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From plant selection by elephants to human and veterinary pharmacopeia of mahouts in Laos.

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Glossary and abbreviations:

ECC: Elephant Conservation Center

EUR: Elephant Use Report

Mahout: A person who takes care of an elephant

NNPA: Namphuy National Protected Area

Abstract

Ethnopharmacological relevance

To what extent has animal observation contributed to the development of human pharmacopeias? We approach this question here through the study of mahouts' knowledge regarding the responses by elephants to their health problems, and the human medicinal uses of plants and the care of domestic animals that result from their observations.

Materials and methods

32 mahouts were interviewed in Thongmyxay district and 28 at the Elephant Conservation Center in the province of Xayabury. Interviews focused on the elephants' diet, health problems, plant items they consume in particular physiological or pathological contexts and the treatments that mahouts provide them. For each plant mentioned, the part of the plant consumed and mode of preparation and administration if used by mahouts were recorded. Species samples were then collected and later identified by specialists.

Results

114 species were recorded as being consumed by elephants during interviews with mahouts and forest outings with them to collect samples. Twenty species were identified as used by elephants in particular pathological conditions or physiological states. According to interviewed mahouts, the consumption of certain plants improves the health of the elephant. We observed clear convergences between the observations interpreted by the mahouts as self-medication behaviour from elephants and their own medicinal practices (for human and veterinary purposes).

Conclusion

Beyond a mere reproduction of elephant self-medication behaviours observed, the human or veterinary medicinal cares derived from these observations are the result of complex arrangements integrating all available medicinal and conceptual resources into elaborate preparations.

We recommend that mahouts' knowledge about traditional medicinal care given to elephants be further compiled, as it could have a beneficial impact on veterinary health care provided in elephant resorts and elephants' well-being.

1 Introduction

The study of animal self-medication behaviour and zoopharmacognosy (Rodriguez et Wangham, 1993) began about 20 years ago with scientific observations made about primates, especially chimpanzees (Wrangham 1995; Huffman et al., 1997). However, this type of behaviour can be found in many accounts from traditional oral cultures that attribute an animal origin to certain medicinal uses of plants (Huffman, 2003) as well as in ancient literature (Boeme, 2008). Studies have documented convergences of therapeutic uses of some plants between animals and humans (Huffman, 2001; Krief et al., 2005, 2006; Morrogh-Bernard, H.C., et al., 2017) suggesting either independent convergences, or transfers of knowledge from animals to humans. A few cases of transfers have been reported where direct observation of a sick animal's behaviour can be linked to the subsequent and effective use of the same remedy by humans presenting the same condition (Huffman, 2001; Krief and Brunois, 2017). However, there has been little exploration of how medicinal practices are adapted and shaped by the observation of animal behaviour.

During a survey on traditional plant uses conducted in southern Thailand in 2014, we looked at the knowledge of two mahouts (the English term borrowed from India for a person in charge of a domestic elephant in Asia) that suggested that this particular human-animal relationship between mahouts and their elephants can be a significant source of knowledge to better understand the origin of human medicine (Dubost, 2015). Indeed, in the traditional way of managing elephants within the village context, elephants are not fed but are allowed to feed themselves in the surrounding forests (Maurer et al., 2017; Maurer, 2018). Because of the comparable life span between elephants and humans, mahouts who spend a large part of their lives with the same animal are able to observe its needs and responses according to its state of health, responses that they sometimes interpret as a form of self-medication from these animals. Moreover, the traditional care they provide elephants places mahouts at the interface of these presumed animal self-medication behaviours and local traditional medicine, providing a good opportunity to study the convergence of medicinal plant use between men and elephants. We therefore carried out a study to explore the relationship between traditional human and veterinary medicine and observations on elephant behaviour by mahouts in an area of Laos where mahouts and owners still keep their elephants in the vicinity of villages. Data obtained were supplemented with elephant observations and interviews conducted in an elephant center dedicated to the conservation of this species in Laos.

2 Background

Laos is located in a humid tropical zone. The climate is seasonal, with a rainy season (May-October) a cool-dry season (November-February) and a hot-dry season (March-May). Characterized by extensive forest cover, the country is part of the Indo-Burma biodiversity hotspot (Myers et al., 2000), but this cover has drastically decreased and is becoming more and more fragmented. In the mid-1960s, forested areas accounted for 70% of the territory, compared to 41% in 1999 (Southavilay, 1999) and areas of over 1000 ha decreased from 88% of the total forest area in 1992 to 54% in 2004 (Evrard, 2004), indicating a process of landscape fragmentation. However according to the most recent assessment of forest cover by the Department of Forestry of the Lao PDR, reduction of forest cover decreased significantly from 2002 to 2010, and according to official sources forest cover has increased slightly in the north of the country (Kim and Alounsavath, 2015).

2.1 *Elephas maximus* in Asia and Laos

The Asian elephant *Elephas maximus* is classified as an endangered species by the IUCN. The loss and fragmentation of its habitats is the main cause of this decline of elephant populations in Asia (Leingruber et al., 2003), where it is found in 13 countries (IUCN, 2016).

In Laos, the elephant is an emblematic species, and the country was previously called Lan Xang "Land of the million elephants". However, the population estimated at 2000-3000 wild elephants in 1988 (Phantavong and Santiapillai, 1992) had reduced to just 600-800 individuals by 2009 (Khouboline, 2011). Domestic elephant numbers are also declining sharply in Laos and are now comparable to the number of their wild counterparts (Khouboline, 2011; Suter et al., 2014). These elephants living in contact with humans have an intermediate status between wild and captive or domesticated animals. Traditionally sourced from wild populations (Lair, 1997; Sukumar, 2003), they have not undergone a selection process like most domesticated animals. According to traditional management methods, they are not fed and are periodically released in the forest over long periods (Maurer, 2018). It is therefore equally inappropriate to apply the epithet of captives to them, which refers instead to animals whose movements are much more restricted. We will thus use for the elephants of Thongmyxay district the term "village elephant" proposed by Maurer (*ibid*) and used by Lainé (2017) and will use "captive elephant" when talking about elephants kept in camps. Village elephants often have several owners within the same family, but usually just one will be in charge of looking after them and is described as their mahout (Suter, 2013).

2.2 *Diet and Habitat*

Elephants are generalist postgastric herbivores that feed on a wide variety of plant items, whether in terms of species consumed, life form (trees, vines, grasses, herbs) or of parts selected such as leaves, fruits, twigs, barks, roots, woody stems (Sukumar, 1992, 2003; Chen et al., 2006; Himmelsbach et al., 2006; Joshi and Singh 2008; Campz-Arceiz et al., 2008; Santra et al., 2008; Lithong et al., 2007; English et al. 2014). Areas which constitute ecotones between cultivated areas and regrowth or disturbed forests colonized by pioneer species, which display higher levels of understory vegetation than old-growth forest, are optimal for elephants in terms of resources and carrying capacity (Fernando and Pastorini 2011; Fernando et al., 2005; Evans et al., 2017). These characteristics regularly bring elephants to frequent the outskirts of anthropized areas.

3 Material and method

3.1 *Study area*

This study was conducted in Xayabury province (Figure 1), which is home to 80% of the village and captive elephants in Laos (Lassausaie et al., 2015), in two sites:

1. In the district of Thongmyxay, whose inhabited area is encompassed by the Namphuy National Protected Area (NNPA) which covers 1912 km² (WWF, 2019) and shelters the second largest population of wild elephants in Laos, estimated at 60-80 individuals in 2009 (Khouboline, 2011). The inhabited area of Thongmyxay is mainly surrounded by forested areas consisting of degraded secondary forests, *Dypterocarpaceae* forests, riverine forests and hill bamboo forests.
2. At the Elephant Conservation Center (ECC) in the north of the province. This center, dedicated to wild and captive elephant conservation and research in Laos, develops ecotourism activities focused on elephant observation. It is delegated by the Ministry of

Forests to be responsible for the NNPA's wild elephant protection activities, and has a concession of 512 ha where elephants feed themselves. Vegetation consists mainly of young, dry dipterocarp forest dominated by *Shorea siamensis* Miq. within a broad topographic range covering the area and an abundance of bamboo in patches running along the bank of a stream. Signs of logging are present and the area is surrounded by rice farms.

3.2 Survey

We carried out an inventory of plants which the mahouts indicated were consumed by elephants, specifying the parts consumed. Then we organized forest outings with mahouts (in Thongmyxay district and at ECC) to explore different areas where they let their elephants feed, in order to collect samples of the listed plants, which were dried to prepare herbarium specimens. The taxonomic identification was carried out under the responsibility of Vichith Lamxay in the Department of Botany at the National University of Laos. Plants names were checked and updated according to the standard database "The Plant List" (<http://www.theplantlist.org>). Voucher specimens were deposited at the Herbarium of the National University of Laos in Vientiane.

We conducted semi-structured interviews with 60 mahouts - 32 in Thongmyxay district (aged 38 to 78) and 28 in ECC (aged 35 to 63) - all of whom were Tai-Lao, the dominant ethnic group in Laos.

The interviews focused on:

- Elephant management practices and changes that have occurred since the beginning of their mahout activity, especially issues of access to food resources, in order to assess the context of the observations reported by mahouts.
- The feeding behaviour of their elephants, by requesting qualitative information on the context of consumption of the plant items they consume.
- Elephant health problems, their needs, the possible care provided (including preparation and administration methods) and observations regarding how elephants respond to their own problems. When plants were cited as being consumed by elephants in a particular physiological context, mahouts were also asked if they used them themselves in the family environment.

We also followed a female elephant that had been released into the forest (on average six hours a day for five days) at the ECC site to observe its feeding behaviour. This enabled us to get a better understanding of the observations reported by the mahouts and thus inform our discussions with them on the behaviour of their elephants.

3.3 Ethics and authorizations

Ethical approval was obtained from the National Ethics Committee for Health Research (NECHR) under the supervision of the Ministry of Health of the Lao PDR (0894NIOPH/NECHR). Authorization to collect the plants was obtained from the relevant authorities. The study was approved by the local Nagoya protocol office (N°008/SABS).

Voucher specimens were deposited at the herbarium of the Department of Biology, Faculty of Sciences, National University of Laos (NUoL), in Vientiane.

4 Results and discussion

4.1 Elephant management practices in Thongmyxay district

In recent decades, there have been three successive phases in the evolution of elephant management and use. Of the 32 mahouts interviewed in Thongmyxay district, 21 are no longer active, either because they have sold or rented out their elephant (*cf. infra*) or because they have handed over their responsibility to relatives. They described the traditional elephant management system that prevailed before the construction of the road linking Thongmyxay district, which was built 20 years ago. Elephants were then used mainly for the transportation of goods - mostly rice after the November harvests - and on demand for occasional village-scale logging to provide locally-used timber. These activities took place in the dry season from November to April when the land is passable. During this period, elephants were tethered (with a 30-40 m chain) or simply hobbled in the wooded areas near the village, and were moved once or twice a day to renew their feeding areas and to allow them to drink. During the rainy season, when all available human resources were used to plant crops, elephants were released in small groups in the forest that is now part of the NNPA. They were visited from time to time and sometimes came back on their own at the beginning of the dry season, or the mahouts would go looking for them and bring them back.

About thirty years ago, with the development of the road network and the arrival of vehicles, elephants were no longer used for transport. They were used instead for logging, meeting the demand of forestry companies who were then engaged in a massive exploitation of timber wood. (Suter, 2010). As a result, since elephants no longer have any use in terms of work except for occasional logging for the villagers, the owners have tended to free themselves from the burden that their animal now represents by selling it (11 respondents) or renting it out to elephant camps (8 resp.). However, other owners in Thongmyxay chose to keep their elephants (11 resp.). This is due firstly to the fact that the district enclosed in the NNPA offers crop-free areas where they can still release their elephants. Secondly, this protected area, which houses the second largest population of wild elephants in Laos, provides opportunities for the new income activity of elephant breeding for sale. The female elephants are thus left in the forest to mate with wild males (reported by 6 mahouts out of the 11 still working) and an elephant calf can be advantageously sold or rented to elephant camps for which it is a first-choice attraction (Maurer et al., 2017).

4.2 Inventory of plants indicated by mahouts as being consumed by elephants

When they keep their elephant tethered, mahouts can see which species have been consumed by observing changes in the vegetation cover of the area where their elephant has been feeding and the marks left on specimens. The daily movements to bring the elephant to a new feeding area or the regular visits to them when released also provide an opportunity for many direct observations of plant consumption. A total of 114 species were recorded as being consumed by elephants during mahout interviews and forest outings with them, with the parts taken for each amounting to 197 plant items. However, according to all mahouts, bamboo twigs and leaves make up the staple part of the elephants' diet. This inventory will be the subject of a future publication. Parts of plants taken may include roots, stems, twigs, bark, wood, leaves, fruits, and young shoots. Plant forms are also very diverse, ranging from mature trees, saplings and vines to grasses. Other than the consumption of plants, 19 mahouts report the occasional geophagous behaviour of elephants, this issue will be discussed in section 4.4.

Observing elephant feeding behaviour has demonstrated the high selectivity that an individual can show in the choice of items consumed, uprooting a tree to consume only the root (Figure 2), or stripping twigs to keep either the stem or the leaves. The elephant often first brushes the plant item with the tip of its trunk before choosing to consume it or not, and uses a whole range of techniques involving the trunk, front legs, tusks and jaws, and the animal's weight and strength. Some parts such as tree roots and bark require a sustained effort to be collected and are consumed in significant quantities (for example, a trunk 15 cm in diameter can be debarked by 50 cm in about 20 minutes).

4.3 Knowledge about elephant health

The elephant is perceived by mahouts as an animal with generally few health problems, and they explain that in most cases the elephants know how to heal themselves using the resources around them. When asked what they need to do to keep an elephant healthy, mahouts say that the most important thing is to make sure that it can find what it needs on its own. Elephants should therefore be released as often as possible (5 resp.). When tethered, suitable places with abundant and diversified vegetation should be carefully chosen (15 resp.) and the elephant moved once or twice a day to allow it to drink and renew its feeding area. In these conditions, mahouts say that elephants rarely experience health problems. They evaluate the condition of their elephant using various signs. When it is tethered and they go to fetch it, the faeces that are present inform them of its digestive state: diarrhoea, constipation (hard or absent), or presence of macroscopic parasites. A look at the browsed area tells them if the elephant has a normal appetite and what has mainly been eaten. A pathological condition is often reflected in the fact that the elephant sleeps a lot during the day, seems apathetic and eats little (7 resp.), sometimes by an abnormal dryness of the interdigital space which is normally wet because here elephants have glands similar to human eccrine sweat glands (Fowler and Mikota, 2008). Among the health problems mentioned that could affect elephants are firstly digestive disorders (35 resp.) characterized by diarrhoea (31 resp.), constipation (4 resp.) or bloating (3 resp.). Also mentioned are accidental injuries or abrasions due to the chain used to tether elephants (11 resp.), purulent abscesses (9 resp.), skin rashes (8 resp.), eye pain with discharge (5 resp.), and *amidal* (3 resp.) a local term that refers according to veterinarians to an infection by EEHV (Elephant Endotheliotropic HerpesVirus), and can be fatal to the calves that contract it (Long et al., 2016; Bouchard et al., 2014). The term *amidal* is borrowed from the French word "amygdale" meaning "tonsil" because one of the visible symptoms of this condition in elephant calves, according to mahouts, is swelling of the throat area.

In a study conducted in South India (Jayakumar et al., 2017) investigating ethnoveterinary care given by mahouts to their elephants, digestive disorders are also cited as the most frequent problems among the captive elephants considered. However, constipation is reported to be much more frequent than diarrhoea, unlike in our study where diarrhoea is the main elephant digestive disorder reported. The South Indian study also notes that intestinal disorders, among other problems observed, are related in particular to inadequate husbandry practices such as poor hygiene in the elephant housing area, lack of exercise and monotonous food. These conditions differ in many respects from those experienced by elephants in Thongmyxay District or the ECC, where:

- they probably access a much more diverse diet as they feed themselves in a forested area
- they might spend much more time on feeding than fed animals

- they stay permanently in natural areas and probably have more opportunities for exercise (even when tethered they are moved daily from one area to another and still have to obtain their own food).

Such differences in elephant management practices may explain the different prevalence of constipation versus diarrhoea in the elephants in the South Indian study and ours.

In a report published about veterinary care provided to elephants by Elephant Asia (an NGO which had set up a mobile elephant care unit in Laos), abscesses, intestinal disorders, nails problems, eye problems and injuries were by decreasing order the main problems found in the 315 elephants examined (Labatut et Suter, 2010). Abscesses are most common among the ailments reported, which may be due to the fact that 78% of the elephants examined were working in the logging industry, where, according to the authors, abscesses were caused by the prolonged chaffing of chains.

When asked if there are periods when elephants are more vulnerable, out of the 13 mahouts who had an opinion, 9 mentioned the end periods and transitions of seasons (from dry to rainy season and vice versa) that they believe correspond to a change in food, indicating for example that tender grasses enjoyed by elephants grow back at the beginning of the rainy season. Sukumar (2003) also notes the appearance of intestinal disorders at the changes of seasons and hypothesizes that they can be induced by a change of diet (pre-eminence of browsing in the dry season and grazing in the rainy season) modifying the fiber/protein ratio of their food, to which their digestive system must readapt. Conversely, according to some mahouts, at the end of the dry season the decline in the quality of the available water, which is more stagnant, may also be the cause of these disorders.

4.4 Elephant behaviour interpreted as self-medication

- *Soil use:* When an elephant has localized pain or discomfort (bite, sting, or abscess), it tends to blow on it (4 resp.), drawing attention to a possible external problem on a less visible area of its body, or may also apply mud on the affected area (7 resp.). While mahouts observe regular geophagic behaviour, three of them report that they have observed this type of behaviour particularly when their animal has intestinal problems, with a subsequent improvement noted. These geophagous behaviours are documented in the literature and the composition of soil licks frequented by African (*Loxodonta cyclotis* and *africana*) and Asian (*Elephas maximus*) elephants has been analyzed in the Central African Republic (Klaus 1998), Zimbabwe (Holdø et al., 2002) and Sri Lanka (Chandrajith et al., 2009). Klaus and Holdø note a higher mineral richness in the soils that could compensate for deficiencies in elephant feeding, but Chandrajith does not note significant differences in mineral elements between soil licks and surrounding soils. Klaus and Chandrajith suggest that the clay elements of these soils could help detoxify some of the elements ingested by elephants by adsorbing secondary toxic compounds.

- *Plant use:* In addition to blowing or applying mud to an affected area and geophagy in the event of intestinal problems, of the 49 mahouts interviewed with at least 10 years' experience, 26 reported observations of search behaviour by their elephants and increased consumption of specific items when they have health problems or in relation to their physiological state. We will call this search behaviour and increased consumption of specific plant items described by mahouts "privileged consumption". For the same condition or physiological state of the elephant, mahouts report a privileged consumption of a single plant item (6 resp.), or of several species, with overlaps that vary from one to the other (19 resp.). We will name this

here Elephant Use Report (EUR) referring to an observation described as recurrent by one mahout, where a particular pathological condition or physiological state identified in the elephant they care for is associated with the search behaviour and consumption of one or more items from the same plant species.

We have thus identified 64 EUR in which 20 species are mentioned, representing 30 plant items. These EURs presented in Table 1 fall into two main categories, one relating to health disorders and the other related to female reproduction including gestation, ante and post-partum, and lactation periods. For convenience, we have grouped this last category of EURs, under the generic term of “motherhood”. This group of EURs is detailed in Table 2.

Diarrhoea is the main context of these plant item intakes: 43 EUR, indicated by 19 mahouts with 19 species collected representing 25 items; this is also the elephant health problem most often mentioned by mahouts. Then comes motherhood: 18 EUR indicated by 8 mahouts with 7 species mentioned and 8 items consumed. Other contexts were mentioned by only one mahout for each: dizziness (the elephant shakes), weakness, and ‘fever’, which is described as an apathetic state with loss of appetite.

The 30 items mentioned in these EURs are included among the 197 items recorded in our inventory of items consumed by elephants. When the mahouts specified the reasons for the self-medication interpretation they give to the recorded EURs, two criteria emerged:

-Firstly, the mode of consumption is in relation to the reported condition. Privileged consumption is the general case, in which the item is part of the elephant’s usual diet but is particularly sought after and consumed in much greater quantities in certain contexts. Alternatively, exclusive consumption is where the item is only consumed in a particular context (19 EUR - 11 resp.). It should be noted that according to each mahout’s own observations, for the same EUR some mahouts mention an exclusive mode of consumption of the plant item for a specific ailment, while others may report the consumption of the same item as part of the elephant’s usual diet.

-Secondly, the consumption of the item is followed by a rapid improvement in the condition of the elephant.

Beyond the observation of the consumption of specific items in a particular physiological context, additional information and observations were provided by mahouts around the question of the interpretation of self-medication by elephants. Five of them have observed that elephants consume certain roots when they have diarrhoea (*Harrisonia perforata* Blanco Merr. for two of them, *Castanopsis indica* Roxb. ex Lindl. A.DC. for another and *Terminalia mucronata* Craib & Hutch. for the last) and have noted that it improves their condition. Knowing this, if their animal suffers from diarrhoea, they will bring it to a place where these plant resources are available. They say that when they return to move the elephant, these plants have largely or entirely been uprooted, their roots consumed, and that the elephant’s condition is improving rapidly. The efficacy of these practices to improve the condition of their elephants has not been quantified or demonstrated, but this approach has in a way acted as a test and has confirmed for the mahouts their interpretations of elephant self-medication based on the plant selection behaviour of the sick elephants they observe.

4.5 Interactions between elephant observations and local medicinal practices

Going further than just facilitating access to plant resources, some mahouts also provide them to their animal. Four mahouts report that when their elephant suffers from diarrhoea, they collect and bring it the roots that they know it seeks when it experiences this condition. These

are *H. perforata* (2 resp.), *T. mucronata* (1 resp.), *Spondias pinnata* L.f. Kurz (1 resp.). They sometime add salt to make the items more appetizing but the items are given in their raw form. In another similar case though it leads to a more elaborate practice, where the mahout had noted that when the elephant has what he calls a fever (which to him means his elephant is sad and listless) it consumes much more of the *Tinospora crispa* L. Hook.f. & Thomson vine and recovers quickly. If he observes this condition in his animal, he crushes the root and stem of this vine with salt and gives it to be eaten. When he passes through a place where this vine is abundant, the mahout collects some of it and dries it to have some at hand when needed.

These are examples of local veterinary care practices resulting from the observation of elephant behaviour. In the last case described this leads to the creation of a reserve of a therapeutic resource, in a more elaborate form suitable for its conservation that can quickly be used in an assimilable galenic preparation (the root is dried and then reduced to powder with salt added before administration). We see here a veterinary preparation involving the observation of specific elephant behaviour (for the choice of ingredients) and an element from the mahout's medicinal background (in the galenic form). But this integration of elements derived from elephant observation and from the mahout's medicinal background into preparations given to elephants does not only concern the ingredients used and their processing. The medicinal background of mahouts may also be involved in the explanations that sometimes come with the interpretation of self-medication given to some of the elephants' behaviour. These explanations can in turn lead to the addition of other ingredients in preparations given to cure elephants. Thus two mahouts explain the consumption of certain plants by elephants by referring to their warm or cold qualities according to a classification of diseases and remedies in use in Laos for human medicine (Souk-Aloun 2001; Pottier, 1971, 2007). One mahout states that diarrhoea is a disorder of the category *ok hon* (literally 'feel hot') that the elephant treats by eating *ya yen* plants (literally 'remedy cool') such as *H. perforata* or *Lithocarpus auriculatus* (Hickel & A.Camus) Barnett. Two other mahouts report that when elephants suffer from tremors (1 resp.) or diarrhoea (1 resp.), they consume bitter roots. In the same vein, another mahout told us about this use that in his conception, diarrhoea results from excessive consumption of sour substances such as tamarind fruit, a disorder that he believes can be treated by consuming bitter substances. He noticed that when his elephant has diarrhoea it consumes more *T. mucronata* bark than usual. He himself uses this bark with that of *H. perforata* against diarrhoea, as it is a family remedy. Therefore, when his elephant is affected by diarrhoea and is tethered, he brings it bark of *H. perforata* and *T. mucronata* and adds bitter edible leaves - steamed and then salted - to strengthen the effectiveness of the remedy. This notion of sour/bitter balance is one of the components of a correspondence system found in traditional Lao medicine. In this system the properties of remedies are ordered by associating flavours with the hot/cold polarity mentioned above: sour and salty flavours being "spicy" are hot, while bitter and sweet flavours being "bland" are cold. Hence the possibility of correcting a "hot" imbalance due to an excess of sourness through the consumption of bitter substances of a "cold" nature (Pottier 2007). Through this last example, we have thus a veterinary preparation combining elements resulting from the observation of an animal's self-medication behaviour - or interpreted as such - (increased consumption of *T. mucronata* in case of diarrhoea), with elements borrowed from partially converging family uses (use of *H. Perforata* and *T. mucronata* in case of diarrhoea) and elements corresponding

to concepts stemming from Lao traditional medicine (adding edible leaves for their bitterness).

But this type of complex medicinal construction is not limited to veterinary uses: in Laos, it is common practice to macerate various vegetable or animal substances known for their therapeutic properties in alcohol, to be used for various ailments (Vidal, 1958), but often taken as a fortifier (Strigler, 2011). One of the mahouts told us that when he sees his elephant eating roots, he takes some of them and puts them in alcohol to macerate, a preparation that he then consumes as a tonic. We have here an example of a human health practice that integrates data and knowledge built on the observation of the behaviour of animals frequented on a daily basis (elephants know how to treat themselves, they eat roots for that purpose - *cf infra*) into an already-existing traditional human practice (alcohol maceration of medicinal items).

4.6 Ethnoveterinary preparations

Table 3 shows ethnoveterinary treatments for elephants collected from 11 mahouts. Besides plant items, the ingredients used include clay, elephants' faeces and urine, and human urine. Five out of the twelve species used in these treatments are listed in the EUR: *Tinopora crispa*, *Entada rheedii* Spreng., *Spondias pinnata*, *Lithocarpus auriculatus* and *Harrisonia perforata*. Six species are used by several mahouts, but in different preparations given for different ailments: *Alpinia galanga* (L.). (2 resp.), *Lasia spinosa* (L.) Thwaites, (3 resp.), *Pterocarpus macrocarpus* Kurz (2 resp.), *Spondias pinnata* (L. f.) Kurz (2 resp.), *Tinospora crispa* (2 resp.), *Harrisonia perforata* (2 rep.). One of the mahouts uses the stem of the sappy *Entada rheedii* Spreng. vine on wounds and skin outbreaks. For the latter use, he soaks and twists it in water with detergent added. At first sight that may seem surprising, but the alkaline medium thus formed might facilitate the extraction of secondary active compounds from this vine.

None of the plants used in these preparations are found in the above-mentioned study on ethnoveterinary care for elephants in South India (Jayakumar et al., 2017) in which the authors trace the origin of ethnoveterinary care in India in scholarly traditions, particularly Ayurveda, recorded in treatises dating back to the earliest antiquity. This background may have diffused over time in the practices of mahouts in the region studied, but the possible continuities between these scholarly treatises and local mahouts' care for elephants using "indigenous plant-based medicines" are not considered as it is not the focus of this study. To our knowledge, there are some manuscripts in Laos dealing with elephant disease and care. In his study, Lainé (2017) mentions also manuscripts written in Tai or Pali which are used by traditional healers, the *mo ya*, but none of the mahouts we have interviewed mentioned or referred to such documents. The present study shows that the medicine provided to elephants rather reflects the individual practices and observations of each of the mahouts interviewed as illustrated by the examples given in Section 4.5. as well as by the fact that there is little overlap between the various preparations presented in Table 3.

Fourteen mahouts use conventional veterinary medicine (three among these also use traditional treatments) to treat their elephants, mainly using antibiotic-based treatments for diarrhoea, abscesses and injuries. Four of them give or used to give their elephants energizers or vitamin supplements purchased from the veterinary pharmacy when their elephant is tired or to keep it in good shape. They use products sold for buffaloes and adjust the dose to be injected to their elephant.

4.7 Convergence between EUR and human medicinal uses

Six mahouts told us that sick elephants generally consume more roots than usual. Indeed, roots are present in 90% (58/64) of EUR. Interestingly, the preponderance of roots in Lao pharmacopeia was also highlighted in two studies conducted in Laos (Delang 2007, Libman et al., 2006). Out of the 20 species mentioned in the EUR, 15 are also used by mahouts for therapeutic purposes in their households, and for 13 of these, the same part is used for the same type of indication (gastrointestinal disorder in all the cases mentioned).

These convergences of medicinal uses found in the mahouts' own practices for treating human diseases and in the EURs could reflect interspecific convergences of medicinal uses of plants between humans and elephants. But it is also possible that the interpretation of self-medication given to the consumption of medicinal items by elephants is induced by the mahouts' own medicinal uses of these plants. However, if we consider the uses of the *H. perforata* root, which is the subject of a significant number of EUR concerning diarrhoea (13 reports), seven of the mahouts told us that they use this item for the same indication in the household context while six did not know about any human use (Table 1). This rules out for the latter the possibility of induction of their own practices and knowledge in their self-medication interpretation by elephants when they search for this item. In addition, many EUR do not have a counterpart in terms of medicinal uses known by mahouts for humans. This is the case in particular for the 18 EUR linked to the motherhood period in elephant females where the seven species mentioned are not known to them to be used by women for similar indications. This in itself is not surprising as among Tai-Lao people the medicinal knowledge about motherhood is mostly transmitted between women (Pottier, 2007) while the management of elephants is a male prerogative. The interpretation of self-medication linked to these EURs in this cultural context of sexual segregation of certain knowledge and activities appears also to be independent of the mahouts' medicinal knowledge. These aspects suggest that even if the medicinal background of mahouts may contribute *a posteriori* to account for certain behaviour observed in elephants (as for the hot or cold plants uses - *cf. supra*), it does not play a decisive role in the interpretation of self-medication that is given to them. It is more likely that the multiple convergences between the observations of privileged consumption of specific plant items by sick elephants and the use made by mahouts of the same items for the same type of pathology reflect convergences of medicinal plant uses between elephants and mahouts.

These interspecific convergences could result either from independent acquisitions of uses in both species or from transfers of knowledge from elephants to humans. The closeness of life that is established in a daily relationship between mahouts and their elephants, and the few examples we have collected of the integration of behaviour observed in elephants into local veterinary and medicinal practices, such as the mahout collecting the roots consumed by elephants to prepare a medicinal maceration, rather pleads in favour of the second hypothesis. A more in-depth investigation is under way into the medicinal practices of local healers to shed light on this issue.

4.8 Another way to approach interspecific convergences of plants uses

Rather than considering the question of use convergence from the alternative perspective of knowledge transfers versus convergence of independently acquired uses, a more fruitful approach may be the one that Lestel, Brunois and Gaunet (2006) propose under the term etho-ethnology. According to the authors this approach involves the study of "the hybrid

communities comprised of humans and animals sharing meaning, interests and affect" (*Ibid*) in which both animals and humans play an active role in the production of knowledge about their environment. Krief and Brunois (2017) in their study in Kibale National Park in Uganda gives an illustration of such an attempt regarding the particular relationship linking the Batoroo ethnic group and the chimpanzees who share the medicinal use of plant species. The Batoroo's awareness of this knowledge sharing between humans and animals is reflected in the use of a specific term to describe this perceived capacity for "reciprocal imitation between humans and animals" (*ibid*, our translation). This approach in which mahouts and village elephants would be viewed as a hybrid community seems more appropriate in the context of Thongmyxay district to account for the intertwining that characterizes elephant behaviours, the EURs indicated by mahouts, mahouts own medicinal uses, and the traditional veterinary care they provide to elephants. We have seen for instance in Section 4.5 that some mahouts give their elephants who suffer from diarrhoea the roots that they know it seeks when it experiences this condition.

4.8 Convergences identified in other studies

Figure 3F shows the number of mahouts who quoted each species mentioned in the EUR.

Table 4 shows ethno-medicinal uses identified and pharmacological properties studied in the literature for species cited in the EUR by at least three mahouts.

The anti-diarrheic property of *H. perforata* reported (Perry and Metzger, 1980) is in accordance with EUR and mahouts own uses. However, one mahout uses this item in case of elephant constipation (table 2). An observation consistent with this last use is found in the "elephant care manual for mahouts and camp manager" published by the FAO (Phuangkum et al., 2005). In this manual it is reported that elephants purge themselves once or twice a year to remove intestinal parasites using for this purpose different barks and roots, including that of *H. perforata*. Thus this vegetal item, in addition to its anti-infective properties (table 2), could have a regulatory effect on intestinal transit, as it is the case for instance with *Malva sylvestris* L. which is reported to be used by humans for both diarrhoea and constipation cases (Jabtri et al., 2017; Barros et al., 2010; DellaGreca et al., 2009).

Surprisingly, we did not find any mention of medicinal uses or properties in the literature for *Lithocarpus auriculatus*, cited in EUR by seven mahouts, four times in the context of motherhood and three times for diarrhoea.

5 Conclusion

We have recorded numerous convergences between the observations interpreted by the mahouts as self-medication behaviour on the part of elephants and their own medicinal practices. The validity of these interpretations would require a specific ethological study to be established, but what seems remarkable is the dual interface that is at work around a forest environment common to elephants and humans. Village elephants standing at the first interface between the plants they select and the mahouts who observe them become a source of knowledge for humans. The mahouts stand at the second interface between elephants and the human culture they belong to. It is the place where behavioural elements observed on elephants are integrated into the care provided to them and into mahouts' own medicinal practices.

Our initial concern was to better understand how the observation of animal self-medication behaviour has contributed to human medicinal practices. Mahouts' practices in Thongmyxay district show that beyond a mere reproduction of these animal behaviour observations, the human or veterinary medicinal practices from which they may have been derived are the result of complex arrangements, in which all available medicinal and conceptual resource are integrated.

The current trend in Laos to transfer village elephants to elephant resorts leads to a disruption in the transmission of mahouts' family knowledge (Suter et al., 2014). It is therefore urgent to continue to collect this knowledge and in particular traditional veterinary care in order to transmit it to the new generation of mahouts employed in these resorts and to the people responsible for the health of captive elephants.

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5 References

- Barros, L., Carvalho, A.M., Ferreira, I.C.F.R., 2010. Leaves, flowers, immature fruits and leafy flowered stems of *Malva sylvestris*: A comparative study of the nutraceutical potential and composition. *Food and Chemical Toxicology* 48, 1466–1472.
- Batm, S.N., Kondo, S., Itharat, A., 2011. Antimicrobial Activity of the Extracts from Benchalokawichian Remedy and Its Components. *Journal of the Medical Association of Thailand* 94, 6.
- Boehm, I., Luccioni, P. (Eds.), 2008. *Le médecin initié par l'animal: animaux et médecine dans l'Antiquité grecque et latine : actes du colloque international tenu à la Maison de l'Orient et de la Méditerranée-Jean Pouilloux les 26 et 27 octobre 2006*. Maison de l'Orient et de la Méditerranée, Lyon, France.
- Boonnak, N., Karalai, C., Chantrapromma, S., Ponglimanont, C., Kanjana-Opas, A., Chantrapromma, K., Kato, S., 2010. Chromene and Prenylated Xanthenes from the Roots of *Cratoxylum formosum* ssp. *pruniflorum*. *Chem. Pharm. Bull.* 58, 386–389.
- Boonsri, S., Karalai, C., Ponglimanont, C., Kanjana-opas, A., Chantrapromma, K., 2006. Antibacterial and cytotoxic xanthenes from the roots of *Cratoxylum formosum*. *Phytochemistry* 67, 723–727. <https://doi.org/10.1016/j.phytochem.2006.01.007>
- Borah, P.K., Gogoi, P., Phukan, A.C., Mahanta, J., 2006. Traditional medicine in the treatment of gastrointestinal diseases in Upper Assam. *IJTK Vol.5(4)* [October 2006].
- Bouchard, B., Xaymountry, B., Thongtip, N., Lertwatcharasarakul, P., Wajjwalku, W., 2014. First reported case of elephant endotheliotropic herpes virus infection in Laos. *Journal of Zoo and Wildlife Medicine* 45, 704–707. <https://doi.org/10.1638/2013-0264R1.1>
- Bunluepuech, K., Tewtrakul, S., 2009. Anti - HIV-1 integrase activity of Thai Medicinal Plants 4.
- Campos-Arceiz, A., Lin, T.Z., Htun, W., Takatsuki, S., Leimgruber, P., 2008. Working with mahouts to explore the diet of work elephants in Myanmar (Burma). *Ecological research* 23, 1057–1064.
- Chandrajith, R., Kudavidanage, E., Tobschall, H.J., Dissanayake, C.B., 2009. Geochemical and mineralogical characteristics of elephant geophagic soils in Udawalawe National Park, Sri Lanka. *Environ Geochem Health* 31, 391–400. <https://doi.org/10.1007/s10653-008-9178-5>
- Chea, A., Jonville, M.-C., Bun, S.-S., Laget, M., Elias, R., Duménil, G., Balansard, G., 2007. In vitro Antimicrobial Activity of Plants used in Cambodian Traditional Medicine. *The American Journal of Chinese Medicine* 35, 867–873. <https://doi.org/10.1142/S0192415X07005338>
- Chen, J., Deng, X., Zhang, L., Bai, Z., 2006. Diet composition and foraging ecology of Asian elephants in Shangyong, Xishuangbanna, China. *Acta Ecologica Sinica* 26, 309–316.
- Chotchoungchatchai, S., Saralamp, P., Jenjittikul, T., Pornsiripongse, S., Prathanururug, S., 2012. Medicinal plants used with Thai Traditional Medicine in modern healthcare services: A case study in Kabchoeng

Hospital, Surin Province, Thailand. *Journal of Ethnopharmacology* 141, 193–205.
<https://doi.org/10.1016/j.jep.2012.02.019>

Delang, C.O., 2007. The role of medicinal plants in the provision of health care in Lao PDR. *Journal of Medicinal Plants Research* 1, 050–059.

DellaGreca, M., Cutillo, F., Abrosca, B.D., Fiorentino, A., Pacifico, S., Zarrelli, A., 2009. Antioxidant and Radical Scavenging Properties of *Malva Sylvestris*. *Natural Product Communications* 4, 1934578X0900400.
<https://doi.org/10.1177/1934578X0900400702>

Dolai, N., Karmakar, I., Kumar, R.S., Kar, B., Bala, A., Haldar, P.K., 2012. Free radical scavenging activity of *Castanopsis indica* in mediating hepatoprotective activity of carbon tetrachloride intoxicated rats. *Asian Pacific Journal of Tropical Biomedicine* 2, S243–S251. [https://doi.org/10.1016/S2221-1691\(12\)60168-3](https://doi.org/10.1016/S2221-1691(12)60168-3)

Dubost Jean-marc, 2015. Medicinal knowledge input from animal observation: the case of Asian elephant feeding observations linked to specific medicinal uses in Chumphon province - Thailand. Presented at the International Conference of the European Association of Southeast Asian Archaeologists, Université Paris Ouest Nanterre la Défense.

English, M., Gillespie, G., Ancrenaz, M., Ismail, S., Goossens, B., Nathan, S., Linklater, W., 2014. Plant selection and avoidance by the Bornean elephant (*Elephas maximus borneensis*) in tropical forest: does plant recovery rate after herbivory influence food choices? *Journal of Tropical Ecology* 30, 371–379.
<https://doi.org/10.1017/S0266467414000157>

Evans, L.J., Goossens, B., Asner, G.P., 2017. Underproductive agriculture aids connectivity in tropical forests. *Forest Ecology and Management* 401, 159–165. <https://doi.org/10.1016/j.foreco.2017.07.015>

Evrard, O., 2004. La mise en oeuvre de la réforme foncière au Laos : impacts sociaux et effets sur les conditions de vie en milieu rural, LSP Working Paper. FAO, Rome.

Fernando, P., Pastorini, J., 2011. Range-wide status of Asian elephants. *Gajah* 35, 15–20.

Fernando, P., Wikramanayake, E., Weerakoon, D., Jayasinghe, L.K.A., Gunawardene, M., Janaka, H.K., 2005. Perceptions and Patterns of Human–elephant Conflict in Old and New Settlements in Sri Lanka: Insights for Mitigation and Management. *Biodiversity and Conservation* 14, 2465–2481. <https://doi.org/10.1007/s10531-004-0216-z>

Fowler, M., Mikota, S.K., 2006. *Biology, Medicine, and Surgery of Elephants*. Blackwell Publishing, Ames, USA.

Ghani, A., 2003. *Medicinal Plants of Bangladesh with Chemical Constituents and Uses*, 2nd ed. ed. Asiatic Society of Bangladesh, Dhaka.

Himmelsbach, W., Tagle, M.A.G., Földner, K., Hoefle, H.H., Htun, W., 2006. Food plants of captive elephants in the Okkan Reserved Forest, Myanmar (Burma), Southeast Asia. *Ecotropica* 12, 15–26.

Holdø, R.M., Dudley, J.P., McDowell, L.R., 2002. Geophagy in the African Elephant in Relation to Availability of Dietary Sodium. *J Mammal, Journal of Mammalogy* 83, 652–664. [https://doi.org/10.1644/1545-1542\(2002\)083<0652:GITAEI>2.0.CO;2](https://doi.org/10.1644/1545-1542(2002)083<0652:GITAEI>2.0.CO;2)

Huffman, M.A., 2003. Animal self-medication and ethno-medicine: exploration and exploitation of the medicinal properties of plants. *Proceedings of the Nutrition Society* 62, 371–381.
<https://doi.org/10.1079/PNS2003257>

Huffman, M.A., 2001. Self-Medicative Behavior in the African Great Apes: An Evolutionary Perspective into the Origins of Human Traditional Medicine. *BioScience* 51, 651–661. [https://doi.org/10.1641/0006-3568\(2001\)051\[0651:SMBITA\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2001)051[0651:SMBITA]2.0.CO;2)

Huffman, M.A., Gotoh, S., Turner, L.A., Hamai, M., Yoshida, K., 1997. Seasonal trends in intestinal nematode infection and medicinal plant use among chimpanzees in the Mahale Mountains, Tanzania. *Primates* 38, 111–125. <https://doi.org/10.1007/BF02382002>

IUCN, 2016. *Elephas maximus* (Asian Elephant, Indian Elephant) [WWW Document]. URL <http://www.iucnredlist.org/details/7140/0> (accessed 5.9.16).

Jabri, M.-A., Wannes, D., Hajji, N., Sakly, M., Marzouki, L., Sebai, H., 2017. Role of laxative and antioxidant properties of *Malva sylvestris* leaves in constipation treatment. *Biomed. Pharmacother.* 89, 29–35. <https://doi.org/10.1016/j.biopha.2017.02.020>

Jayakumar, S., Sathiskumar, S., Baskaran, N., Arumugam, R., Vanitha, V., 2017. Ethno-veterinary practices in Southern India for captive Asian elephant ailments. *J Ethnopharmacol* 200, 182–204. <https://doi.org/10.1016/j.jep.2017.02.039>

Joshi, K., Joshi, R., Joshi, A.R., 2011. Indigenous knowledge and uses of medicinal plants in Macchegaun, Nepal. *IJTK Vol.10(2)* [April 2011].

- Joshi, R., Singh, R., 2008. Feeding behaviour of wild Asian elephants (*Elephas maximus*) in the Rajaji national park. *The Journal of American Science* 4, 34–48.
- Khounboline, K., 2011. Current status of Asian elephants in Lao PDR. *Gajah* 35, 62–66.
- Khuankaew, S., Srithi, K., Tiansawat, P., Jampeetong, A., Inta, A., Wangpakapattanawong, P., 2014. Ethnobotanical study of medicinal plants used by Tai Yai in Northern Thailand. *Journal of Ethnopharmacology* 151, 829–838. <https://doi.org/10.1016/j.jep.2013.11.033>
- Kim, S.B., Alounsavath, O., 2015. Forest policy measures influence on the increase of forest cover in northern Laos. *Forest Science and Technology* 11, 166–171. <https://doi.org/10.1080/21580103.2014.977358>
- Klaus, G., Klaus-Hügi, C., Schmid, B., 1998. Geophagy by large mammals at natural licks in the rain forest of the Dzanga National Park, Central African Republic. *Journal of Tropical Ecology* 14, 829–839. <https://doi.org/10.1017/S0266467498000595>
- Kobayashi, M., Mahmud, T., Yoshioka, N., Shibuya, H., Kitagawa, I., 1997. Indonesian Medicinal Plants. XXI. Inhibitors of Na⁺/H⁺ Exchanger from the Bark of *Erythrina variegata* and the Roots of *Maclura cochinchinensis*. *Chem. Pharm. Bull.* 45, 1615–1619. <https://doi.org/10.1248/cpb.45.1615>
- Kongkiatpaiboon, S., Tungsukruthai, P., Sriyakool, K., Pansuksan, K., Tunsirikongkon, A., Pandith, H., 2017. Determination of Morin in *Maclura cochinchinensis* Heartwood by HPLC. *J Chromatogr Sci* 55, 346–350. <https://doi.org/10.1093/chromsci/bmw191>
- Krief, S., Brunois-Psina, F., 2017. L'interspécificité du pharmacôn dans le parc Kibale (Ouganda) : savoirs partagés entre humains et chimpanzés ? *Cahiers d'anthropologie sociale* 112–134.
- Krief, S., Hladik, C.M., Haxaire, C., 2005. Ethnomedicinal and bioactive properties of plants ingested by wild chimpanzees in Uganda. *Journal of Ethnopharmacology* 101, 1–15. <https://doi.org/10.1016/j.jep.2005.03.024>
- Krief, S., Wrangham, R.W., Lestel, D., 2006. Diversity of items of low nutritional value ingested by chimpanzees from Kanyawara, Kibale National Park, Uganda: an example of the etho-ethnology of chimpanzees. *Social Science Information* 45, 227–263. <https://doi.org/10.1177/0539018406063642>
- Labatut, Florence, Suter, Ingrid, 2010. The Veterinary Care of Domesticated Elephants in Laos by a Mobile Veterinary Unit. *Gajah* 32, 21–26.
- Lainé, N., 2017. Travail interspèces et conservation. *Ecologie & politique* 45–64.
- Lair, R.C., 1997. Gone astray. The care and management of the Asian elephant in domesticity. RAP Publication (FAO).
- Laopaksa, A., 1988. Preliminary study on antibacterial action of Thai medicinal plants for respiratory tract infection (I). *Thai J. Pharm. Sci.* 13, 23–36.
- Lassausaie, J., Bret, A., Bouapao, X., Chanthavong, V., Castonguay-Vanier, J., Quet, F., Mikota, S.K., Théorêt, C., Buisson, Y., Bouchard, B., 2015. Tuberculosis in Laos, who is at risk: the mahouts or their elephants? *Epidemiology and Infection* 143, 922–931. <https://doi.org/10.1017/S0950268814002180>
- Leakaya, Nantakarn, Sato, V.H., Chewchinda, S., 2018. Antioxidant Activity, Total Phenolic, Total Flavonoid Content and HPTLC Analysis of Morin in *Maclura cochinchinensis* Heartwood Extract. *TJPS* 5.
- Leimgruber, P., Gagnon, J.B., Wemmer, C., Kelly, D.S., Songer, M.A., Selig, E.R., 2003. Fragmentation of Asia's remaining wildlands: implications for Asian elephant conservation. *Animal Conservation* 6, 347–359. <https://doi.org/10.1017/S1367943003003421>
- Lestel, D., Brunois, F., Gaunet, F., 2006. Etho-ethnology and ethno-ethology. *Social Science Information* 45, 155–177. <https://doi.org/10.1177/0539018406063633>
- Libman, A., Bouamanivong, S., Southavong, B., Sydara, K., Soejarto, D.D., 2006. Medicinal plants: An important asset to health care in a region of Central Laos. *Journal of Ethnopharmacology* 106, 303–311. <https://doi.org/10.1016/j.jep.2005.11.034>
- Lihong, W., Liu, L., Qian, H., Jinguo, Z., Li, Z., 2007. Analysis of nutrient components of food for Asian elephants in the wild and in captivity. *Frontiers of Biology in China* 2, 351–355. <https://doi.org/10.1007/s11515-007-0052-0>
- Long, S.Y., Latimer, E.M., Hayward, G.S., 2016. Review of Elephant Endotheliotropic Herpesviruses and Acute Hemorrhagic Disease. *ILAR J* 56, 283–296. <https://doi.org/10.1093/ilar/ilv041>
- Malla, B., Chhetri, R.B., 2009. Indigenous knowledge on ethnobotanical plants of Kavrepalanchowk district. *Kathmandu University Journal of Science, Engineering and Technology* 5, 96–109.
- Maneenoon, K., Khuniad, C., Teanuan, Y., Saedan, N., Prom-in, S., Rukleng, N., Kongpool, W., Pinsook, P., Wongwiwat, W., 2015. Ethnomedicinal plants used by traditional healers in Phatthalung Province, Peninsular Thailand. *Journal of Ethnobiology and Ethnomedicine* 11, 43. <https://doi.org/10.1186/s13002-015-0031-5>

Maurer, G., 2018. Conservation de l'éléphant d'Asie (*Elephas maximus*) par l'étude des interactions entre humains et populations sauvages et semi-captives d'éléphants: une approche intégrée des dimensions démographiques, génétiques, économiques et socioculturelles (Ph.D. Thesis). Université de Montpellier, Université de Montpellier.

Maurer, G., Rashford, B.S., Chanthavong, V., Mulot, B., Gimenez, O., 2017. Wild-captive interactions and economics drive dynamics of Asian elephants in Laos. *Scientific Reports* 7. <https://doi.org/10.1038/s41598-017-13907-x>

Morrogh-Bernard, H.C., Foitová, I., Yeen, Z., Wilkin, P., Martin, R. de, Rárová, L., Doležal, K., Nurcahyo, W., Olšanský, M., 2017. Self-medication by orang-utans (*Pongo pygmaeus*) using bioactive properties of *Dracaena cantleyi*. *Scientific Reports* 7, 1–7. <https://doi.org/10.1038/s41598-017-16621-w>

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature* 403, 853–858. <https://doi.org/10.1038/35002501>

Najib Nik A Rahman, N., Furuta, T., Kojima, S., Takane, K., Ali Mohd, M., 1999. Antimalarial activity of extracts of Malaysian medicinal plants. *Journal of Ethnopharmacology* 64, 249–254. [https://doi.org/10.1016/S0378-8741\(98\)00135-4](https://doi.org/10.1016/S0378-8741(98)00135-4)

Nguyen, L.H.D., Harrison, L.J., 1999. Triterpenoid and xanthone constituents of *Cratoxylum cochinchinense*. *Phytochemistry* 50, 471–476. [https://doi.org/10.1016/S0031-9422\(98\)00467-1](https://doi.org/10.1016/S0031-9422(98)00467-1)

Nguyen-Pouplin, J., Tran, Hop, Tran, Hung, Phan, T.A., Dolecek, C., Farrar, J., Tran, T.H., Caron, P., Bodo, B., Grellier, P., 2007. Antimalarial and cytotoxic activities of ethnopharmacologically selected medicinal plants from South Vietnam. *Journal of Ethnopharmacology* 109, 417–427. <https://doi.org/10.1016/j.jep.2006.08.011>

Noor, H., Ashcroft, S.J.H., 1989. Antidiabetic effects of *Tinospora crispa* in rats. *Journal of Ethnopharmacology* 27, 149–161. [https://doi.org/10.1016/0378-8741\(89\)90087-1](https://doi.org/10.1016/0378-8741(89)90087-1)

Omulokoli, E., Khan, B., Chhabra, S.C., 1997. Antiplasmodial activity of four Kenyan medicinal plants. *Journal of Ethnopharmacology* 56, 133–137. [https://doi.org/10.1016/S0378-8741\(97\)01521-3](https://doi.org/10.1016/S0378-8741(97)01521-3)

Perry, L.M., Metzger, J., 1980. Medicinal plants of East and Southeast Asia: attributed properties and uses. *Medicinal plants of East and Southeast Asia: attributed properties and uses*.

Phanthavong, B., Santiapillai, C., 1992. Conservation of elephants in Laos. *IUCN/SSC Asian Elephant Specialist Group Newsletter* 8, 25–33.

Phuangkum, P., Lair, R.C., Angkawanith, T., others, 2005. Elephant care manual for mahouts and camp managers. *FAO Regional Office for Asia and the Pacific*, Bangkok.

Pottier, R., 2007. *Yû dî mê hêng, être bien avoir de la force : essai sur les pratiques thérapeutiques lao*, Monographie. École française d'Extrême-Orient, Paris.

Pottier, R., 1971. Le végétal dans la pharmacopée traditionnelle lao. *Bulletin de la Société Botanique de France* 118, 263–273. <https://doi.org/10.1080/00378941.1971.10838897>

Rodriguez, E., Wrangham, R., 1993. Zoopharmacognosy: The Use of Medicinal Plants by Animals, in: Downum, K.R., Romeo, J.T., Stafford, H.A. (Eds.), *Phytochemical Potential of Tropical Plants*. Springer US, Boston, MA, pp. 89–105. https://doi.org/10.1007/978-1-4899-1783-6_4

Saha, A., Masud, M.A., Bachar, S.C., Kundu, J.K., Datta, B.K., Nahar, L., Sarker, S.D., 2007. The Analgesic and Anti-Inflammatory Activities of the Extracts of *Phyllanthus reticulatus*. in Mice Model. *Pharmaceutical Biology* 45, 355–359. <https://doi.org/10.1080/13880200701212973>

Santiapillai, C., Jackson, P., 1990. *The Asian Elephant: An Action Plan for Its Conservation*. IUCN.

Santra, A.K., Pan, S., Samanta, A.K., Das, S., Halder, S., 2008. Nutritional status of forage plants and their use by wild elephants in South West Bengal, India. *Tropical Ecology* 49, 251.

Souk-Aloun, P.N., 2001. *La médecine du bouddhisme Théravâda au Laos : avec index des plantes médicinales indochinoises*. l'Harmattan, Paris Budapest Turin.

Southavilay, Thongleua, C., Tuukka, 1999. Timber trade and wood flow study for Lao PDR 30.

Strigler, F., 2011. *L'alimentation des Laotiens: cuisine, recettes et traditions au Laos et en France*. Éd. Karthala : CCL, Paris, France.

Sukumar, R., 2003. *The living elephants: evolutionary ecology, behavior, and conservation*. Oxford University Press, New York.

Sukumar, R., 1992. *The Asian Elephant: Ecology and Management*. Cambridge University Press, New York.

Sulaiman, MR, Zakaria, ZA, Lihan, R, 2008. Antinociceptive and anti-inflammatory activities of *Tinospora crispa* in various Animal models. *J Trop Med*. 3, 66–9.

Suter, I., Hockings, M., Baxter, G.S., 2013. Changes in Elephant Ownership and Employment in the Lao PDR: Implications for the Elephant-Based Logging and Tourism Industries. *Human Dimensions of Wildlife* 18, 279–291. <https://doi.org/10.1080/10871209.2013.788235>

Suter, I., Maurer, G., Baxter, G., 2014. Population viability of captive Asian elephants in the Lao PDR. *Endangered Species Research* 24, 1–7. <https://doi.org/10.3354/esr00578>

Vidal, J., 1958. La thérapeutique par les plantes au Laos. *Journal d'agriculture tropicale et de botanique appliquée* 5, 601–616. <https://doi.org/10.3406/jatba.1958.2495>

Weerapreeyakul, N., Nonpunya, A., Barusrux, S., Thitimetharoch, T., Sripanidkulchai, B., 2012. Evaluation of the anticancer potential of six herbs against a hepatoma cell line. *Chinese Medicine* 7, 15. <https://doi.org/10.1186/1749-8546-7-15>

Wrangham, R.W., 1995. Relationship of chimpanzee leaf-swallowing to a tapeworm infection. *American Journal of Primatology* 37, 297–303. <https://doi.org/10.1002/ajp.1350370404>

WWF, n.d. Nam Pouy Elephant Project | WWF [WWW Document]. URL http://www.wwf.org.la/projects/nam_pouy/ (accessed 5.23.19).

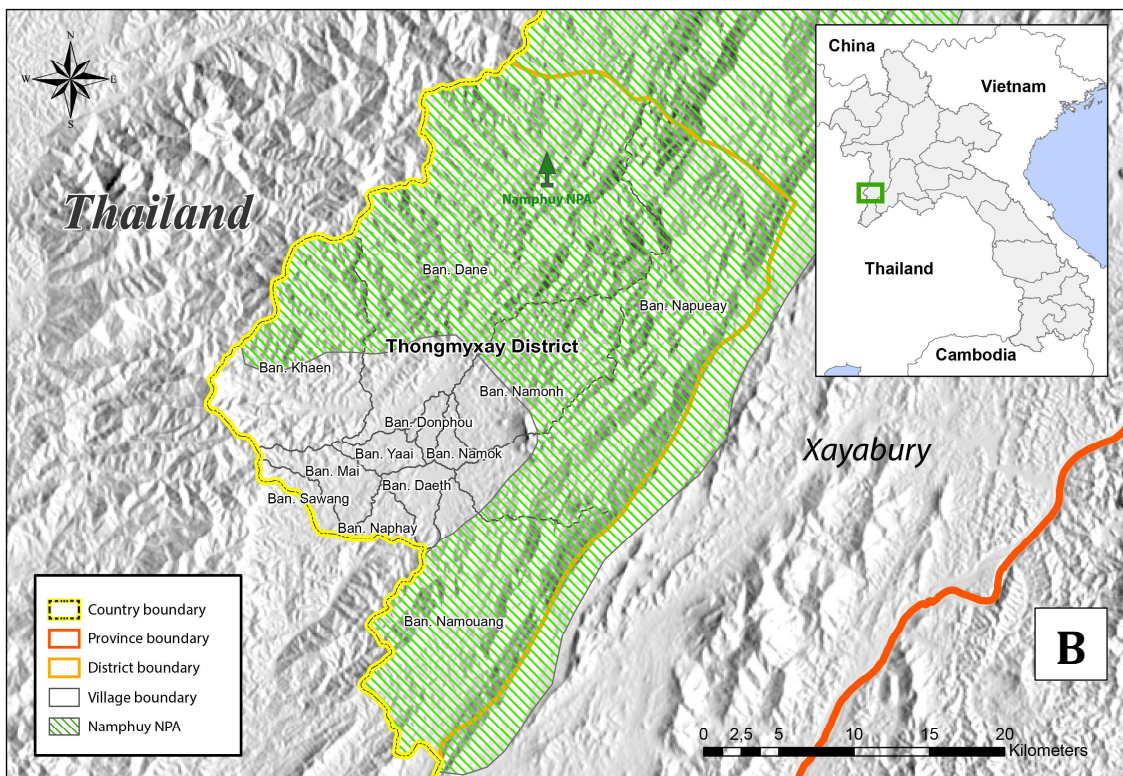
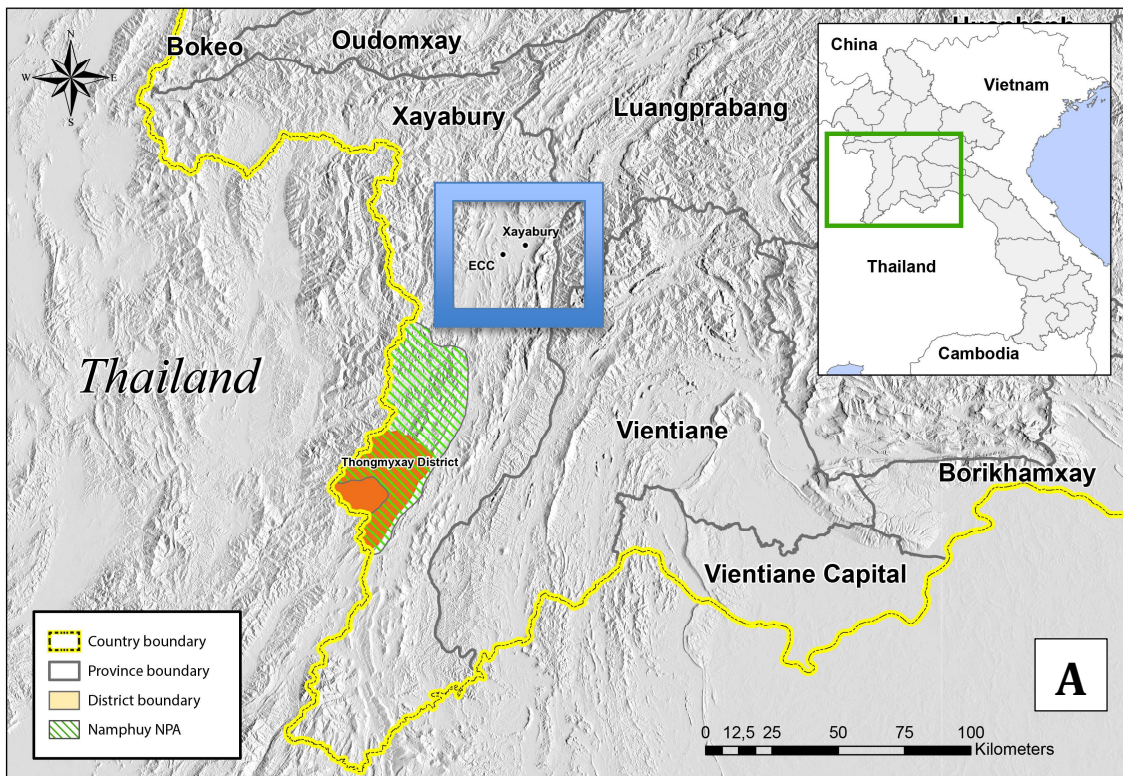


Fig. 1: Contextual maps of Thongmyxay district and location of the ECC centre (Juan A. Torres) wide view (A) close-up view (B)



Fig. 2 : Female uprooting a tree (A) to eat the root part (B) (Photo JM Dubost)

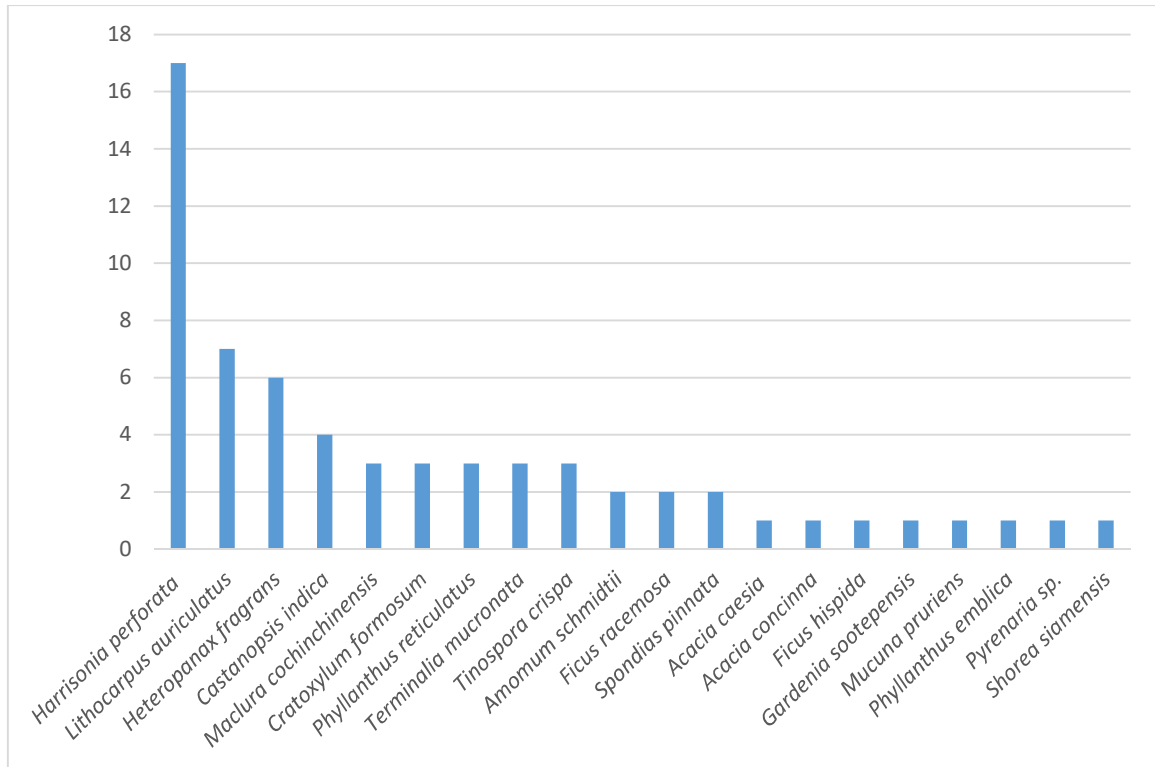


Fig. 3: Number of mahouts citing each species listed in the EURs.

Family	Botanical name	Voucher	Vegetal Type	Parts eaten	EUR (nb mahouts)	Mahout medicinal use
Fabaceae	<i>Acacia caesia</i> (L.) Willd.	JMD 1127	C	r	diarrhoea: r and s (1)	yes (1)
Fabaceae	<i>Acacia concinna</i> Willd. A.DC.	JMD 1149	C	r, l	motherhood: r (1)	no
Zingiberaceae	<i>Amomum schmidtii</i> K.Schum. Gagnep.	JMD 1113	H	r, wp	diarrhoea: wp (1)	yes (1) (flatulence*)
Zingiberaceae	<i>Amomum schmidtii</i> K.Schum. Gagnep.	JMD 1113	H	r, wp	tonic: r (1)	no
Fagaceae	<i>Castanopsis indica</i> Roxb. ex Lindl. A.DC.	JMD 1151	T	r, b	motherhood: r: (2)	no (2)
Fagaceae	<i>Castanopsis indica</i> Roxb. ex Lindl. A.DC.	JMD 1151	T	r, b	diarrhoea: r (1) r and b (1)	yes (1) no (1)
Guttiferae	<i>Cratoxylum formosum</i> Jack Dyer	JMD 1096	T	l, s, t, b, r, sh	motherhood: r (1)	no (1)
Guttiferae	<i>Cratoxylum formosum</i> Jack Dyer	JMD 1096	T	l, s, t, b, r, sh	diarrhoea: r (2)	yes (1)
Moraceae	<i>Ficus hispida</i> L.f.	JMD 1134	T	b, t, sh, r	diarrhoea: r (1)	yes (1)
Moraceae	<i>Ficus racemosa</i> L.	JMD 1002	T	r, b, l, sh, f	diarrhoea: r (1) r + b (1)	yes (1)
Rubiaceae	<i>Gardenia sootepensis</i> Hutch.	JMD 963	T	l, t, r, b	diarrhoea: b (1)	yes (1)
Simaroubaceae	<i>Harrisonia perforata</i> Blanco Merr.	JMD 1144	Sh	r, sh	motherhood: r (5)	no (4)
Simaroubaceae	<i>Harrisonia perforata</i> Blanco Merr.	JMD 1144	Sh	r, sh	diarrhoea: r (13)	yes (7) no (6)
Araliaceae	<i>Heteropanax fragrans</i> Roxb. Seem.	JMD 957	T	b, r, t, sh	motherhood: r (3), b (1)	no (4)
Araliaceae	<i>Heteropanax fragrans</i> Roxb. Seem.	JMD 957	T	b, r, t, sh	diarrhoea: r (1), s (1)	yes (2)
Fagaceae	<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	JMD 1150	T	r	motherhood: r (4)	no (3)
Fagaceae	<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	JMD 1150	T	r	diarrhoea: r (3)	no
Moraceae	<i>Maclura cochinchinensis</i> Lour. Corner	JMD 972	Sh	l, s, b, sh	diarrhoea: r (3)	yes (1) no (2)
Fabaceae	<i>Mucuna pruriens</i> (L.) DC.	JMD 1112	C	s, r	diarrhoea: r (1)	no
Euphorbiaceae	<i>Phyllanthus emblica</i> L.	JMD 1142	T	f, b	diarrhea: b (1)	yes (1) (cough*)
Euphorbiaceae	<i>Phyllanthus reticulatus</i> Poir.	JMD 995	T	l, r, sh	diarrhea: r (3)	no (3)
Theaceae	<i>Pyrenaria</i> sp.	JMD 958	T	r, b, s, l, sh	motherhood: r and b (1)	no
Dipterocarpaceae	<i>Shorea siamensis</i> Miq.	JMD 1148	T	r, b, s	diarrhoea: r (1)	yes
Anacardiaceae	<i>Spondias pinnata</i> L.f. Kurz	JMD 1115	T	b, sh, b, r	diarrhoea: r (2)	yes (1) no (1)
Combretaceae	<i>Terminalia mucronata</i> Craib & Hutch.	JMD 1108	T	s, b, r	diarrhoea: r and b (2), b (1)	yes (2) no (1)
Menispermaceae	<i>Tinospora crispa</i> L. Hook.f. & Thomson	JMD 1126	C	s, r, l	diarrhoea: r (1)	yes (1)
Menispermaceae	<i>Tinospora crispa</i> L. Hook.f. & Thomson	JMD 1126	C	s, r, l	tremor: s (1)	no
Menispermaceae	<i>Tinospora crispa</i> L. Hook.f. & Thomson	JMD 1126	C	s, r, l	fever, (apathy + appetite loss): r and s (1)	no

Table 1: EUR presented by species.

4th column indicates the context of elephant use and items selected, and in brackets the number of mahouts reporting the EUR; 5th column gives the number of mahouts using the item for the same ailment in their household (* indication have been specified when different from EUR). b= bark, f=fruit, r= root, l= leaves, s=stem, sh=shoots, t=twigs, wp=whole plant.

Botanical name	Family	EUR
<i>Acacia concinna</i> Willd. A.DC.	Fabaceae	post-partum and lactation during first months: root
<i>Castanopsis indica</i> Roxb. ex Lindl. A.DC.	Fagaceae	ante and postpartum during 2 months: root
<i>Castanopsis indica</i> Roxb. ex Lindl. A.DC.	Fagaceae	postpartum during 2 months: root
<i>Cratoxylum formosum</i> Jack Dyer	Guttiferae	post-partum and lactation during first months: root
<i>Harrisonia perforata</i> Blanco Merr.	Simaroubaceae	lactation during first months: root
<i>Harrisonia perforata</i> Blanco Merr.	Simaroubaceae	post-partum and lactation during first months root
<i>Harrisonia perforata</i> Blanco Merr.	Simaroubaceae	postpartum during 2 months: root
<i>Harrisonia perforata</i> Blanco Merr.	Simaroubaceae	postpartum for 1 week: root
<i>Harrisonia perforata</i> Blanco Merr.	Simaroubaceae	pregnancy: root
<i>Heteropanax fragrans</i> Roxb. Seem.	Araliaceae	ante and postpartum: root
<i>Heteropanax fragrans</i> Roxb. Seem.	Araliaceae	ante and post-partum: bark
<i>Heteropanax fragrans</i> Roxb. Seem.	Araliaceae	post-partum and lactation during first months: root
<i>Heteropanax fragrans</i> Roxb. Seem.	Araliaceae	pregnancy: root
<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	Fagaceae	ante and postpartum during 2 months: root
<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	Fagaceae	post-partum and lactation during first months root
<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	Fagaceae	pregnancy: root
<i>Lithocarpus auriculatus</i> (Hickel & A.Camus) Barnett	Fagaceae	pregnancy: root
<i>Pyrenaria sp.</i>	Theaceae	pregnancy, ante and post-partum: root and bark

Table 2: Details of EUR related to female elephants motherhood period.

Diarrhoea	Root of <i>Lasia spinosa</i> (L.) Thwaites with <i>Tinosposra crispa</i> stem in equal quantity are sliced, dried and then pulverized in a mortar, a little honey is added for palatability. The mixture is dried out and given in a rice ball one time a day for 2-3 days.	Unhusked rice is given with salt and elephant is brought daily to a swampy place where it can eat mud.	Steamed leaves of <i>Bischofia javanica</i> Blume with salt added are given to eat.	Chopped barks of <i>H. perforata</i> and <i>Terminalia mucronata</i> mixed with steamed bitter leaves and salt are given to eat.
Other digestive disorders	<i>Constipation:</i> Root of <i>Lasia spinosa</i> is sliced, dried and then crushed with unhusked rice in equal parts. A ball of the size of a fist is given 2 times a day.	<i>Constipation:</i> Root of <i>Harrisonia perforata</i> is boiled and then mashed in the decoction, salt is added and the mixture is given to the elephant.	<i>Bloating:</i> Root of <i>Lasia spinosa</i> is mixed in equal parts with the fruit of <i>toona sp.</i> , husked rice powder and rice bran. Water is added to form a paste. A ball the size of a fist is given 2 times a day until healing.	
Abscess	Abscess is lotioned with a decoction of barks of <i>Pterocarpus macrocarpus</i> Kurz and of another tree not identified (mai kao).	Bark of <i>Dillenia parviflora</i> Griff. with salt is given to eat.	Grilled unhusked rice is applied on abscess.	
Skin outbreak	A piece of the juicy stem of <i>Entada rheedii</i> Spreng. is crushed with a mallet and twisted in water with detergent added. Spots are lotioned with the stem dipped into the preparation.	Chopped <i>Alpinia galanga</i> (L.) Willd. stems are mixed with elephant urine and applied on the affected area 2-3 times a day until healed.	Crushed fruit of <i>Spondias pinnata</i> combined with human urine is then applied to the skin.	
Wounds	A decoction of barks of <i>Cratoxylum formosum</i> Jack Dyer, <i>Pterocarpus macrocarpus</i> , <i>Bauhinia malabarica</i> Roxb. (10kg each) and fruits of <i>Spondias pinnata</i> (4-5 kg), is prepared with 10 liters of water, until it reduces to 2 liters. A stem of <i>Entada rheedii</i> , crushed with a mallet is twisted in preparation and used to lotion the wounds twice a day until cured.	Urine and dry elephant faeces are mixed with crushed <i>Alpinia galanga</i> (in equal amounts) and applied by hand on the wound.	A decoction of sliced stem of <i>Acacia caesia</i> (500g for 2l of water) is used to lotion the wound everyday.	A mixture of clay and elephant faeces is placed in a square of banana stem and applied as a poultice on wounds.
<u>Apathetic state</u>	Root and stem of <i>Tinospora crispa</i> , dried or fresh is crushed with salt and given to eat.			

Table 3: Ethnoveterinary preparations given to elephants.

Plant species	Traditional uses	Pharmacological activity
<i>Harrisonia perforata</i>	Root is used as a remedy for treatment of wound healing, diarrhoea , dysentery and cholera (Perry and Metzger, 1980), and as antitoxic (Libman, 2006) and fever (Maneenoon et al., 2015)	Anti-pyretic, anti-diarrhoea properties (Laopaksa, 1988 cited in Batm et al., 2011). Root inhibits <i>Staphylococcus aureus</i> , <i>Streptococcus pyrogenes</i> (Batm et al., 2011), <i>Mycobacterium smegmatis</i> (Chea et al., 2007). Leaves have anti <i>Plasmodium falciparum</i> activity (Nguyen-Pouplin et al. 2007). Wood showed activity against HIV-1 IN (Bunluepuech et al., 2009).
<i>Heteropanax fragrans</i>	Bark is used in a preparation for diarrhoea root and bark are included in another preparation given in case of jaundice (Borah et al., 2006)	
<i>Tinospora crispa</i>	Stem is used to promotes blood flow, as appetizer, to reduce fever , body heat and thirst, against diabetes, (Maneenoon et al., 2015)	Antimalarial activity (Najib et al., 1999), antinociceptive and anti-inflammatory activities (Sulaiman et al., 2008), decreased blood glucose and increased insulin levels in diabetic rats (Noor and Ashscoff, 1989)
<i>Terminalia mucronata</i>	Bark is used in case of sore teeth (Khuankaew et al., 2014). Wood is used in a preparation for leucorrhoea and infertility due to menstrual disorders (Chotchoungchatchai et al., 2012)	Stem extract has shown cytotoxicity against HepG2 cells (Weerapreeyakul, 2012)
<i>Castanopsis indica</i>	Leaves are used to treat stomach disorder and skin diseases. Plant resin is given to treat diarrhoea . A paste of leaves is applied for headache (Malla and Chhetri, 2009). Bark paste is applied on chest to control chest pain (Joshi et al., 2011)	Free radical scavenging activity of leave extract could have potential hepatoprotective properties (Dolai et al., 2012)
<i>Maclura cochinchinensis</i>	Root is used to cure malaria and colds (Kobayashi et al., 1997). Heartwood used to treat chronic fever, skin infection, abnormality of the lymph node, diarrhoea , fainting, skin infection; Leakaya et al., 2018)	Extract from heartwood showed antibacterial activity against <i>Staphylococcus aureus</i> , <i>Staphylococcus epidermidis</i> , <i>Bacillus subtilis</i> ; anti-fungal activity (dermatophytes) and antiherpes simplex virus (HSV) activity (Kongkiatpaiboon et al., 2017).
<i>Phyllanthus reticulatus</i>	Leaves and bark are used as astringent and diuretic. Juice of leaves is used for the treatment of diarrhoea in children (Ghani, 2003)	The bark showed antiviral (Saha et al., 2007) and antiplasmodial activity (Omulokoli et al., 1997). Aerial parts Aerial parts extract shows analgesic and anti-inflammatory properties (Saha et al. 2007).
<i>Cratoxylum formosum</i>	The bark, root and leaves are used in folk medicines to treat fevers, coughs, diarrhoea, itches, ulcers and abdominal complaints (Nguyen and Harrison, 1999)	Xanthenes extracted from root has shown antibacterial and antifungal activity and cytotoxic activity (Boonsri et al., 2006; Boonnak et al., 2010)

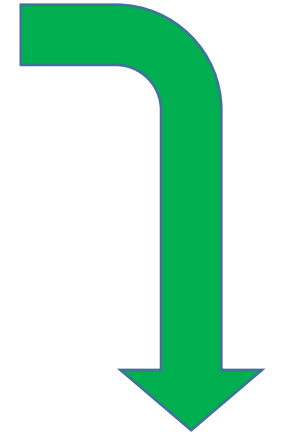
Table 4: Some ethno-medicinal uses and properties found in the literature for the species cited by at least three mahouts. Convergences with EUR on plant parts or indications are highlighted in bold font.



Elephant plant selection



Mahout medicinal practice



Mahout interview



Specimen collection with mahout



Elephant/mahout plant use convergence