with two "Y"-shaped markings on each side; superior anal appendages pale yellow, short, straight, slightly separated, and directed straight backwards (Fraser 1934). The species is very similar to *Cyclogomphus ypsilon* Selys, 1854 and *Cyclogomphus wilkinsi* Fraser, 1926. Fraser (1934) stated that the differences indicated by Selys are found inconsistent on examination of a large number of specimens, so that no dependence can be placed on the colouration and nodal index to separate *C. heterostylus* from *C. ypsiion* and *C. wilkinsi*. Few characteristics to differentiate these three species are given by Fraser such as, the distinctly thicker black band on the lower part of

frons, entirely yellow labrum, two "Y"-shaped markings on each side of the thorax, superior anal appendages short, straight, slightly separated, and directed straight backwards and the inferior is relatively much longer and directed straight up possessed by *C. heterostylus*. The difference between male and female of *C. heterostylus* are not stated by Fraser but female of rest of two species have only some minor differences like bigger size, extensive black markings etc.

Family Macromiidae Needham, 1903

4. *Macromia cingulata* Rambur, 1842

IUCN status: Least Concern (Subramanian 2011)

Sighted on: 07.vii.2020, 08.vii.2020; Study site: S1

Comments: Only one male and one female individual have been found by AKN, hanging vertically from an electric wire. Identification has been done using Fraser (1924, 1936) and Subramanian et al. (2018). Mitra (2002) reported its distribution in Bengal as per literature review Dawn (2021), reports its distribution from Purulia District, southern West Bengal. In the present paper authors report a confirm photographic record of the species from southern West Bengal. The distribution of this species now extends from Purulia to Paschim Bardhaman District, West Bengal.

5. *Macromia flavicincta* Selys, 1874

IUCN status: Data Deficient (Dow 2010)

Sighted on: 02.viii.2018, 23.vi.2020, 10.x.2020; Study sites: S4, S16

Comments: This species was found from the same place (S16) in 2018 and 2020 by Arijit Mondal. Recently AKN found a female hanging from the branch of a tree near Durgapur Barrage (S4). Identification has been done using Fraser (1924, 1936), Subramanian et al. (2018), and images in 'India Biodiversity Portal' website (Tiple 2013; Balachandran 2016). No photographic record of this species was found from West Bengal. But the distribution of this species in West Bengal was reported by Srivastava & Sinha (1993) on the basis of literature review. Mitra (2002) also reported its distribution in West Bengal. Apart from West Bengal it has photographic report from Maharashtra by Tiple & Koparde (2015). Diagnostic characteristics of *Macromia flavicincta* are given by Fraser (1936) – for male: a medium size dragonfly (Abdomen: 47–50mm, Wing span: 41–43mm) with black abdomen and ringed with citrine-yellow. Labium is bright yellow-orange colour, labrum is bright yellow, frons bright citrine-yellow with a broadly black thick line. Eyes are emerald green, ociput dark brown and yellow spot behind vesicle. Prothorax and thorax are also dark brown with metallic blue reflex and marked with citrine-yellow. Bold and large stripes on the humeral region. Legs are black. Wings hyaline and palely tinted with yellow-brown. Pterostigma is black. Anal appendages is dull yellow-orange colour, superiors as long as segment 9. Female (Abdomen: 50–53mm, Wing span: 43–44mm) of the species is brighter in colour, abdomen markedly compressed and of even width throughout as seen from the above. Wings are more tinted with brown and anal appendages is reddish brown and shortly conical. This species can be distinguished from other species of same genus by its very broad abdominal yellow annules, entirely yellow labium, and by the black T-shaped mark on the frons. It differs from *M. cingulata* in having an entirely yellow labium. *M. cingulata* is also more slender insect. *Macromia flavicincta* is closely allied to *M. flavovittata* Fraser, 1935. The distinguishing characteristics of these two species are - *M. flavovittata* has labrum with no broadly black stripe, no yellow spot behind eyes, abdominal segments 3 to 6 with paired dorsal spots and shape of the male anal appendages (Fraser 1936).

Family Libellulidae Leach, 1815

6. *Hydrobasileus croceus* Brauer, 1867

IUCN status: Least Concern (Mitra 2010)

Sighted on: 05-ix-2020; Study site: S1

Comments: The species is a new record for the Paschim Bardhaman District. The photographic record of the species has been found from northern West Bengal (Pal 2017). Mukherjee et al. (2016) also reported the species from Bankura District. So this is the second report of the species from southern Bengal. Only a single male individual was observed by AKN, found hanging from an open branch of a tree beside a pond in study site S1.

7. *Lathrecista asiatica* Fabricius, 1798

IUCN status: Least Concern (Dow & Kakkasery 2017)

Sighted on: 21.iv.2020, 30.vii.2020; Study site: S1

Comments: Both times single female individuals were sighted by AKN, from the study area. It is not so common in the region. It has widespread distribution throughout the state (Nayak et al. 2019c), however this is the first photographic report of the species from Paschim Bardhaman District.

8. *Neurothemis fulvia* (Drury, 1773)

IUCN status: Least Concern (Mitra 2010)

Sighted on: 23.ix.2017, 21.x.2020, 17.xii.2019, 12.viii.2020, 15.ix.2020, 18.xi.2020, 18.x.2020; Study

sites: S3, S12, S18, S19

Comments: This species can commonly be seen in some forested areas in Paschim Bardhaman District. During the study one female individual was sighted by AKN, from the study point S3. SR also found both male and female of this species frequently from study point S18. A male individual has also been sighted at S19 by SR. Sagar Adhurya, also sighted a female individual from S12. The authors acknowledge few more reports of its finding from outside the study area but inside the district (Nayak et al. 2019b).

9. *Orthetrum chrysis* Selys, 1891
IUCN status: Least Concern (Subramanian 2010)
Sighted on: 07.xi.2013; Study site: S3

Comments: Previously the species was confused with *Orthetrum pruinosum* Burmeister, 1839 sub-adult male. Only a single male individual was sighted by AKN from the study area. Diagnostic characteristics are given by Fraser (1936) are as follows – frons bright scarlet colour, throax ferruginous and abdomen bright blood red, wings with basal markings and extending to the first antenodal nerve. Wings hyaline, tinted with very pale brown. Female of the species without any basal markings, abdomen bright yellow-orange in colour (same for the sub-adult). The dark purplish-red, rather crimson than scarlet, tint of the abdomen, darker thorax and the abdomen more slender, gradually tapering rather than evenly broad to S7, well distinguished it from *O. pruinosum* male.

Suborder Zygoptera Selys, 1854
Family Lestidae Calvert, 1901
10. *Lestes praemorsus* Hagen in Selys, 1862
IUCN status: Least Concern (Dow & Sharma 2020)
Sighted on: 21.xi.2018, 02.xi.2019; Study sites: S2, S15

Comments: SR observed six individuals both males and females flying around the study point S15. Weak agile flying and egg laying were observed during the study. Only one female individual was found by Arijit Mondal from a paddy field near S2. It prefers bushes and shaded areas.

Family Chlorocyphidae Cowley, 1937
11. *Libellago indica* (Fraser, 1928)
IUCN status: Not assessed.
Sighted on: 22.x.2018, 02.xi.2018, 5.ix.2020; Study sites: S1, S14

Comments: Debdulal Banerjee observed a single female individual for the very first time on 22 October 2018 from south bank of Tumni River (S14), a tributary of the Ajoy River. At first it was presumed to be *Libellago lineata* (Burmeister, 1839) on the basis of identification keys by Fraser (1934). On 2 November 2018, SR, guided and accompanied by Debdulal Banerjee, observed at least 20 individuals along 100m stretch of S14. Images of male, female, oviposition, copula and predation were captured. About two years later AKN found a single male individual from study point S1. In the dorsal photo of the male individual, the thick mid-dorsal dumbbell-shaped black marking in segment 2 and significantly broader mid-dorsal stripes in segments 3 to 5 compared to typical *L. lineata*, as mentioned by Fraser (1934) helped us conclude it as *L. indica*. Consultation with administrators of the 'Odonata of India' (Joshi et. al. 2020) helped the authors affirm that it should be *Libellago indica* (Fraser, 1928). Fraser (1928) described it from the type locality Pune (present Maharashtra) and also collected individuals from southern India, along the Western Ghats up to Kerala. Lahiri & Sinha (1991) extended the range eastwards to Bastar District (present Chhattisgarh State). Authors found recent distributional range extension reports of the species by Payra et al. (2020). These two papers extended its range up to Madhya Pradesh and Odisha, respectively. This paper confirms the extension of the species beyond the easternmost slope of the Chhotanagpur Plateau region (which is an extension of the Deccan Plateau) of West Bengal into the peneplains. The authors found no previous report of *Libellago indica* (Fraser, 1928) from entire West Bengal. The present manuscript reports a range extension of the species from Odisha to West Bengal, which is also a new record for the state. Given the vast geographical range across the Deccan and Chhotanagpur Plateaus, *L. indica* also has shown considerable variations like *L. lineata*. The mid-dorsal black markings, in particular, though considerably thicker compared to the typical *L. lineata*, are narrower compared to the individuals found in the southern Western Ghats.

Family Coenagrionidae Kirby, 1890
12. *Agriocnemis lacteola* Selys, 1877
IUCN status: Least Concern (Dow 2009)
Sighted on: 18.x.2020; Study sites: S17

Comments: Only one male individual was sighted by SR during field survey. According to the key provided by Fraser (1933), the male of this species is easily identifiable in the field by its characteristic white abdomen, completely unmarked with black. The type specimen is from 'Bengal'. Fraser (1933) had mentioned distribution of the species from Alipurduar (Hasimara) and Jalpaiguri districts of West Bengal. Prasad & Ghosh (1988) reported

collection of it from Purba Medinipur District. Payra & Tiple (2019) also reported the photographic record of this species from coastal area of Purba Medinipur District. Mukherjee et al. (2016) reported this species from Bankura District. Pal (2017) reported it from North Bengal University campus in Darjeeling District. There is also a recent photographic record of a male individual by SR from Jhargram District (Nayak et al. 2019a). The above records prove it to be quite widespread in West Bengal. The authors report the first photographic report of the species from Paschim Bardhaman District in this present paper.

13. *Pseudagrion australasiae* Selys, 1876
IUCN status: Least Concern (Dow 2009)
Sighted on: 03.x.2014, 21.xi.2018; Study sites: S6, S15

Comments: Commonly found from the study area along with other damselflies. Confusion arises in the field with *P. microcephalum* (Rambur, 1842) male, but the prominent view of male anal appendages can clear all doubts. It prefers bushes and marshes near shallow water bodies. Fraser (1933) and Srivastava & Sinha (1993) stated the diagnosis of the species along with distinguishing features to other species of same genus. For male, identification characteristics are - face, frons, vertex and occiput bluish-green, marked with black. Thorax azure blue on dorsum and sides marked with humeral and mid-dorsum broad black stripes. Prothorax is pale blue, the middle lobe on dorsum with black crown-shaped marking. Legs are pale blue. Small black spot on the lateral side of mesepimeron and a thicker spot on the upper end of lateral suture. Superior anal appendage half the length of abdomen 10, apically bifid, hooded strongly inward. And identification keys for female are dorsal markings on segments 2 and 8 very broad, extending the whole length of segments, that on 2 broads at the base. Segment 2 with a diamond- or cordate shaped subapical spot on dorsum connected finely to base and apex. This species has some similarity with *P. microcephalam*, but is distinguishable from same by elongate vase-shaped spot on abdominal segment – 2 instead goblet-shaped and in absence of basal spines. The thoracic black stripes are much wide in *P. australasiae*, and superior anal appendages shorter. The half circle mark at the mesepimeron in case of *P. australasiae*, whereas restricted to single dot in *P. microcephalum*. Comparison of the male's head & thorax; dorsum of thorax with three broad black bands, crown-shaped marking on the middle of prothorax, spots on and most importantly the male anal appendages, the superior anal appendages only half as long as segment 10; which differentiate this species from other species of *Pseudagrion* genus. Mitra & Babu (2010) reported its distribution from Howrah, Kolkata and North 24 Parganas districts, Srivastava & Sinha (1993) also reported its distribution from Birbhum District. Most recently Pal (2017) reported photographic record of it from North Bengal University campus, Darjeeling District. Both the author found this species from the study area. Hence this present manuscript claims first photographic record of the species from southern West Bengal.

Discussion

With the addition of these 13 newly recorded species from the study region, the total number of Odonata species stands at 76. Due to the geographical position of the region, a microclimatic variation can be noted (Choudhury et al. 2018; Gupta et al. 2019) and it reflects itself in the Odonata diversity of the region. Since this region represents one of the largest industrial and urban agglomerations in West Bengal (Choudhury et al. 2018), most of the water bodies and streams are highly polluted with industrial and domestic wastes (Dey et al. 1985; Banerjee & Gupta 2013). Since odonates are considered as biological indicator species (Clark et al. 1996; Corbett 1999; Catling 2005), it is necessary that other than diversity and abundance studies, a long-term monitoring needs to be taken up in the study region as well as in the state. We strongly believe that through continuous studies and long-term observation in more study points, new records for the state can be found from the region which will enrich the Odonata diversity of the state too, even we can describe some new species to science. We also believe that sustained and co-ordinated efforts are necessary for documenting the Odonata diversity of the state.

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Image 1. *Anax indicus female*, location – S14, 02.xi.2018.

Image 2. *Gynacantha* cf. *subinterrupta* male, location – S3, 24.vii.2013.

Image 3. *Cyclogomphus heterostylus* male, location – S4, 19.vii.2015.

Image 4. *Macromia cingulata* male, location – S1, 07.vii.2020.

Image 5. *Macromia flavicincta* female, location – S16, 23.vi.2020.

Image 5a. Head and Thorax of *Macromia flavicincta* unknown gender, location – S16, 02.viii.2018.

Image 6. *Hydrobasileus croceus* Brauer, 1867, male, location – S1, 05.ix.2020.

Image 9. *Orthetrum chrysis* male, location – S3, 07.xi.2013.

Image 7. *Lathrecista asiatica* female, location – S1, 21.iv.2020.

Image 10. *Lestes praemorsus* male, location – S15, 21.xi.2018.

Image 8. *Neurothemis fulvia* male, Location – S18 , 18.xi.2020.

Image 11. *Agriocnemis lacteola* male Selys, 1877, location – S17, 18.x.2020.

Image 12. *Libellago indica* copula, location – S14, 02.xi.2018.

Image 13. *Pseudagrion australasiae* male, location – S6, 03.x.2014.

Image 12a. Dorsal view of male *Libellago indica*, location – S14, 02.xi.2018.

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SHORT COMMUNICATION

A note on the ecology and distribution of Little Bloodtail *Lyriothemis acigastra* Brauer, 1868 (Insecta: Odonata: Libellulidae) in Kerala, India

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Abstract: The behaviour and ecology of an elusive dragonfly, *Lyriothemis acigastra* (Insecta: Odonata: Libellulidae) based on observations from Kadavoor Village, Ernakulam District, Kerala are detailed. Range extension of the species within Kerala after its first report in 2013 is also discussed.

Keywords: Facebook group, odonates of Kerala, range extension, southern India.

Lyriothemis Brauer, 1868 is a genus of dragonflies in the family Libellulidae (Insecta: Odonata: Anisoptera) with 17 known species, mostly found in eastern Asia (Paulson & Schorr 2020). Five species in the genus are known from India: *L. acigastra* (Selys, 1878), *L. bivittata* (Rambur, 1842), *L. cleis* Brauer, 1868, *L. tricolor* Ris, 1916, and *L. mortoni* Ris, 1919 (Subramanian & Babu 2017; Dawn 2021). *Lyriothemis* species were thought to be restricted to the northeastern parts of the country, but in 2013, *L. acigastra* and *L. tricolor* were recorded from the southern state of Kerala. *L. tricolor* was found to breed in the tree holes of evergreen and semievergreen forests in the southern Western Ghats (Das et al. 2013). Not much is known about the behaviour and ecology of *L. acigastra* (Emiliyamma et al. 2013).

L. acigastra is a small dragonfly with brown-capped greenish-yellow eyes. The base colour of male is blood red, marked with black. Its abdomen is tapered from base to end and caudal appendages are black (Image 2). The female is similar to the male, except that the abdomen is cylindrical rather than tapered from base to end and has reddish-yellow as base colour instead of blood red (Image 3) (Fraser 1936). *L. acigastra* is categorized as a Data Deficient species by IUCN and is also known to occur in China, Myanmar, and Bangladesh (Dow 2009; Kalkman et al. 2020). In Kerala, it was first recorded from Aravanchal and Madayipara areas in Kannur District between July and September 2010 (Emiliyamma et al. 2013). Here, we present some insights on its behaviour and breeding habitat based on observations from Kadavoor, Ernakulam District, Kerala. Dragonflies of Kerala (https://www.facebook.com/groups/1401144716840784) is a Facebook group administered by Society for Odonate Studies (https://odonatesociety.org/), a non-governmental organization formed for the study and conservation of odonates in Kerala. It is a public group started in 2014 and has over 2,500 members at present. The members post photographs of odonates from various locations in Kerala and discuss their taxonomy, behaviour, and ecology. We

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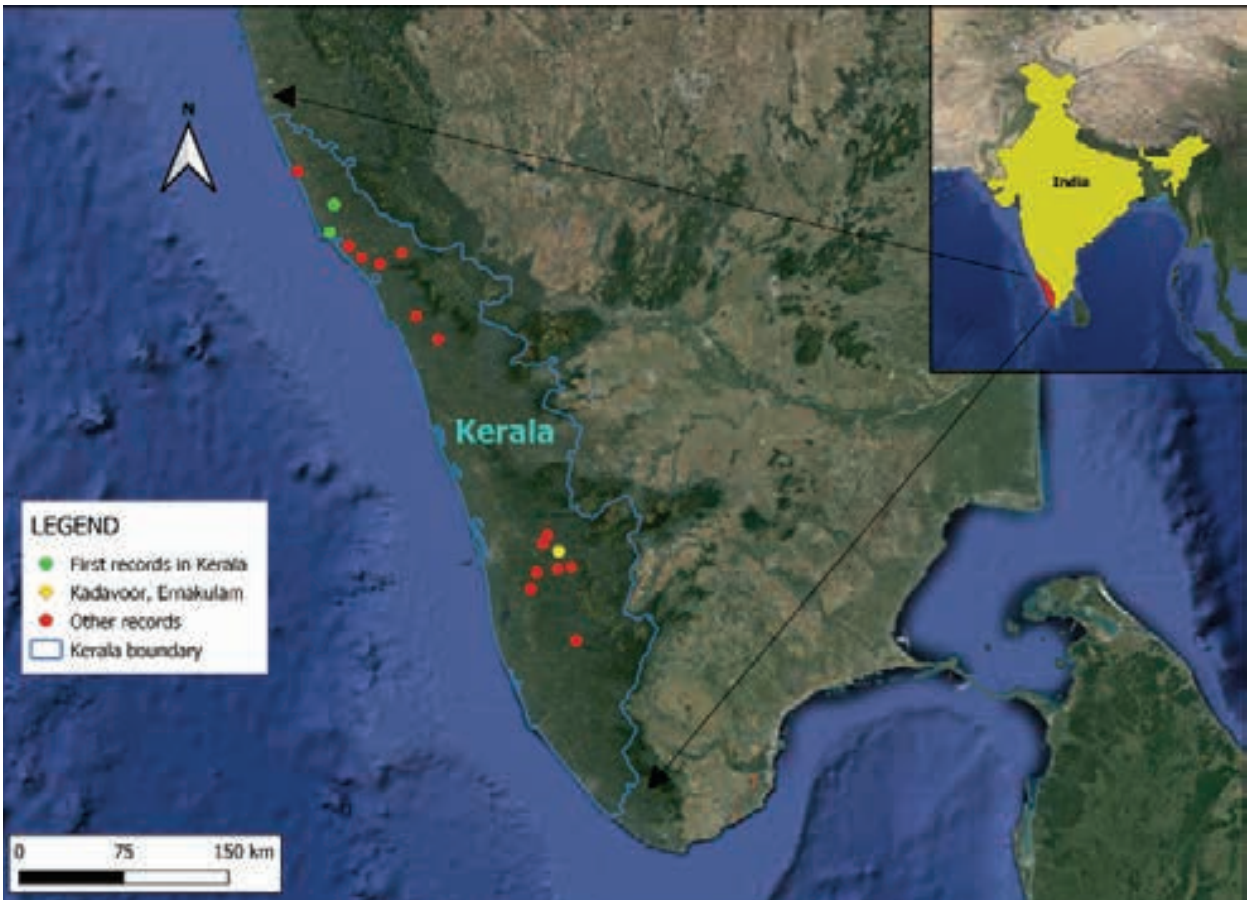

Image 1. Records of *Lyriothemis acigastra* from Kerala.

discuss the range extension of *L. acigastra* based on the observations in this social media group.

Materials and Methods

Kadavoor is a village in the Paingottoor Gramapanchayat of Kothamangalam Taluk, Ernakulam District, Kerala (10.001°N & 76.741°E, 25m). It is a small agricultural village nestled near the foothills of the Western Ghats (Image 4). The northern side of the village is bordered by forests of Kothamangalam Division. The southern side is bordered by Kaliyar River, which is a major tributary of Muvattupuzhayar. Several streams originate from the forest and flow through the village to join Kaliyar River. Most of these streams run dry after December. The Pothencheeni- Kadakolmuri thodu, which is the main stream of the village, flows very narrowly during the early summer days and ends up as a mere waterhole in peak summer. The area is dotted with paddy fields, banana plantations and pineapple farms. Numerous man-made canals crisscross the agricultural fields, running into Pothencheeni- Kadakolmuri Stream which in turn drains into the Kaliyar River.

JJ has been observing odonates in the village and maintaining a checklist of the species observed since 2003. The individual odonates were photographed using Sony ILCA 77M2 DSLR camera and 250mm lens, and identified referring to taxonomic monographs (Fraser 1933, 1934, 1936) and field guides (Subramanian 2005, 2009; Kiran & Raju 2013). A total of 68 species of odonates belonging to 13 families under 49 genera were recorded from the area (Jose 2016).

Results and Discussion

Observations of *L. acigastra* from Kadavoor

A few individuals of *L. acigastra* were first seen at Kadavoor in June 2015. The species was observed in and around the canals associated with pineapple and banana plantations near the paddy fields (Image 5). Since then, every year, the species would first appear in June with the onset of the south-west monsoon. Mass emergence was observed during the months of June and July. More than 1,000 individuals were recorded in July 2016 and there on in every June–July period till 2020. Interestingly, no individuals were observed after the

Table 1. Observations of *Lyriothemis acigastra* from the Facebook group 'Dragonflies of Kerala'.

Year	Location/District	Month	Name of the Observer
2015	Kadavoor, Ernakulam	June & July	Jeevan Jose
2015	Kannur	July	Sandeep Gangadharan
2016	Kadavoor, Ernakulam	June & July	Jeevan Jose
2016	Madayippara, Kannur	July	Suhas Perambra
2016	Kannur	August	Premraj
2017	Kuruvilangad, Kottayam	July	Deepu G Nair
2018	Kadavoor, Ernakulam	June	Renjith Jacob Mathews
2018	Chedikkulam & Ambalakkandy, Kannur	June & July	Yadu
2019	Kadavoor, Ernakulam	June	Jeevan Jose
2019	Koothattukulam, Ernakulam	July	Renjith Jacob Mathews
2019	Kattampally, Kannur	September	Afsar Nayakkan
2020	Udumbanoor, Idukki	May & June	Arun Lal
2020	Kadavoor, Ernakulam	June	Jeevan Jose
2020	Vechoochira, Kottayam	June	Tony Antony
2020	Thodupuzha, Idukki	June & August	Ambily
2020	Peravoor, Kannur	June	Vibhu Vipanjika
2020	Punnekkad, Kottayam	June	PJ George
2020	Kothamangalam, Ernakulam	June	Ajith TK
2020	Panayal, Kasaragod	June & July	Muhammed Haneef
2020	Vechoochira, Kottayam	June	Renjith Jacob Mathews
2020	Kuthuparamba, Kannur	July & August	Vishnu Thavara
2020	Iriveri, Kannur	August	Prasoon Prakash

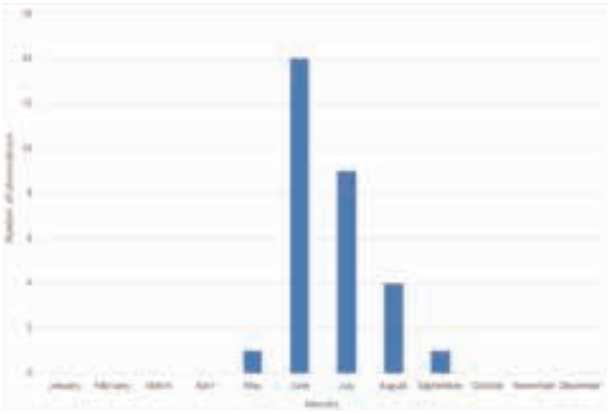

Figure 1. Month-wise observations of *Lyriothemis acigastra* from the Facebook group 'Dragonflies of Kerala'.

month of August.

L. acigastra seems to be a shade-loving insect, most active during evenings. On monsoon days, when there were gaps between rains, they were seen flying around actively. They have a slow, low lying flight, covering short distances at a time. The males were usually seen perched on vegetation along the banks of canals. Females were seen rarely, nearer to water, mostly inside the canals**.** The prey of *L. acigastra* consisted mostly of small dipteran flies and microlepidoptera.

Males were observed to be fiercely territorial, chasing away rival males. The mating was quick, in flight, and the pair occasionally perched on vegetation for the last few seconds (Image 6). Mating was always observed near the canal banks. Immediately after mating, females were observed laying eggs in the canals, the banks of which had thick herbaceous cover. It was noted that the water in these canals were stagnant or semi-stagnant with explosive growth of green algae. Egg laying in free flowing water was never observed. Males kept watch from a distance (distance guarding) while the females laid the eggs. Females were seen hovering in a particular location flicking their abdomen like a spoon, occasionally touching their abdomen in the water. The egg laying lasted for a few minutes (Image 7).

It is interesting to note that these canals dry up after the north-east monsoon and there would be no water in them from January to May. With the arrival of the south-west monsoon showers in June, mass emergence of *L. acigastra* could be seen in these canals. Throughout the world, different drought-resistant methods have been documented in odonate larvae. For instance, larvae of Aeshnidae such as *Rhionaeschna californica* (Calvert, 1895), *Aeshna cyanea* (Müller, 1764), *A. sitchensis* Hagen, 1861, and *Anax parthenope* (Selys, 1839) have been observed resting under rocks, logs or other debris embedded in mud. Larvae of *Libellula depressa* Linnaeus, 1758 have been reported to survive in dry mud for six weeks. Larvae of *Ceriagrion melanurum* Selys, 1876 hide under dead leaves in dry swamps and those of *Trithemis arteriosa* (Burmeister, 1839) survive by burying 30cm under sand in dried ponds. In Japan, the larvae of *Lyriothemis pachygastra* (Selys, 1878) have been observed to tide over the dry period by hiding under dead leaves in dried up swampy fields. It is believed that odonate larvae survive desiccation not by entering a state of suspended animation, or cryptobiosis, but by reducing activities such as transpiration and feeding (Corbet 1999). It is unclear what strategy the larvae of *L. acigastra* use to overcome the extended dry period; however, it can be concluded that *L. acigastra* has only one life cycle in a year, as tenerals could be seen only in the June–July period of a year and no adult could be

Image 2. *Lyriothemis acigastra* male.

Image 3. *Lyriothemis acigastra* female.

Image 4. The landscape of Kadavoor Village, Ernakulam District, Kerala.

Image 5. One of the man-made canals in Kadavoor where *Lyriothemis acigastra* breeds since 2015.

Image 6. A pair of *Lyriothemis acigastra* mating.

Image 7. A female *Lyriothemis acigastra* ovipositing.

seen from September to May.

Range extension of *L. acigastra* within Kerala

Over the years, multiple observers have shared their observations of *L. acigastra* from Kerala in the Facebook group 'Dragonflies of Kerala' (Table 1 & Image 1). According to these observations, the flight period of *L. acigastra* is from May to September with a peak in observations in June (Figure 1). Till date, the species has been reported from Kasaragod, Kannur, Ernakulam, Kottayam, and Idukki districts. While very small populations of *L. acigastra* were seen in other places, at least a 1,000 individuals were seen every year at Kadavoor. It is curious that even in Kadavoor, it is not widespread but restricted to a small area of less than 0.1km^2.

Since JJ has been continuously monitoring odonates of Kadavoor since 2003, it can be assumed that *L. acigastra* colonized the area in 2015, two years after its first report from peninsular India (Kannur District, Kerala in 2013) or increased in numbers as a result of changes in environmental conditions. Dragonflies are known to colonize new areas with favourable conditions and establish breeding populations (Samways & Simaika 2016). The other localities from which *L. acigastra* was reported must be monitored over the next few years to understand if the species is able to establish good breeding populations like it did in Kadavoor. A detailed study of its microhabitat requirements would help in predicting the expansion of its range in Kerala. The larva of *L. acigastra* is taxonomically undescribed. A detailed study of the larva could throw light on its drought-resistant adaptations. Also, the observations reported here are mostly opportunistic. The study can be improved by continuously monitoring *L. acigastra* over a few years to generate quantitative data that can give a clearer understanding of its ecology.

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VIEWPOINT

A unique archetype of conservation in Himachal Pradesh, western Himalaya, India

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Abstract: Owing to numerous emerging threats to biodiversity, its conservation has been of paramount importance in today's world. Interestingly, many modern practices have been followed globally for the conservation of natural resources, yet traditional conservation practices that could set an excellent example need to be explored worldwide. Keeping this in view, the current communication aims to highlight a unique conservation method that has been practiced in the remote and cold-arid region of the state of Himachal Pradesh in the western Himalaya. Locally known as 'Praja Mandal', this indigenous system of conservation needs to be addressed and adopted nationwide with an eye towards a sustainable ecosystem.

Keywords: Conservation, Himalaya, Praja Mandal, sacred grove, traditional knowledge.

The Himalaya, a massive biodiversity hotspot supplying ample ecosystem services, is one of the active and youngest mountain ranges in the world (Roy & Purohit 2018). Covering a vast area of >2500km long and 80–300 km wide amidst five countries, India shares 12 states with 95 districts, eventually known as the Indian Himalayan Region (IHR). The region is quite rich in endemic and threatened flora and fauna such as *Panthera uncia* (Snow Leopard), *Moschus moschiferus* (Musk Deer), *Pinus gerardiana* (Chilgoza), *Betula utilis* (Bhojpatra), *Aconitum heterophyllum* (Atis), and *Nardostachys jatamansi* (Jatamansi) (Singh & Kumar 2017). Conservation of biodiversity holds importance for the steady flow of ecosystem services as well as for ecological balance. Notably, in order to conserve these natural resources, native knowledge has been of paramount importance to land productivity, food security, and ensuring environmental conservation (Sillitoe 2017). It acts as a bridge between culture and nature, so as to aid the process of conservation and management of biological resources (Reimerson 2013; Potts 2017). These time-honored ideas with a deep understanding of protecting natural resources are primitive and transfer from one generation to another.

Several developed countries have been practicing many forest policies and conservation programs for the preservation of their natural resources, on the other hand, some developing countries have documented their traditional practices for sustainable environment conservation (Ens et al. 2015; Aya & Waswa 2016). For instance, sustainable management of forests by Cordillera communities in Philippines has continued to thrive with their limited resources and habitat whilst following their cultural practices of conservation (Camacho et al. 2015). Therefore, blending indigenous and modern practices

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Image 1. Magnificent view of *Betula utilis* forest conserved by *Praja Mandal* in Sural Bhatori, Pangi, Himachal Pradesh. © Amit Kumar

will be a boon for conserving resources (Reniko et al. 2018). Concerning this, Mavhura & Mushure (2019) also suggested documentation of indigenous practices and mainstreaming in the teaching and learning pedagogy.

In India, especially IHR, limited studies have been undertaken and reported conserving biodiversity through traditional practices. An excellent example of conservation of medicinal plants was reported in the sacred groves of Manipur where rare species are preserved that are already extirpated in the locality (Khumbongmayum et al. 2005). Similarly, the sacred land of Tholung, Silkkim has put forward a perfect example of analogy between culture and ecosystem (Arora 2006). In Uttarakhand too, taboos and sacred grooves act as a tool for biodiversity management through people's participation (Anthwal et al. 2010; Kumar et al. 2013). Furthermore, in Himachal Pradesh (HP), traditional practices and local cultural beliefs play a significant role in the sustainable conservation of the ecosystem and its services (Kandari et al. 2014). In HP, a few areas such as Shivbadi (Una), Murari, and Naina Devi (Mandi) have been studied in terms of ethno-botany and ethno-medicine of sacred groves (Jaryan et al. 2010; Sharma et al. 2015). Although, HP is known to have the largest number of ca. 5,000 sacred groves in the country (Kandari et al. 2014), there is poor documentation of indigenous conservation practices and the floristic and faunistic composition of known sacred groves. The current communication aims to highlight a unique and indigenous archetype, popularly known as 'Praja Mandal' in the Pangi Valley (32.1916–33.2183 ^{0}N and 75.75–77.059 ^{0}E) of HP in the western Himalaya, India (Image 1). The valley mainly lies in the rain shadow or cold-arid zone with scanty rainfall (<800mm) and relatively high snowfall. Covering a total area of 1,601km^{2} with 16 village councils (locally known as panchayat) and 60 villages inhabited by *Pangwals* and *Bhots* (local communities), the valley has 18,868 human population (GOI 2011). 'Praja' means community and 'Mandal' is federation and it exists solely in the Pangi Valley of HP. This local practice of conservation has been successful in protecting the wild resource base of not only medicinal and aromatic plants, but also managing the resources such as timber fuelwood, fodder, and non-wood forest products by designating a forest or community forest as a separate conservation unit. Depending on the number of villages included in a village council (Panchayat), there can be more than one Praja in a council. During British rule, Praja Mandal was a part of the Indian Independence movement in the 1920s where the people fought for their democracy and similar rights against the princely states and British administrators. Presently, however, the concept of Praja Mandal has been directed towards conservation of local biodiversity (Image 2).

Locally known as the Praja Mandal, it is entirely governed by a village council with one member from each family. Owing entirely to a community-based approach, decisions on matters such as conservation

Image 2. A dense coniferous forest patch protected by Praja Mandal of Punto Village, Pangi, Himachal Pradesh. © Rupali Sharma.

of natural resources and social issues are of prime importance in this archetype. Furthermore, the local inhabitants in a Praja Mandal have their rights as well as limitations to the conservation ethos of biological resources. In order to prevent exploitation as well as sustainable management of the community forests, the forested area confined to a particular village are closed for a defined number of years with a set of rules framed by the Praja Mandal. As per the community rules and regulations, no legal jurisdiction is required as the Praja Mandal through its council penalizes the offenders. Boycotting violators from their regular rights is a major penalty in this system along with a deposit of tangible goods. A Praja Mandal includes 'pradhan' (village head), 'up-pradhan' (sub-head), cashier, secretary, 'chad' & 'batwar' (messengers), and 'swar' or 'bhoti' (cook) in its hierarchy. The penalty is determined case by case basis such as INR 5,000–10,000, 40kg 'atta' (whole wheat flour), 10kg 'ghee' (clarified butter), and a goat for cutting a tree or harvesting medicinal plants from their community land. Additionally, taboos also play a vital role in the conservation practices of locals; for instance, *Betula utilis* forests around monasteries have been conserved in such a way that even collection of fallen barks and twigs is not permitted. Although, this unique practice has remained intact in community forests of Pangi Valley in western Himalaya, it needs to be promoted and practiced for the sustainable utilization of wild resources in other regions of the country and set an example worldwide.

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NOTE

SMALL WILD CATS SPECIAL SERIES

A camera trap record of Asiatic Golden Cat *Catopuma temminckii* (Vigors & Horsfield, 1827) (Mammalia: Carnivora: Felidae) in State Land Forest, Merapoh, Pahang, Malaysia

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The Asiatic Golden Cat *Catopuma temminckii* is listed as Near Threatened in the IUCN Red List of Threatened Species (McCarthy et al. 2015). It is widely distributed from the eastern Himalaya (Ghimirey & Pal 2009; Bashir et al. 2011; Dhendup 2016; Chatterjee et al. 2018; Koju et al. 2020;) across southeastern Asia (Grassman et al. 2005; Coudrat et al. 2014; Than Zaw et al. 2014; McCann et al. 2020) to Sumatra (Pusparini et al. 2014). In Malaysia, it enjoys the highest legal protection under the Wildlife Conservation Act 2010 as a totally protected species (Gumal et al. 2014). In Peninsular Malaysia, it inhabits Taman Negara National Park (Kawanishi & Sunquist 2004), Jerangau Forest Reserve (Azlan & Sharma (2006) and Endau Rompin National Park (Gumal et al. 2014).

Little is known about its distribution outside protected areas in Peninsular Malaysia, making it difficult to develop a specific conservation plan in the country (Azlan & Sharma 2006). We report a record of an Asiatic Golden Cat outside a protected area in central Peninsular Malaysia. This record was obtained during a survey to assess the wildlife diversity in a State Land Forest in Pahang State.

Our study area was located in a State Land Forest west of National Park in Pahang State, Malaysia (Figure 1). State Land Forests and all forest products growing

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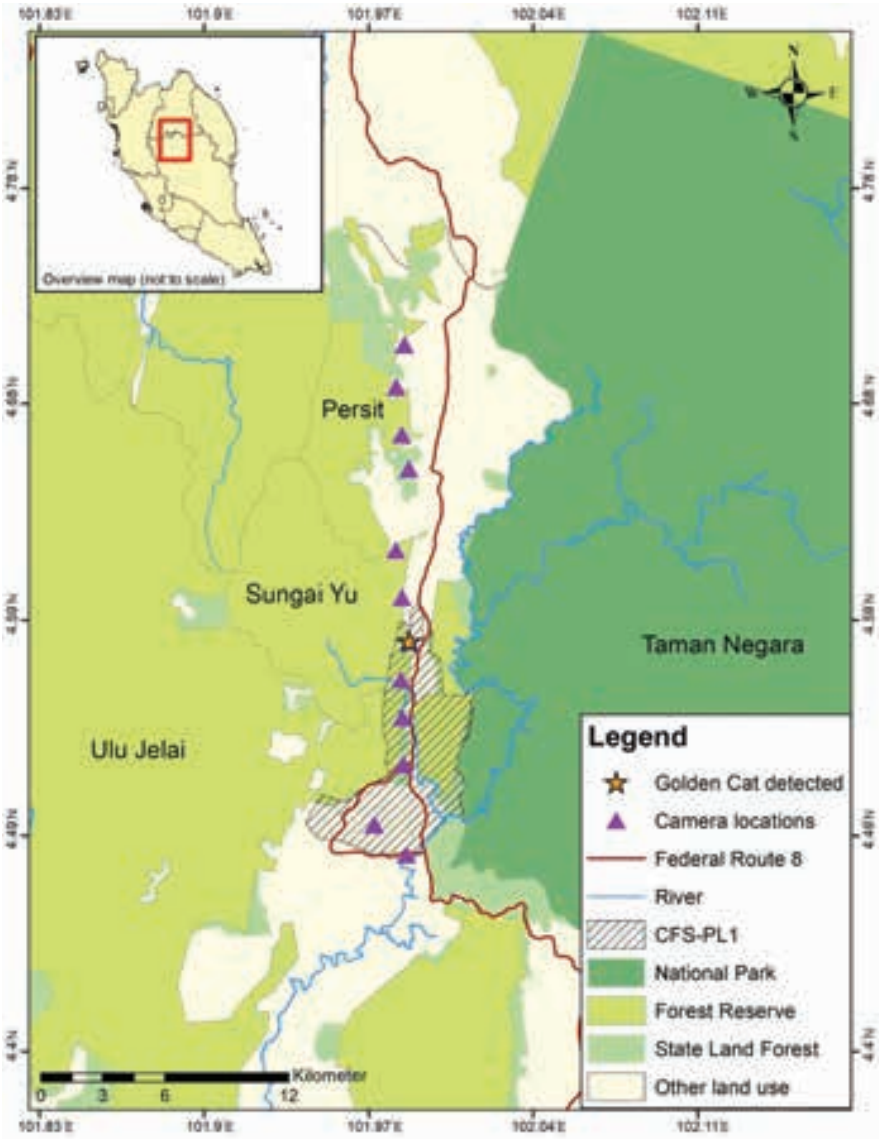

Figure 1. Study area in State Land Forest west of Taman Negara National Park in Pahang State with the location where the Asiatic Golden Cat *Catopuma temminckii* was detected.

therein are the property of the State Authority (National Forestry Act 1984). The 23.24km^2 large study area is composed of a mosaic of secondary and selectively logged lowland dipterocarp forest and agricultural areas with oil palm and rubber plantations at an elevation range of 20–538 m. It partially overlaps the Malaysian Government's Central Forest Spine – Primary Linkage 1 (CFS-PL1) (Regional Planning Division 2009), an important wildlife corridor for Tiger *Panthera tigris*, Asian Elephant *Elephas maximus*, Malayan Tapir *Tapirus indicus* and other threatened species.

We deployed 12 unpaired Browning Model BTC-8A and Reconyx Hyperfire HC500 camera traps. They were attached to trees 30cm above the ground and placed opportunistically along human trails at a distance of 2km. No bait or lure was used. Camera traps were active 24 hours per day with no delay between consecutive photographs. We replaced batteries and memory cards every four weeks. All camera traps were left in the same location for the entire study period. The coordinates of each camera trap were determined by using a Garmin GPSMap 64s device set to Kertau 1948 datum.

Our camera trap survey lasted from 25 August to 25 October 2019 with a total survey effort of 542 camera trap days. On 21 September 2019 at 17:12 h, a camera trap recorded a solitary Asiatic Golden Cat at 4.5793°N, 101.9870°E (Image 1). The camera trap was deployed along a logging road at the elevation of 167m. Other species recorded at the same location include Banded Linsang *Prionodon linsang*, Common Palm Civet *Paradoxurus hermaphrodites*, Dhole *Cuon alpinus*, Wild Boar *Sus scrofa*, Large Indian Civet *Viverra zibetha*,

Image 1. Asiatic Golden Cat *Catopuma temminckii* recorded in unprotected State Land Forest, Pahang, Peninsular Malaysia on 21 September 2019. © Universiti Malaysia Kelantan and Malayan Rainforest Station.

Malayan Tapir and Red Jungle Fowl *Gallus gallus*.

Our records in the State Land Forest of Merapoh indicate that this selectively logged forest serves as a wildlife corridor. In the adjacent Taman Negara National Park, the Asiatic Golden Cat has been recorded on multiple occasions (Kawanishi et al. 1999; Kawanishi & Sunquist 2004, 2008; Jambari et al. 2019).

To date, the Asiatic Golden Cat has been recorded in the unprotected Forest Reserves of Jerangau east of Taman Negara National Park (Azlan & Sharma 2006) and Gunung Basor in northern Peninsular Malaysia (Darmaraj 2007). Gumal et al. (2014) reported records farther south in the Endau Rompin Landscape, both inside and outside Endau Rompin National Park. In the Himalaya, the Asiatic Golden Cat has also frequently been recorded outside protected areas (Jigme 2011; Vernes et al. 2015; Dhendup & Dorji 2018; Joshi et al. 2019; Nijhawan et al. 2019; Rai et al. 2019).

The key implication of our study is that even small and degraded forest blocks are used by the Asiatic Golden Cat and other wildlife. They also hold potential prey such as Red Jungle Fowl and Wild Boar. Faecal samples of the Asiatic Golden Cat collected in the national park contained remains of birds, primates, and rodents (Kawanishi & Sunquist 2008). It also preys on larger mammals such as Wild Boar and Muntjac *Muntiacus* (Kamler et al. 2020).

Forest fragmentation and degradation due to land clearing for agriculture, logging and road construction is leading to the extirpation of wildlife in large swaths of tropical forests (Kleinschroth & Healey 2017); however, secondary and selectively logged forests provide habitat for a variety of medium and large mammal species such as Leopard Cat *Prionailurus bengalensis*, Marbled Cat *Pardofelis marmorata*, Tiger, Sun Bear *Helarctos malayanus*, Malayan Porcupine *Hystrix brachyura*, Southern Pig-tailed Macaque *Macaca nemestrina*, Malayan Tapir, and Asian Elephant (Azlan 2006; Hambali et al. 2019). Therefore, such forests outside the protected area network should be prioritised for wildlife conservation, particularly when they act as wildlife corridors. Continued monitoring is essential to generate necessary baseline knowledge for devising appropriate management measures.

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NOTE

Reappearance of Dhole *Cuon alpinus* (Mammalia: Carnivora: Canidae) in Gujarat after 70 years

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Dhole *Cuon alpinus* (Pallas, 1981) is a pack hunting, highly social canid and the only species of this genus (Pocock 1936; Cohen et al. 1978; Johnsingh 1982; Alfred 2000). Dholes are also known as Wild Dogs or Whistling Dogs, but the terms are misnomers since they are taxonomically more closely related to jackals than wolves and correctly termed as Dhole – the Asian origin term meaning recklessness and daring (Mivart 1890). In the past, Dholes were the most widely spread canids in the oriental region, distributed from around 50°N and 70°E over the continental Asia (Pocock 1936; Ellerman & Morrison-Scott 1966; Johnsingh & Acharya 2013; Selvan et al. 2013). Due to loss of forests and thereby the prey base (Gopi et al. 2010; FAO 2020), Dholes were extirpated from more than 75% of their global historic range with the remaining estimate of 949 to 2,215 individuals (Kamler et al. 2015). Looking to this scattering trend, IUCN categorized Dholes from Vulnerable to Endangered (Kamler et al. 2015), and are placed in Schedule II of Indian Wildlife (Protection) Act 1972, and in Appendix II of CITES (2019).

India lost around 60% of Dholes in the last 100 years (Karanth et al. 2010) and less than 1,500 individuals are left in Indian forests (Johnsingh & Acharya 2013; Kamler et al. 2015), surviving majorly in Western and Eastern Ghats, Terai, Kumaon, Himalayan region, northeastern states, and relatively larger population in central India (Srivastava & Singh 2003; Durbin et al. 2004; Iyengar et al. 2005; Jhala et al. 2008; Karanth et al. 2009; Gopi et al. 2010; Johnsingh & Acharya 2013; Kamler et al. 2015). Although the population disappeared from former range (Johnsingh 1985; Kamler et al. 2015), the recent rediscoveries in newer areas have raised the hope in Sikkim (Bashir et al. 2014), western Himalaya (Pal et al. 2018), Tso Kar, Ladakh (Kamler et al. 2015), and in different parts of Nepal (Khatiwada et al. 2011; Thapa et al. 2013; Lamichhane et al. 2018; Yadav et al. 2019). These discoveries indicate that the species is moving out to ensure fewer competition and less disturbance, which in future may foster resilience and expand its range.

In Gujarat, many claim to have sighted dhole in Dangs, Shoolparneshwar, Bharuch, Surat, Ratanmahal, and even in northern Gujarat (Singh 1998, 2001, 2013; Alfred 2000; GFD 2013; Kumar & Pathan 2016); however, no authentic evidence could ever be produced to ensure the certainty of the species in these areas, and therefore, the literatures endorsed Dhole as an exterminated species

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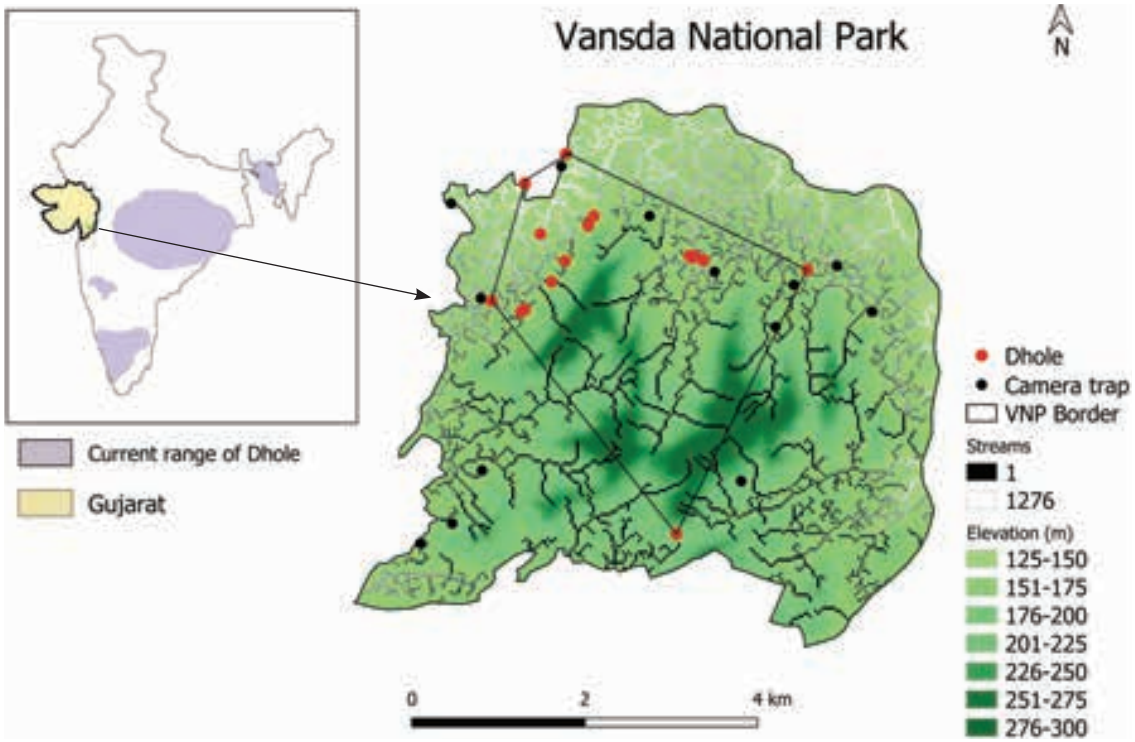

Figure 1. Current distribution of Dhole *Cuon alpinus* in India; camera trap locations (black dots) and Dhole capture locations (red dots) in Vansda National Park, Gujarat; and minimum convex polygon for the Dhole pack.

Image 1. The historic photo of Dhole *Cuon alpinus* from Vansda National Park, Gujarat clicked on 4 October 1949. Photo: Digveerendrasinhji Solanki

Image 2. The diurnally active Dhole *Cuon alpinus* in Vansda National Park, Gujarat.

from Gujarat (Johnsingh 1985; Ginsberg & Macdonald 1990; Singh 1998, 2001, 2013; GFD 2013; Kumar & Pathan 2016). In the Bharuch District Gazette (GoI 1961) Wild Dogs were reported from Dediapada, Sagbara, and Gora range. The then Maharaja of Vansda State Shri Digveerendrasinhji Solanki states to have observed Dhole packs in Vansda National Park (VNP) in 1970 (Singh 2013). Authentic sighting records from 1949 and 1970 are known, but without confirmed presence thereafter (Jayveerendrasinhji Solanki pers. comm. 2020). In the middle of all the ambiguity on Dhole's historic presence, the only reliable source is Digveerendrasinhji's photo of 4 October 1949 from Vansda forest of present day Vansda National Park. This is the only historic sighting record of Dhole from Gujarat (Image 1).

To confirm the presence of Dhole, from January–May 2020 camera traps were laid at 30 sampling locations in VNP along the select trails, waterpoints and crossings where Dhole movements were anticipated (Table 1). GPS coordinates, elevation, and habitat type were recorded at each sampling location. Camera trap photo/video

Table 1. Details of camera trap locations to confirm the presence of Dhole *Cuon alpinus* in Vansda National Park (VNP) during January to May 2020.

Trap location Code	VNP Beat	Altitude (m)	Trap duration	No of trap days	No.of photos	No.of videos	Activity	Sex	Other species captured
L1	Kevdi	139	II	45	3	1	Dr	M	LE, CH, CL, BD, WB, BPC, RM, GL
L2	Kevdi	141	I	15	1	-	Pa	UI	LE, CL, WB, SIC, BPC, RM
L3	Tadpada	160	I	15	-	-	-	-	CL, BD, WB, RM
L4	Tadpada	155	I	15	-	-	-	-	CL, BD, WB, RM
L5	Tadpada	156	I	15	-	-	-	-	RM, GL
L6	Kevdi	145	I	15	1	-	Ru	-	LE, CH, CL, BD, WB, BPC, RM, GL
L7	Kevdi	144	II	45	25	14	Dr, Pa, Ru	M, F	LE, CH, CL, BD, WB, BPC, SIC, RM, GL
L8	Kevdi	151	I	15	2	-	Pa	UI	CL, BD, WB, BPC, SIC, RM, GL
L9	Tadpada	168	I	15	-	-	-	-	-
L10	Tadpada	167	I	15	-	-	-	-	CL, BD, WB
L11	Kala-amba	173	II, V	56	27	3	Dr, Pa, Ru	M, F	LE, CH, CL, BD, WB, BPC, SIC, RM, GL, ICP, IGM
L12	Kala-amba	110	III	15	-	-	-	-	LE, CL, WB, SIC, RM
L13	Kala-amba	160	III	15	1	1	Ea	M	LE, CL, WB, SIC, RM
L14	Navtad	169	III	15	-	-	-	-	CL, WB, SIC, RM
L15	Navtad	187	III	15	-	-	-	-	CL, WB, SIC, RM
L16	Kevdi	136	III	15	1	-	Pa	UI	LE, CL, WB, SIC, RM, GL
L17	Kevdi	140	III	15	2	-	Pa	M	LE, CL, BD, WB
L18	Kevdi	132	III	15	1	-	Pa	UI	LE, CL, WB, SIC, RM, GL
L19	Kala-amba	163	II, V	56	80	2	Pa, Ru	M	LE, CL, WB, SIC, BPC, RM
L20	Kevdi	157	III	15	1	-	Pa	M	CL, WB, RM
L21	Navtad	143	IV	8	-	-	-	-	RM, GL
L22	Kevdi	153	IV	8	1	-	Pa	UI	WB, RM, GL
L23	Kevdi	161	IV	8	1	-	Pa	UI	CL, WB
L24	Navtad	195	IV	8	-	-	-	-	RM, GL
L25	Kala-amba	164	IV	8	1	-	Pa	F	CL, BD
L26	Kilad	118	IV	8	-	-	-	-	RM, GL
L27	Kilad	126	IV	8	-	-	-	-	CL, WB, SIC
L28	Navtad	156	IV	8	-	-	-	-	RM, GL
L29	Kala-amba	123	IV	8	-	-	-	-	CL, WB, SIC, GL
L30	Kevdi	161	IV	8	1	1	Pa, Dr	M	RM, GL

I—30 January–14 February 2020 | II—30 January–14 March 2020 | III—15 February–1 March 2020 | IV—17–24 April 2020 | V—15–25 May 2020
Dr—Drinking | Pa—Passing by | Ru—Running | Ea—Eating | M—Male | F—Female | UI—Unidentified.
LE—Leopard *Panthera pardus* | CH—Chousingha *Tetracerus quadricornis* | CL—Chital *Axis axis* | BD—Barking Deer *Muntiacus vaginalis* | WB—Wild Boar *Sus scrofa* | SIC—Small Indian Civet *Viverricula indica* | BPC—Brown Palm Civet *Paradoxurs jerdoni* | RM—Rhesus Macaque *Macaca mulatta* | GL—Gray Langur *Semnopithecus hypoleucos* | ICP—Indian Crested Porcupine *Hystrix indica* | IGM—Indian Grey Mongoose *Herpestes edwardsii*.

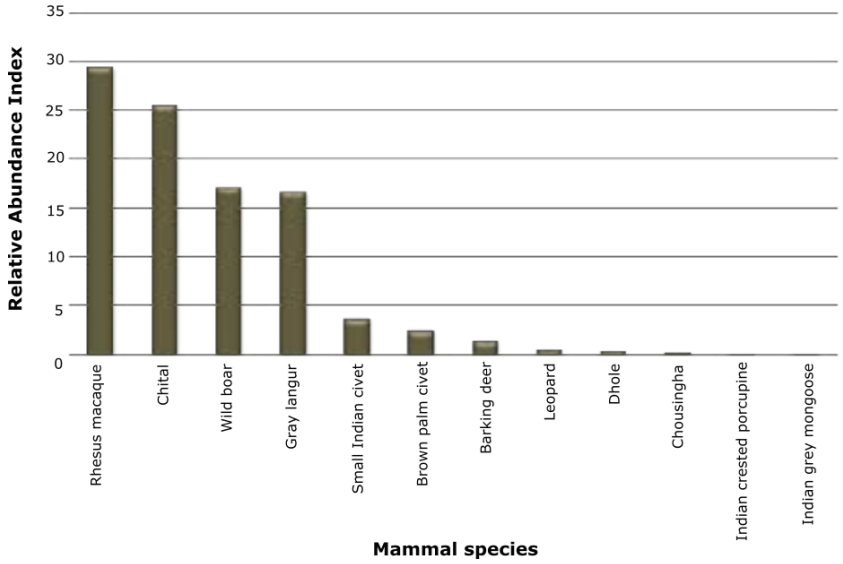

Figure 2. Relative abundance index of mammals of Vansda National Park, Gujarat.

captures were monitored on regular basis, at least once a week. From 15,660 trap nights, we derived 34,206 photos and 481 videos, which included 149 photographs and 22 videos of Dhole. The highest number of photographs (n= 132) and videos (n= 19) of Dhole were from Kevdi beat (L7) and Kala-amba beat of VNP (L11 and L19). Through minimum convex polygon from 16 locations, the minimum home range of Dhole pack was 13.7km^2 in VNP. Minimum distance between Dhole's current extent in central India and VNP is 367km (Figure 1). We recorded 11 other mammals during the study and calculated their relative abundance index (RAI). The maximum photographed species was Rhesus Macaque *Macaca mulatta* (RAI= 29.52), followed by Chital *Axis axis* (RAI= 25.52). The minimum was for Indian Grey Mongoose *Herpestes edwardsii* (RAI= 0.05). The RAI of Leopard and Dhole were 0.67 and 0.43, respectively (Figure 2).

Dhole prefers to live in tropical moist and dry deciduous forests (Kamler et al. 2015), avoid hunting in the same area for a long time and keep changing forest patches time to time to ensure hunting success (Venkataraman et al. 1995). They are hypercarnivore (Van Valkenburgh 1991; Kamler et al. 2015) and their preferred prey is Chital *Axis axis* and Sambar *Rusa unicolor* (Cohen 1978; Johnsingh 1992; Karanth & Sunquist 1995; Venkataraman et al. 1995; Acharya 2007; Ramesh et al. 2012; Johnsingh & Acharya 2013; Selvan et al. 2013; Hayward et al. 2014; Dar & Khan 2016). They have also been reported to prey on buffalo, birds, insects, lizards (Fox 1984), Mouse Deer (Kawanishi & Sunquist 2008; Dar & Khan 2016), Gaur, Mithun (Lyngdoh et al. 2014), sheep, goats (Sosnovskii 1967; Cohen et al. 1978), Wild Boar, hare (Dar & Khan 2016) and even plant matter such as grass, fruits, and leaves (Fox 1984; Gopi et al. 2010). Depending upon prey biomass, interspecific competition and capture efficiency, the Dhole pack size varies from 2 to 40 individuals (Cohen 1978; Johnsingh 1982; Venkataraman et al. 1995; Johnsingh & Acharya 2013) with home range varying from 23–199 km^2 (Johnsingh 1982; Venkataraman et al. 1995; Karanth & Sunquist 2000; Acharya 2007; Acharya et al. 2010; Kamler et al. 2015). Southern Gujarat is the potential habitat for Dhole since it has 28.60% (5228.85km^2) of moist deciduous forest distributed in seven districts with three protected areas covering 792.53km^2 (Champian & Seth 1968; GoG 2019).

We confirm the reoccurrence of Dhole from Gujarat after 70 years in Vansda National Park. We recommend concerted management efforts in the area to ensure long term survival and conservation of the species in the Park and initiation of scientific studies on species ecology and population for effective management and conservation planning.

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NOTE

Mating behavior of Eastern Spotted Skunk *Spilogale putorius* Linnaeus, 1758 (Mammalia: Carnivora: Mephitidae) revealed by camera trap in Texas, USA

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Eastern Spotted Skunks *Spilogale putorius* are an understudied small carnivore listed as 'Vulnerable' by the International Union for Conservation of Nature (IUCN Red List; Gompper & Jachowski 2016), and Vulnerable or Imperiled in most states across their range (Trani et al. 2007). Prairie Spotted Skunks *Spilogale putorius interrupta* are listed as a Species of Concern by the United States Fish and Wildlife Services (USFWS; USFWS 2012). Eastern Spotted Skunks were a common furbearer species throughout the eastern and midwestern United States (Kinlaw 1995; Sasse 2017; Eng & Jachowski 2019), before suffering a notable range-wide decline in the mid-1900s (Gompper & Hacket 2005). The cause of this decline and factors shaping their current distribution are not well understood, although overexploitation, habitat loss, and pesticides likely contributed (Thorne et al. 2017; Eng & Jachowski 2019). As a result, current research has primarily focused on quantifying abundance, occupancy, and habitat relationships (Lesmeister et al. 2009; Thorne et al. 2017; Perry et al. 2018; Eng & Jachowski 2019), and determining effective methods of detection which is often as low as 1.6 or 2.8 detections/100 camera trap nights (Hackett et al. 2007; Eng & Jachowski 2019).

Minimal focus has been on studying the demographics or mating behavior of Eastern Spotted Skunks compared to areas such as habitat preferences and distribution, possibly due to the overshadowing knowledge gaps in these areas. Yet, demographic and mating behavioral information is crucial for effective management and conservation and should be a focal point for species of concern. For most solitary carnivores such as skunks, the distribution of females determines the distribution of males during the mating season (Sandell 1989), and male Eastern Spotted Skunk home range size grows substantially during mating season suggesting questing behavior (Lesmeister et al. 2009), although no study has directly examined this. The only detailed demographic study with cause specific mortality for Eastern Spotted Skunks found a low mean annual survival of 0.354 (95% CI= 0.339–0.368) with similar estimates across age and sex categories (Lesmeister et al. 2010). Two studies monitoring Eastern Spotted Skunk den sites documented food provisioning by females to juveniles, demonstrating parental care and providing information

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Figure 1. Photographs via camera trap of Eastern Spotted Skunks mating on Fort Hood Army Installation. Photographs show the male on top of the female and biting her nape in the first picture but not the second. The date and time are documented in upper left corner of each photographs.

about prey selection (mainly herpetofauna and small mammals in these studies, Sprayberry & Edelman 2016; Thorne & Waggy 2017). Like other solitary carnivores, male Eastern Spotted Skunks likely mate with many females during a mating season and do not remain with any female or contribute to offspring care (Sandell 1989). Other similar studies focused primarily on den site selection which is important for adult survival as well as the care and protection of offspring. Sprayberry & Edelman (2018) found that in forests, Eastern Spotted Skunks preferred to den in dense vegetation with ample understory, likely for protection from predators. Contrarily, Harris et al. (2020) found that in dry prairies, den site characteristics were more important than habitat characteristics and breeding females preferred small mammal burrows. To our knowledge, no studies have been published on Eastern Spotted Skunk mating or communication behaviors.

We used camera traps to monitor wildlife at Fort Hood, an Army installation in central Texas, USA. Fort Hood is a de-facto bioreserve with diverse habitats, protected from surrounding development (Hayden 2014). The Eastern Spotted Skunk population decline is likely due in part to habitat loss, making such bioreserves likely important refugia for the species (Gompper & Hackett 2005). We set 20 Reconyx (Hyperfire and Ultrafire; Reconyx Inc., Holmen, Wisconsin USA) camera traps 500m apart in each of seven grids (n= 140 camera trap locations, we moved cameras every five weeks) between December 2019 and May 2020 as part of a larger wildlife monitoring project aimed at understanding carnivore community structure (full details in Avrin et al. In Press). We programmed camera traps to take 10 photos each time the motion sensor was triggered with no delay between triggers. We took a total of 180,562 photos over 4,908 trap nights, including 2,224 independent capture events of carnivores and 56 independent capture events of Eastern Spotted Skunks (minimum time between independent captures= 30 minutes).

On 15 April 2020 at 04.57h one of our cameras captured images of two Eastern Spotted Skunks mating (Figure 1). The skunks were in front of the camera for six minutes, producing 200 images (Supplementary Material 1 <https://doi.org/10.6084/m9.figshare.14650320.v1>). The male appeared to follow the female before wrestling on top of her at 04.59h and biting her nape. They mated for approximately two minutes, the male maintained a hold on the female's nape intermittently throughout. The mating was very active, and the pair appeared to be wrestling during much of the time. The female ran off towards the east once the male let go and the male departed towards the south.

This observation adds to the minimal natural history knowledge of Eastern Spotted Skunks by providing insight into their mating behavior. Similar mating behavior, including the male biting the female while they wrestle, has been documented in Polecats *Mustela putorius* (Blandford 1987) and captive Pygmy Spotted Skunks *Spilogale pygmaea*, though these species exhibited longer mating durations (18 minutes–1 hour) than we documented. The captive spotted skunks had low conception and parturition success (1 out of 9 pairings produced live offspring; Teska et al. 1981) and it is unknown if wild spotted skunks have greater success. Eastern Spotted Skunks mate during March and April (Kinlaw 1995) similar to other carnivores with

defined breeding seasons in North America. Although we found no research on how Eastern Spotted Skunks find mates, most other solitary carnivores use scent marking to find and select mates (Allen et al. 2015, Kean et al. 2011). It is possible Eastern Spotted Skunks share these and other behavioral and demographic traits with other carnivores, but further research is needed to understand how they find and select mates, their reproductive success, and other aspects that affect the fecundity of wild populations. As a species of concern across its range, such information could prove crucial to conservation and management efforts.

Our detection of Eastern Spotted Skunks mating highlights the utility of camera traps for documenting rarely observed behaviors while monitoring wildlife (Caravaggi et al. 2020). Depending on the study design, remote recording may allow for documentation of rarely exhibited behaviors unbiased by human presence (Pesendorfer et al. 2018; Farías-González & Vega-Flores 2019; Caravaggi et al. 2020). Adjusting camera settings (i.e., increasing the number of pictures taken per trigger, decreasing lag times between triggers, or taking videos) can further improve the likelihood of capturing behaviors. We encourage researchers to publish such documentation of rare or novel behaviors as they add to the collective knowledge and inspire more in-depth future research.

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NOTE

Record of Indian Roofed Turtle *Pangshura tecta* (Reptilia: Testudines: Geoemydidae) from Koshi Tappu Wildlife Reserve, Nepal

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Testudines are the least documented wildlife species, hardly prioritized for the research and conservation actions in Nepal and across the world. The Indian Roofed Turtle *Pangshura tecta* (Gray, 1831) is one of the 16 species of freshwater turtles found in Nepal (Shah & Tiwari 2004; Aryal et al. 2010; Kästle et al. 2013). Nepal hosts three species of the *Pangshura* genus out of a total of four species endemic to southern Asia.

The turtles in Nepal are classified into three families: Trionychidae, Geoemydidae, and Testudinidae (Kästle et al. 2013). Eleven species of turtles belonging to the family Geoemydidae are known to occur in Nepal, viz., *Batagur dhongoka*, *B. kachuga*, *Cyclemys gemeli*, *Geoclemys hamiltonii*, *Hardella thurjii*, *Melanochelys tricarinata*, *M. trijuga*, *Morenia petersi*, *Pangshura tecta*, *P. tentoria* (with two subspecies—*flaviventer* and *circumdata*), and *P. smithii* (with two subspecies—*smithii* and *pallidipes*) (Günther 1861, 1864; Moll 1987; Schleich & Kästle 2002; Kiesel & Schleich 2016).

The Indian Roofed Turtle is recorded from India, Bangladesh, Pakistan, and Nepal (Ahmed et al. 2021). With the help of the available information on its distribution and the documented threats, *P. tecta* is listed as 'Vulnerable' in the IUCN Red List (Ahmed et al. 2021) and under Appendix I in CITES (CITES 2020). *P. tecta* has different vernacular names in Nepal: 'Bharatiya Dhuri Kachhuwa' (Indian Roofed Turtle), 'Dhond' (Kästle et al. 2013), and 'Dharke Kachhuwa' (Striped Turtle).

In Nepal, various surveys and research have reported *P. tecta* from different districts of central and western Nepal including from eastern district Sunsari (Schleich & Kästle 2002; Shah & Tiwari 2004; Aryal et al. 2010; Bista & Shah 2010; KTWR 2018; Bhattarai et al. 2020; Rawat et al. 2020). However, there is no report of the evidence of a live specimen record of *P. tecta* from eastern Nepal till the date. In this note, we report the live specimen record of *P. tecta* for the first time from Koshi Tappu Wildlife Reserve (KTWR) in eastern Nepal (Figure 1).

With the permission from Department of National Parks and Wildlife Conservation (DNPWC), a survey team led by the first author sighted a juvenile *P. tecta* in KTWR for the first time in March 2020. The turtle was encountered at around 12.00h in a lake (26.531^{0}N, 86.921^{0}E; 64m) nearby the Koshi Barrage in Saptari during the chelonian diversity survey in KTWR (Image 1). The individual was found basking on the grassland beside the lake. The lake's dominant aquatic plants were water hyacinth *Eichhornia crassipes* and water lily *Nymphaea*

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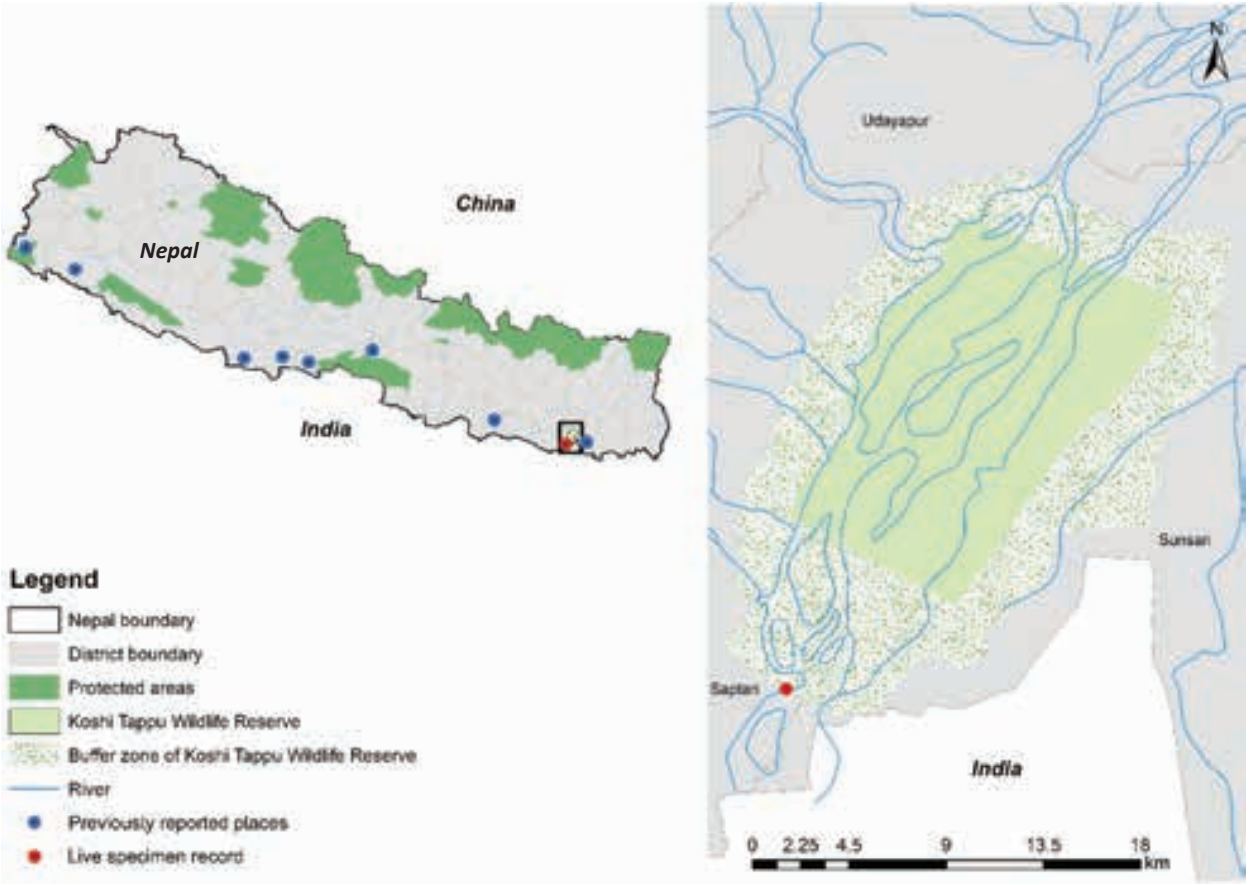

Figure 1. Reported distribution of *Pangshura tecta* across Nepal and new live specimen record from Koshi Tappu Wildlife Reserve, Nepal.

Image 1. *Pangshura tecta* habitat in Koshi Tappu Wildlife Reserve, Nepal. © Ashmita Shrestha

sp. The species was identified as *P. tecta* based on the identification key provided by Kästle et al. (2013). The turtle's body measurements were taken with a vernier caliper (15cm ±1.0mm) and a measuring tape (1m ±1.0mm). Details of the individual are given in Table 1. The turtle was released in the lake after morphometric measurements.

The species was identified as a female because it had a yellow longitudinal band on the dorsal side of the tail (Image 2). The individual has a dark brown head with dull orange, black-bordered stripe and crescent-shaped post-ocular markings curving up from below the eyes to

Image 2. *Pangshura tecta* found on 12 March 2020 in Koshi Tappu Wildlife Reserve, Nepal. © Ashmita Shrestha

Table 1. Morphometric measurements (cm) of *Pangshura tecta* recorded in Koshi Tappu Wildlife Reserve, Nepal.
SCL—Straight carapace length | SCW—Straight carapace width | CCL—Curved carapace length | CCW—Curved carapace width | PL—Plastron length | PW—Plastron width | SH—Shell height

SCL	SCW	CCL	CCW	PL	PW	SH
7.3	4.9	10	9	6.3	2.5	3

meet on the forehead. Iris is greenish, and behind each eye, there is a kidney-shaped purple color spot. The neck is dark, with 32 reddish-yellow longitudinal lines. The plastral formula is abd > fem > an > < hum > an > gul. The carapace is elevated, oval with a distinct vertebral keel spiked, especially on vertebral III. The carapace is brownish with a light brown, orange stripe along the first three vertebral, the marginals with a narrow yellow border plastron is truncated anteriorly, notched posteriorly, and the snout is pointed. The plastron is pinkish-orange with two to four black markings of irregular shape in each plastral scute (Kästle et al. 2013).

Pangshura tecta inhabits deep water of large rivers or oxbow lakes with plenty of aquatic vegetation while basking intensely on land (Kästle et al. 2013). It is less active, herbivorous, and lives for over 17 years (Kästle et al. 2013).

The population size of the *P. tecta* and other testudines is yet to be documented in Nepal; however, the field observation indicates that they are being overexploited for local consumption and trade. Also, giant structures like roads, dams, and new agricultural lands are eroding the turtle habitats. The species is also being used for traditional medicine against hemorrhoids, inflamed eyes, sores, burns, stomach problems, and tuberculosis (Kästle et al. 2013). All these demand detailed species surveys and science-based conservation actions in Koshi and eastern Terai areas of Nepal to save *P. tecta* and other threatened turtle species.

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NOTE

Additional distribution records of *Zimiris doriae* Simon, 1882 (Araneae: Gnaphosidae) from India

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The gnaphosid spider genus *Zimiris* Simon, 1882 has only two representatives in the world: *Zimiris doriae* Simon, 1882 and *Zimiris diffusa* Platnick & Penney, 2004, and both these species are distributed in southern India (Simon 1884; Platnick & Penney 2004). The type species *Z. doriae* Simon, 1882 is widespread and known from Ivory Coast, Sudan, Eritrea, Yemen, and Iran. It was, moreover, introduced into other places such as Mexico, Caribbean, French Guiana, Brazil, Germany, Indonesia (Java) and Malaysia (World Spider Catalog 2021). The species was recorded in India by Simon (1884) and Sherriffs (1919). The specimens collected by Sherriffs were later studied by Cooke (1964) and Platnick & Penny (2004). The aim of this paper is to record this species 102 years since its last record from India and update its distribution records.

Materials and Methods

Specimens were hand collected and studied under a LEICA S8AP0 stereozoom microscope. All measurements are in millimetres (mm). Drawings were made with the aid of a drawing tube attached to the microscope. Microphotographs of the specimens were captured with a Leica DFC2900 digital camera attached to a Leica M205A stereozoom microscope enabled with Leica Application Suite (LAS) version 4.5.0. All the examined specimens are deposited in a reference collection of the Gujarat Ecological and Educational Research (GEER) Foundation, Gandhinagar, India.

Taxonomy

Gnaphosidae Pocock, 1898

***Zimiris* Simon, 1882**

Type species: *Zimiris doriae* Simon, 1882, by original designation.

***Zimiris doriae* Simon, 1882**

Images 1–14: Figures 1–4

Zimiris doriae Simon, 1882: 240, pl. 8, f. 12–15.

Zimiris indica Simon, 1884: 141.

Zimiris doriai? Sherriffs, 1919: 226.

Zimiris doriai Platnick & Penney, 2004: 8, f. 1–8, 12–19.

For a complete list of taxonomic references, refer the World Spider Catalog (2021)

Material examined: GEER421612A, 16.v.2014, two males and one female, Vastrapur (23.037^{0}N & 23.037^{0}E, 4.49m), Ahmedabad, Gujarat, India, coll. D.A. Prajapati & A.V. Prajapati; GEER421612B, 21.ix.2015, one male, Ghatlodia (23.064^{0}N & 72.544^{0}E, 4.69m), Ahmedabad, Gujarat, India, coll. K.D. Prajapati; GEER421612C,

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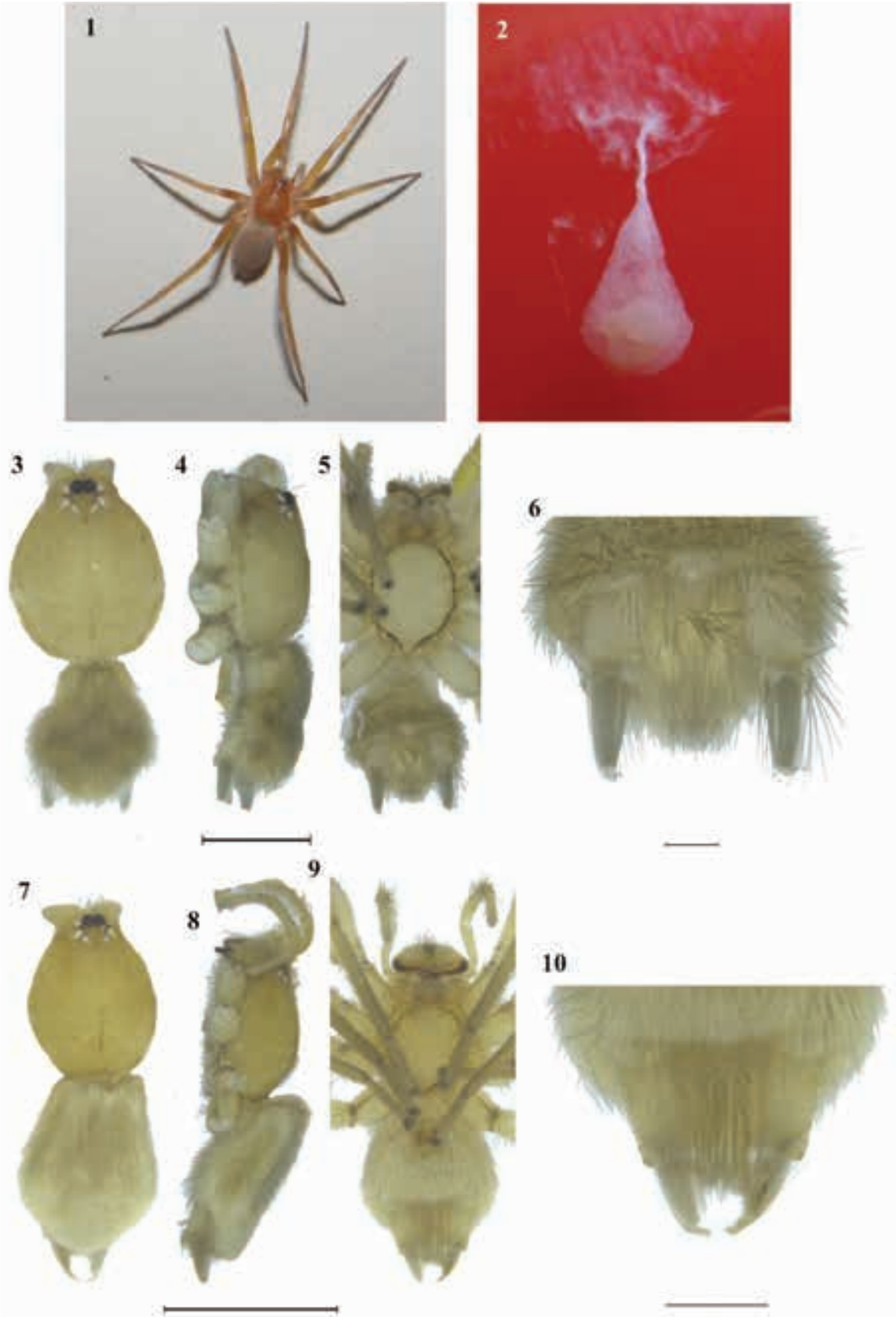
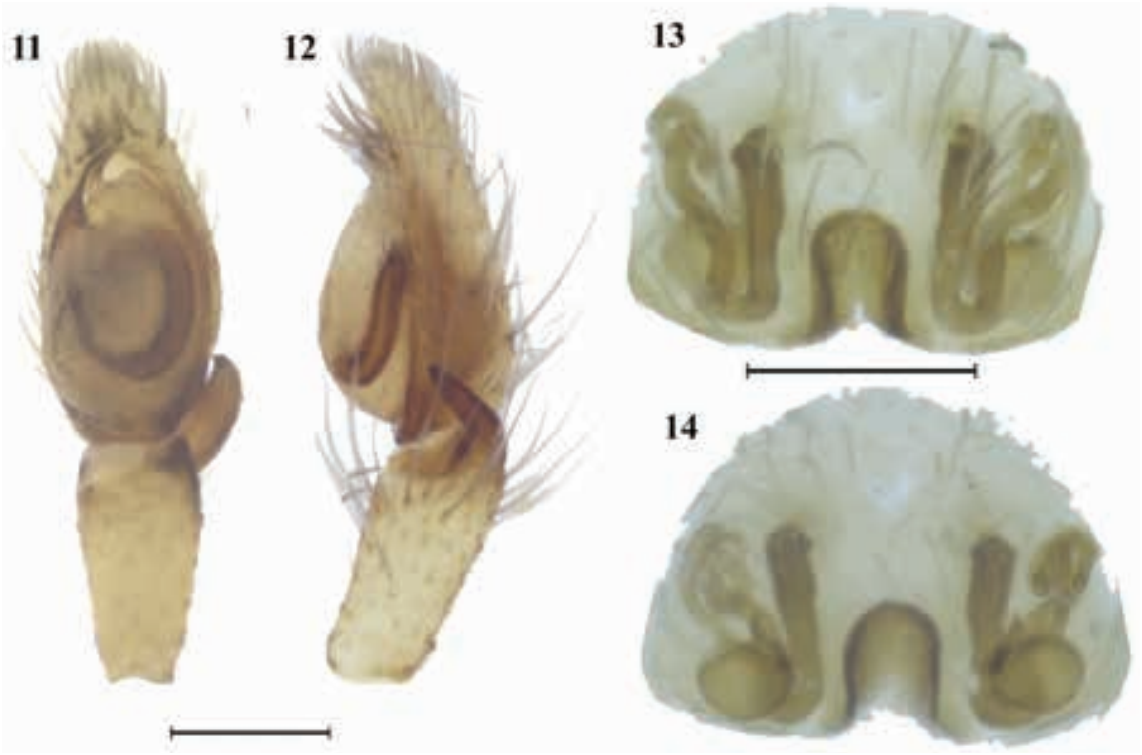
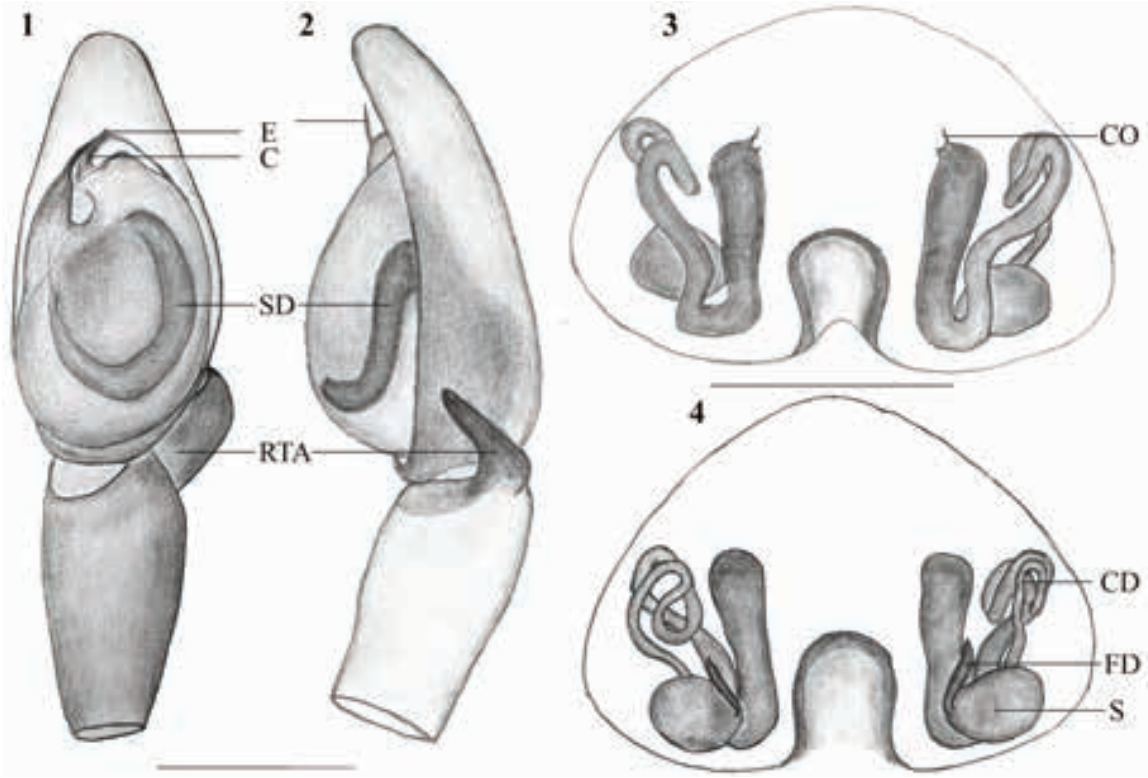


Images 1–10 . ***Zimiris doriae*** **Simon, 1882. 1—Female habitus in life | 2—Egg sac | 3—Male habitus, dorsal view | 4—Same, lateral view | 5—Same, ventral view | 6—Male spinnerets, ventral view | 7—Female habitus, dorsal view | 8—Same, lateral view | 9—Same, ventral view | 10—Female spinnerets, ventral view. Scale bars: 1mm (3–5); 0.2mm (6); 2mm (7–9); 0.5mm (10).**



Images 11–14. *Zimiris doriae* Simon, 1882. 11—Left male pedipalp, ventral view | 12—Same, retrolateral view | 13—Epigyne, ventral view | 14—Vulva, dorsal view. Scale bars: 0.2mm (11–14). © Dhruv A. Prajapati.



Figures 1–4. *Zimiris doriae* Simon, 1882: 1—Left male pedipalp, ventral view | 2—Same, retrolateral view | 3—Epigyne, ventral view | 4—Vulva, dorsal view. Scale bars: 0.2mm (1–4). Abbreviations: C—conductor | CD—copulatory duct | CO—copulatory opening | E—embolus | FD—fertilization duct | RTA—retrolateral tibial apophysis | S—spermatheca | SD—sperm duct. © Dhruv A. Prajapati.

Figure 5. Distribution records of *Zimiris* spp. from India.

07.xi.2015, one female, Bopal (23.046^{0}N & 72.478^{0}E, 4.19m), Ahmedabad, Gujarat, India, coll. D.A. Prajapati; GEER421612D, 19.viii.2017, one female, Sector 28 (23.235^{0}N & 72.678^{0}E, 6.52m), Gandhinagar, Gujarat, India, coll. D.A. Prajapati.

Diagnosis: For detailed diagnosis, see Platnick & Penny (2004).

Description: Male (Images 3–6). Body length 3.04. Carapace length 1.68, width 1.37, height 0.64. Abdomen length 1.36, width 1.10, height 0.64. Pedipalp (Images 11–12, Figures 1–2): embolus filiform, supported by a narrow conductor (Image 11, Figure 1); sperm duct makes a crescent shaped curve before leading to the embolus (Image 11, Figure 1); RTA broad at the base, and narrowing toward a bunt tip, directed ventrad (Images 12, Figure 2).

Female (Images 1, 7–10): Body length 3.84. Carapace length 1.83, width 1.51, height 0.68. Abdomen length 2.01, width 1.54, height 0.97. Epigynum with ventro-medial omega shaped structure (Image 13, Figure 3); spermathecae spherical (Image 14, Figure 4); copulatory ducts long, narrow at proximal end and broad distally (Image 14, Figure 4).

Distribution in India: Gujarat: Ahmedabad and Gandhinagar (present record), Tamil Nadu: Chennai (erstwhile Madras), Puducherry, a union territory (erstwhile Pondicherry) and Ramanathapuram (erstwhile Ramnad) (Simon 1884; Sherriffs 1919; Cooke 1964) (Figure 5).

Natural history: This species is nocturnal and can be synanthropic (Sherriffs 919; Platnick & Penny 2004). All specimens in the present study were collected during the night, as they were wandering on walls in houses. However, one specimen was collected during the day time from a cloth shop, from inside a cloth box. A gravid female was also captured to observe its egg sac, which appeared as a hanging bell and it contained six pale yellowish eggs (Image 2).

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NOTE

Notes on new distribution records of *Euaspa motokii* Koiwaya, 2002 (Lepidoptera: Lycaenidae: Theclinae) from Bhutan

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The genus *Euaspa* Moore (1884), commonly known as hairstreak butterflies, falls in the Lycaenidae family and is distributed across the Himalayan range to southeastern Asia. With the recent description of *Euaspa zhengi* Huang, 2016 from Motuo, southeastern Tibet (Huang 2016), there are 14 species in the *Euaspa* worldwide (Das et al. 2019). Currently, two *Euaspa* species—*E. pavo* (de Nicéville 1887) and *E. motokii* Koiwaya, 2002—have been recorded from Bhutan. *Euaspa motokii* was first described from Naungomon, Kachin state of Myanmar (Koiwaya 2002), and its distribution extends to Anini (Dihang-Dibang Biosphere Reserve) in Arunachal Pradesh State of India (Das et al. 2019). The IUCN status of this species is not assessed. The present record extends the distribution range of *E. motokii* from Kachin State of Myanmar and the Indian state of eastern Arunachal Pradesh to the foothills of the Himalaya in Bhutan.

***Euaspa motokii* Koiwaya, 2002 (Image 1a,b)**

Diagnosis: *Euaspa motokii* Koiwaya, 2002 is differentiated from all other congeners in having less prominent blackish marks in the subterminal area of the underside of the forewing. These marks are prominent in case of *E. forsteri* (Esaki & Shirôzu 1943). It also has two discal white zig-zag lines and two sub-basal white markings on the underside of the hindwings. An oval-shaped cell spot with semi-circular opening is a prominent feature of this species (Das et al. 2019) (Image 1a,b).

Current record: *Euaspa motokii* was first observed on 9 June 2017 at Dakpai (27.191^{0}N & 90.734^{0}E; 1,245m) and later on 1 June 2020 at Tali (27.166^{0}N & 90.751^{0}E; 1,769m), both in Zhemgang District (Figure 1). Dakpai and Tali are neighboring villages located within 3km of each other. A single individual was photographed at around 08.00h and 09.30h, respectively (Image 1a,b). The species was identified based on the description and photographs provided in Koiwaya (2002; 2007) and Das et al. (2019), and confirmation was provided by Motoki Saito. This species has remained unreported until now, even though it was first observed and archived in 2017

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Competing interests: The authors declare no competing interests.

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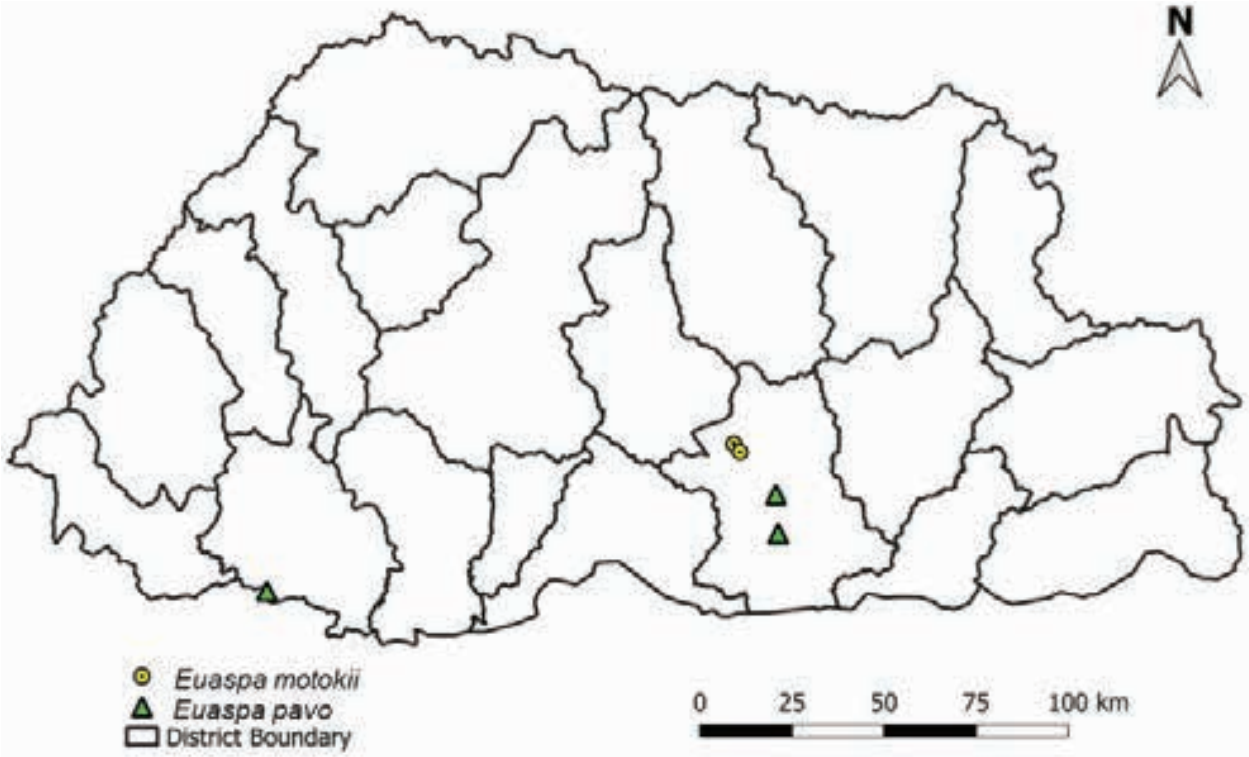

Figure 1. Current records of *Euaspa motokii* from Tali and Dakpai; and distribution records of *Euaspa pavo* from Pasakha, Chukha District, Khomshar and Pantang, in Zhemgang District, Bhutan.

in the photograph collection of the second author. With this new record, Bhutan now has 760 species of butterflies as per Wangchuk et al. (in press).

Remarks: The species was observed perching on the fallen branch of *Castanopsis* sp. and dry soil. The species has been reported only from these two localities despite concerted efforts, suggesting it is rare and may have a restricted distribution in Bhutan. Associated species observed in the same area include *Pedesta pandita*, *Libythea myrrha*, *Cyrestis thyodamas*, *Hebomoia glaucippe*, *Papilio helenus*, and *Papilio polyctor*. In Bhutan the presence of two species of *Euaspa* viz, *E. motokii* and *E. pavo* have been established.

The preferred habitat of this species is cool-broadleaved forest mainly composed of *Castanopsis tribuloides*, *C. hystris*, *Schima wallichii*, *Eurya* sp., *Hobina* sp., *Daphne sureil*, *Artemesia* sp., *Ageternia adonophora*, *Salligenella* sp., *Solanum* sp., *Osbeckia* sp., *Polygals arillara*, and *Leucus cilita.* Typically, this species prefers evergreen forest dominated by oak species. *Castanopsis* was reported to be the food plant of *E. motokii* larvae (Das et al. 2002; Koiwaya 2002) this is probably the case in Bhutan as it was sighted in oak forest. Previously, the local community used this area for shifting cultivation and the forest is typically young and appears to be a favorable habitat for butterflies.

The sighting locality falls within the Nangkhor Local Forest Management Area. The area is primarily used by local people for the extraction of fuelwood and timber, and for cattle grazing. The Territorial Forest Division in Zhemgang under the Department of Forests and Park Services has been safeguarding and protecting wildlife and habitats. The increasing demand for timber and fuelwood has become a concern and increases the pressure on the habitat of *E. motokii* habitat. The practices of seldom shifting cultivation and extraction of non-wood forest products are additional threats which are exacerbated by easy access from motorable road. These factors may pose threats to the existence of this species in Bhutan. We suggest that further assessment to be carried out to ascertain specific threats to the species in Bhutan.

***Euaspa pavo* (de Nicéville 1887)**

Current record: In Bhutan *E. pavo* (de Nicéville 1887) has also been reported from Pantang (26.967^{0}N & 90.855^{0}E; 245m) and Khomshar (27.134°N & 90.948°E; 1,100m) villages in Zhemgang District on 24 September 2018 and 1 July 2019 respectively (Figure 1, Image 2 a,b). Since the first description by de Nicéville in 1887, *E. pavo*

Image 1. *Euaspa motokii* recorded from Zhemgang District, Bhutan: a—Dakphai in 2017 | b—Tali in 2020. © Dhan Bahadur Subba

Image 2. *Euaspa pavo* recorded from Zhemgang District, Bhutan: a—female | b—male, Khomshar Vilage. © Sherub Jamtsho

has been observed at two localities of warm broadleaved forest, extending its distribution from the south western to central foothills of Bhutan.

Remarks: The specimen of *E. pavo* deposited at Carnegie Museum of Natural History in the collection of Mr. Knyvetts was collected from Buxa (Ueda & Koiwaya 2003), currently Pasakha, Bhutan. The reported distribution elsewhere, where this species is known to occur are in northeastern India, Laos, and Myanmar (Gupta & Mondal 2005; Ueda & Koiwaya 2003). The species appears to have a restricted distribution, though concerted efforts are employed for a study. This species has high conservation significance due to its restricted distribution and is protected under the Indian Wildlife Protection Act, 1972, Schedule-I (Part V), primarily to reduce vulnerability against threats such as deforestation, logging, grazing, tourism, and infrastructure development (Gupta & Mondal 2005). A systematic empirical study is suggested as this species require more information on habitat, ecology, life cycle, and distribution to establish the conservation measures and interventions in the localities.

Conclusion: The distribution of *Euaspa* species is confined to the Himalaya and Southeastern Asia. Data on the distribution and ecology of *Euaspa motokii* are in the early stages due to limited investigation and exploration (Saito 2017) and mainly consist of occasional sightings. The current record of *Euaspa motokii* from limited localities reveals the need for systematic sampling in similar subtropical broadleaved evergreen forest (Das et al. 2019), cool-broadleaved forest for former species, and warm broadleaved forest for latter species across Bhutan to establish the approximate distribution in the country. Knowledge of the current records of *Euaspa motokii* and *E. pavo* will not only serve as baseline data to instigate future organized sampling but will also in the long run help evaluate the health of the environment in response to the effects of climate change. Community

awareness to mainstream responsible conservation, and engagement of local residents in monitoring will also help uphold the habitats of butterflies in Bhutan.

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NOTE

New distribution records of two little known plant species, *Hedychium longipedunculatum* A.R.K. Sastry & D.M. Verma (Zingiberaceae) and *Mazus dentatus* Wall. ex Benth. (Scrophulariaceae), from Meghalaya, India

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The East Khasi Hills of Meghalaya home for a very rich and diverse vegetation. It is unique in having a mixture of Asiatic and Indian peninsular elements. Many taxonomists have carried out taxonomic documentation in this region since the British period. A botanical exploration trip was conducted to Mawsynram forest areas of East Khasi Hills District, Meghalaya during March 2017–May 2018, for live plant collection under the allotted Annual Action Plan Project on ex situ conservation of endemic and threatened plants of northeastern India in the Experimental Botanical Garden (EBG), Botanical Survey of India, Barapani, Shillong.

During this trip, the author came across two interesting plant species which are growing on rocky slopes in densely shaded areas near a stream. Subsequently, these two species were collected and grown in the EBG. After critical examination of these specimens with relevant literatures, type specimens, comparison with herbarium sheets deposited in ASSAM, CAL, MH, BM, K, E, these specimens were identified as *Hedychium longipedunculatum* A.R.K. Sastry & D.M. Verma (Zingiberaceae) and *Mazus dentatus* Wall. ex Benth. (Scrophulariaceae). The relevant literatures (Balakrishnan 1981–1983; Haridasan 1985–1987; Joseph 1982; Mao et al. 2016) pertaining to the flora of Meghalaya reveals that, these species so far not reported from the state and hence, reported here as additions to the flora of Meghalaya with photographic illustration, citation, description along with distribution and ecology for easy identification and future reference (Image 1).

Materials and Methods

The materials for the present study were collected from the forest areas of Mawsynram during March 2017–May 2018. Detailed morphological studies on flowering and fruiting timing, associated species, ecology, habitat of occurrence, and elevation were recorded in field note book. The detailed description was prepared after proper diagnosis and examination of a wide range of

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specimens. Observations were made with Magnus MIPS 5.0 mega pixel digital stereo microscope. Standard method of collection, preservation and maintenance of specimens in the herbarium was followed (Jain & Rao 1977). The herbarium specimens are deposited at Madras Herbarium (MH), Coimbatore, Tamil Nadu.

Scrophulariaceae

Mazus dentatus Wall. ex Benth., Scroph. Ind.: 27. 1835; Hook. f., Fl. Brit. India 4: 260. 1884; T. Yamaz. in H. Hara, Fl. E. Himalaya: 288. 1966; Malick & Bhaumik in Lakshminarasimhan et al., Fl. West Bengal 4: 118. 2019.

Erect, small, lithophytic, acaulescent, non-stoloniferous, sparsely hairy herb with perennial root stock, whole plant turns into black when dry. Leaves crowded in a basal rosette; lamina broadly elliptic-oblong, oblong-ovate or rarely obovate, 3–12×2–6 cm, acute, rounded or sub-cordate or rarely oblique at base, dentate or sinuate at margins, obtuse or rounded at apex, usually sparsely hairy on lower surface, rarely densely pubescent, sparsely pubescent or sub-glabrous on upper surface; lateral nerves 4–6 pairs, obscure; petioles 1.5–7.5 cm long, channeled above, sparsely hairy. Flowers large, in terminal racemes, 1–10-flowered, usually distant or sometimes apically fascicled; scape usually solitary, rarely 2, erect or decumbent, slender, leafless, up to 12cm long, densely hairy at base, sparsely hairy towards apex; pedicels 4–8 mm long, pubescent. Bracts 2–4 mm long, setaceous. Calyx campanulate, 4–7×2–4 mm, greenish or pinkish, pubescent hairy outside; teeth 5, ovate or triangular, 1.5–2.5×1.0–2.0 mm long, erect or sub-erect, shorter than tube, margins sometimes slightly recurved, acute at apex; midrib prominent, thick, raised. Corolla whitish or purplish, 1.5–2.5 cm long, 2-lipped, exterior in bud, throat with 2 longitudinal yellowish batch, prominently pubescent hairy; tube up to 1.2cm long, white at base, purplish towards apex; upper lip erect or reflexed, 2-lobed; lower lip much longer than upper, spreading, 3-lobed, mid-lobe oblong, slightly longer than lateral lobes; lobes emarginate or sometimes shallowly 2-lobuled at apex. Stamens 4, didynamous, inserted on corolla tube; anther cells connecting to each other, diverging at base, apically connivent; filaments 0.7–1.5 cm long, glabrous. Ovary hairy or glabrous, 2-celled; style glabrous, up to 1.3 cm long; stigma 2-lamellate. Capsules obovoid, 2–3×1.5–2 mm, obtuse at apex, loculicidal, 2-valved, included;seeds numerous, ovoid, minute.

Flowering & fruiting: March–May.

Habitat & ecology: Very rare in densely shaded tropical moist deciduous forests near waterfall and on dripping rocks, between 1,000m and 1,800m in association with *Argostemma khasianum* C.B. Clarke, *Argostemma verticillatum* Wall., *Begonia ovatifolia* A. DC., *Begonia* spp., *Bulbophyllum* spp., *Dichocarpum adiantifolium* (Hook.f. & Thomson) W.T. Wang & P.K. Hsiao., *Eriocaulon* spp., and *Malaxis* sp..

Distribution: India (Arunachal Pradesh, Meghalaya, Sikkim, and West Bengal), Bhutan, and Nepal.

Specimen examined: Meghalaya, East Khasi Hills District, Mawsynram, 25.359^{0}N & 91.607^{0}E, 25.iii.2017, coll. M. Murugesan, 137302 (MH Accession number 177984).

Zingiberaceae

Hedychium longipedunculatum A.R.K. Sastry & D.M. Verma, J. Bombay Nat. Hist. Soc. 65: 293–295. 1968; A.S. Rao & D.M. Verma, Bull. Bot. Surv. India 14(1–4): 130. 1972; S.C. Srivast. in S.K. Jain & R.R. Rao, Threat. Pl. India: 236. 1983; S.K. Jain & V. Prakash., Rheedea 5(2): 161. 1995; Moaakum & Santanu Dey, Pleione 7(1): 290–294. 2013.

Erect, usually terrestrial, perennial, rhizomatous herbs, sometimes epiphytic or rarely lithophytic. Rhizome creeping, 1.5–2.5 cm wide, creamy yellow or pale greenish-yellow internally, light greyish-green externally, slightly aromatic. Leafy shoot 25–55 cm high, slanting with erect inflorescence, glabrous. Leaves 4–8, alternate, lower ones smaller, sessile, upper ones longer, prominently petioled; petioles 0.2–1.7 cm long, sheathed; sheaths 1–6.5 cm long, lowest 2 or 3 sheaths without lamina; lamina broadly to narrowly elliptic or elliptic-lanceolate or oblong-elliptic, 5–32×2–12 cm, dark green on upper surface, light greenish-pinkish or pinkish-purple on lower surface, glabrous, acute at base, undulate at margins, abruptly acuminate or caudate-acuminate and twisted at apex; lateral nerves many, arched at margins; ligule 1.5–2 cm long, bi-lobed at apex, glabrous, translucent, papery, closely appressed to the stem. Inflorescence of spikes, 4–20 cm long, cylindrical, erect, many-flowered; peduncle up to 14cm long, slightly curved upwards, glabrous, rachis hairy. Bracts 1-flowered, pinkish-red, triangular, ca 1.3×0.8 cm, 9–11-nerved, as long as calyx, glabrous, convolute at margins, acute or sometimes obtuse at apex, translucent, membranous. Bracteoles pinkish or reddish, ovate, ca. 7.5×5 mm, membranous, acute at apex, obscurely 3-nerved, completely enclose the flower. Flowers 3–3.3 cm long, creamy yellow, 8–18 flowers open at a time, ascending, fragrant. Calyx pale yellow or creamy-yellow, tubular, up to 1.2 cm long, 7–9-nerved, densely villous, membranous, tufted hairs

Image 1 a–d. *Hedychium longipedunculatum* A.R.K. Sastry & D.M. Verma: a—whole plant | b—a flowering branch | c—seeds | d—fruits; e–h. *Mazus dentatus* Wall. ex Benth.: e—whole plant | f & h—inflorescence | g—flower side view. a,c–g—© M. Murugesan | b—N. Odyuo | h—Gopal Krishna.

at tip, unilaterally split at apex. Corolla tube creamy yellow with pale red, erect, as long as calyx, villous inside, glabrous outside; corolla lobes 3, ca. 1.8×0.7 cm, creamy yellow, pale red tinged towards apex, linear-lanceolate or lanceolate-oblanceolate, membranous, glabrous, acute at apex, 3-nerved. Lateral staminodes 2, creamy-yellow, spathulate, ca. 1.8×0.8 cm, petaloid, spreading on flower, slightly reflexed back in upper half, prominently clawed towards base, slightly thick; claw ca. 6×3 mm. Labellum deeply bi-lobed; sinus ca. 1cm deep, lobes ovate or oblong or rarely orbicular, obtuse or rounded at apex. Stamen solitary, ca. 2.2cm long, erect; anther ca. 7mm long, oblong, bright-yellow, 2-celled anther locules divergent at base, attached with the filament at 2–3 mm above from base, connective bright yellow; filament ca 1.5cm long ca. 2mm wide at base, yellow, erect. Ovary ca. 3mm in diameter, subglobose, densely villous, obscurely three angled; placentation axile; style filiform, white, ca 2.8cm long glabrous, green tinged towards stigma; stigma ca. 1mm broad, green, cup-shaped, slanting with a depression at center, with hook-like ciliate hairy. Capsule ca. 1.5cm diameter, sub-globose, glabrous or hairy, 3-angled, 3-locular; fruit wall fleshy, reddish or orange internally, completely splitted and reflexed back on dehiscence; seeds black, ellipsoid, ca. 3.5×1.5 mm, smooth; aril red, lacerate, fleshy.

Flowering & fruiting: May–August

Habitat & ecology: Very rare in the margins of densely shaded tropical moist deciduous forests near streams and on rocks, between 1,400m and 2,000m in association with *Begonia* spp., *Carex* sp., *Hedychium* sp., Wall., *Malaxis* sp., and *Phyllanthus* sp.

Distribution: Arunachal Pradesh, Meghalaya and Nagaland; endemic to northeastern India.

Specimens examined: Meghalaya, East Khasi Hills District, Mawsynram, 25.359^{0}N & 91.607^{0}E, 09.vi.2017, coll. M. Murugesan, 137310 (MH Accession number 177985).

Notes: This very rare species previously known based on only few collections from Arunachal Pradesh and Nagaland of northeastern states (Sastry & Verma 1968; Jain & Prakash 1995; Moaakum & Dey 2013). Therefore, the present collection from the study area shows its extended distribution and also forms an addition to the flora Meghalaya.

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Corrigendum

Bhatt, M.R. (2021). A new record of an endangered and endemic rare Rein Orchid *Habenaria rariflora* from Gujarat, India. *Journal of Threatened Taxa* 13(5): 18385–18389. https://doi.org/10.11609/jott.6171.13.5.18385-18389

The author regrets that the title of the paper is incorrect. The correct title reads as follows: "A new record of an endangered and endemic orchid *Habenaria rariflora* A. Rich from Gujarat, India".
The author would like to apologize for any inconvenience caused.

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