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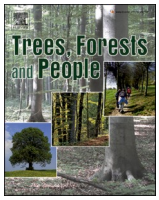

Review Article

Popular Cultural Keystone Species are also understudied — the case of the camphor tree (Dryobalanops aromatica)

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ABSTRACT

Along with landscape degradation and loss of biodiversity there is also a co-occurring loss of cultural and linguistic diversity. When species become rare, there is a corresponding loss of cultural practices and linguistic elements associated with that species. Although cultural assessments of tree species can help in identifying Cultural Keystone Species (CKS) and be used to enhance the cultural relevance of conservation actions, such information is typically lacking for endangered species were the cultural connections may have been lost. Here, we review historic written accounts to assess the cultural status of the critically endangered camphor tree, *Dryobalanops aromatica*, native to Southeast Asia which is recognized for its camphor and crystals forming in the wood. We found that despite centuries of use, the importance of the tree for specific cultures has not been fully understood. Published literature indicate that it could be a CKS to multiple communities. The tree was once culturally significant for many cultures in its native range and beyond, but contemporary data is lacking, especially with respect to persistence and memory of use in relation to cultural change. By virtue of being a culturally recognized tree species, as well as having a distinct ecological role within its natural distribution, we propose *D. aromatica* as a flagship species for conservation and restoration of the habitat it defines. Our review highlights the usability of historic accounts as starting points for identifying CKS and effective conservation of biocultural diversity, especially concerning endangered species. We propose that future research should pay attention to inter and intra-community dynamics of local knowledge on the species, and causes and consequences of varying cultural importance across temporal and spatial scales.

Introduction

Landscape degradation and loss of biodiversity occurring on local to global scales also drives loss of cultural elements of human societies. When species become rare or extinct, there is also a corresponding loss of cultural practices and linguistic elements associated with that species. Such discontinuum in species availability in the landscape impedes opportunities for continued use and spontaneous evolution of human cultures (Axelsson and Grady 2022). Hence, the intricate relationship between biodiversity and human cultures, epitomized as Biocultural Diversity, is vital for resilience in the face of climate change, and the very survival of humankind (Maffi 2007; Bridgewater and Rotherham 2019). The importance of these links is now acknowledged at global policy levels (IPCC 6th, IPBES), as a crucial leverage for transformative change toward sustainability (Horlings 2015; Ives et al., 2020; Leventon et al., 2021). From this follows that conservation and restoration projects may need to consider not only the biological component of landscapes, but also incorporate cultural components into their action plans and objectives (Bowen-Jones and Entwistle 2002; Cuerrier et al., 2015; Axelsson and Grady 2022).

For conservation and restoration of biocultural diversity to be as effective, there is a need to document cultural ties of species. This is a challenging task, especially when the target species is an endangered species for which cultural aspects are already being lost from the collective memory of human communities. Incorporation of cultural aspects into conservation and restoration is also challenging as species do not hold uniform levels of cultural significance across landscapes and communities. A species of high cultural value may be considered a Cultural Keystone Species (CKS) (sensu, Cristancho and Vining 2004) to one culture while being of less importance to another. Such differences in cultural relevance highlight variation in plant knowledge and uses across communities and landscapes (Kazancı et al., 2021)—information

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that is important in tailoring site and culture specific conservation strategies. Therefore, cross-cultural CKS assessment requires community specific information, which is not always available, or even impossible to acquire. Furthermore, assignment of CKS status typically involves surveying a culture for their continued cultural association with the species and its persistence in relation to cultural change (Garibaldi and Turner 2004). For critically endangered species in need of conservation, the persistence criteria may be hard to fulfill, as loss of a species from a landscape may directly influence the persistence of use within a culture.

The cultural importance of species is also applicable in conservation efforts using the Flagship Species approach. The term flagship originally refers to the lead ship of a fleet, distinguished by a unique flag representing the fleet. In conservation, a flagship species is a species used to rally support for conservation of associated species or entire landscape (Bowen-Jones and Entwistle 2002; Garibaldi and Turner 2004). Flagship species are distinguished through a range of properties such as ecological role and 'charisma', defined as a species having the 'ability to capture the imagination of the public' (Walpole and Leader-Williams 2002). Similar to the CKS concept, a flagship species is also distinguished by being culturally relevant. Although most examples of flagship species are large mammals, one example being the Giant Panda, there are also examples where forest trees are used as flagships to promote conservation of focal species and landscapes (Hall et al., 2011; Yadav et al., 2013; Axelsson and Grady 2022). The Koa tree (*Acacia koa)* of Hawaii is one such species that possesse a wide array of ecological properties, facilitates species interactions within an endangered forest type, and also linked to local traditions as its wood is used in crafting the Ukulele, the national music instrument of Hawaii (Axelsson and Grady 2022). Another example is the White pine (*Pinus strobus*) that is a CKS for the Kitcisakik Algonquin community in Canada. White pine is not only a prominent feature in local beliefs and mythology, but also an important ecological component as it provides nesting habitat for the bald eagle (*Haliaeetus leucocephalus*)(Yadav et al., 2013).

Although the above examples provide evidence that cultural relevance of tree species can be used as incentives for conservation and restoration, there is a need to undertake cultural assessments of more species (Reyes-García et al., 2023) and represent a wider diversity of cultures. Failing to ascertain the cultural significance of species could have serious ramifications for under-represented cultures that have a hard time making their world views acknowledged. To plan culturally relevant conservation and restoration projects (Freitas et al., 2020), there is a need to represent these people by prioritizing locally relevant tree species. Nevertheless, a recent review listing 385 species of cultural importance shows that most of them are data-deficient (Reyes-García et al., 2023) which impedes the use of such species in conservation and restoration.

In this article, we review information pertaining to the cultural significance of the iconic tree species *Dryobalanops aromatica*, native to peninsular Malaysia, Borneo and Sumatra, famous for the aromatic camphor oil (borneol), and camphor crystals which were highly sought-after trading items in the past (Box 1). Using written accounts and historical testimonies from the 6th century onward and the CKS framework, we then assess if research has followed up on the historical leads to generate a comprehensive understanding of the contemporary cultural importance of the species. We also assess the potential of the tree as a Flagship Species for promoting conservation and restoration of the

Box 1
The camphor tree – *Dryobalanops aromatica*.

Dryobalanops aromatica, is a large evergreen tree of the Dipterocarpaceae family growing up to 70 m in height and to 2 m in diameter. The species is a distinctive feature of many mixed dipterocarp forests of Southeast Asia (Foxworthy 1932; Vincent 1961; Ashton 1967; Kachi et al., 1995; Norafida et al., 2013). In some of these forests, *D. aromatica* is the dominant upper canopy species (Itoh, 1995), even though it is always accompanied by many other tree species (Foxworthy 1932; Vincent 1961; Norafida et al., 2013). The structure of *D. aromatica* forests, locally known as Kapur forests, is distinctly different from the typical mixed dipterocarp forests (Norafida et al., 2013). Both mixed dipterocarp forests as well as Kapur forests are subjected to considerable degradation and are of high conservation concern. Hence, restoration of landscapes dominated by these species is urgently required (Kettle, 2009). *Dryobalanops aromatica* is listed on the red list as globally vulnerable under criteria A2cd (Barstow and Randi, 2018). It is also listed on the Malaysian red list as near threatened (NT) for Sabah and Sarawak (Chua et al., 2010).

Dryobalanops aromatica is well known for the aromatic camphor oil (borneol), produced from the trunk of the tree, which through crystallization forms true camphor (i.e. a form of "crystals" developing within the wood). Both borneol and camphor crystals were highly sought-after trading items in the past. Camphor was mentioned by Marco Polo as being exported from Southeast Asia to the Middle East since at least the 6th century (Polo 1845). Furness (1902) reports Chinese entrepreneurs trading camphor with local communities of Borneo (Fig 1). The rise of synthetic camphor has diminished the economic value of natural camphor (Ponomarev and Mettee 2017). Yet, camphor continues to be a source of aromatic oil in the flavor, fragrance, food, cosmetics and pharmaceutical industries (Burkill et al., 1966; Le et al., 2017; Suhaimi and Najua, 2020).

Figure 1 Photo showing Kayan camphor collectors selling their camphor crystals to Chinese traders. The original photo is from Furness (1902).

distinctive Kapur forests, i.e., special type of mixed dipterocarp forest characterized by the dominance of *D. aromatica*. Using this information, we ask the following research questions;

1) Is the iconic Camphor tree, *D. aromatica*, a CKS to contemporary cultures?
2) Could *D. aromatica* be considered as a flagship for conserving the characteristic Kapur forests?

Material and methods

To address our research questions, we compiled literature in relation to cultural uses and traditions of the tree. We used our previous knowledge about the literature pertaining to the species, and snowball sampling of citations and references to pinpoint information relevant to our aim. To account for historic data, we made no distinction of the type of literature, and included research articles, conference proceedings and 'gray literature' (books). We then assessed to what extent the published sources provided data to answer the various criteria of the Cultural Keystone Species framework of Garibaldi and Turner (2004) and Flagship Species framework of Bowen-Jones and Entwistle (2002).

Assessment of cultural significance

We follow Garibaldi and Turner (2004) for our assessment of Cultural Keystone Species status (CKS) of *D. aromatica*. The framework includes six main criteria that when assessed, can indicate the cultural significance of a species (See Table 1 under CKS assessment in the result section). For this section, we use secondary data from written accounts to evaluate the extent to which the species meets each of the six criteria. The CKS framework has been widely used before to assess the significance of a species to a particular culture, and has helped in identifying several tree species of importance (Yadav et al., 2013; Franco et al., 2014a; Franco et al., 2014b; Kazancı et al., 2021). Although the assignment of CKS status typically is community specific, there is a clear value in assessing similarities and differences in cultural significance across local communities (Kazancı et al., 2021). Validating the CKS framework and concept for its technical correctness, definitions, and comprehensiveness are beyond the scope of this article.

Flagship species assessment

We assessed the usability of *D. aromatica* as a flagship species for conservation, employing the framework proposed by Bowen-Jones and Entwistle (2002). This framework comprises of 10 different criteria that assess a species' suitability as a flagship for conservation (see Table 2 under Flagship species assessment in result section). The flagship concept pre-dates the cultural keystone frameworks of both Cristancho and Vining (2004), and Garibaldi and Turner (2004). While some of the flagship criteria overlap with the CKS framework (i.e., cultural significance, traditional knowledge, existing use, and recognition), it is distinct in ecological parameters such as 'Ecological role and Conservation status'. CKS are suitable as flagship species since cultural uses increase a species' 'charisma' which is one of the additional attributes assigned to a flagship species (Bowen-Jones and Entwistle 2002). Although 'charisma' certainly is subjective, it is yet valuable, as it portrays a species' 'ability to capture the imagination of the public', especially in its natural habitat, where it matters the most (Walpole and Leader-Williams 2002).

Results

Our literature review unearthed accounts supporting the cultural relevance of *D. aromatica* from the 6th century onward. We present our findings below, using the CKS (Table 1) and the Flagship Species frameworks (Table 2).

Assessing cultural keystone status

Intensity, type, and multiplicity of use

The cultural importance of the camphor tree stems from its iconic borneol that has ceremonial and medicinal uses—both historical (Furness 1902; Burkill et al., 1966) and current (Le et al., 2017). Borneol was used by the Malays and the Sumatran people in the ceremonial purification of corpses and their preservation until burial, and was also used and traded as medicine in the past (Burkill et al., 1966). Ancient traditions also include harvesting the camphor tree for the 'mystical'

Table 1
Assessment of the Cultural Keystone Species (CKS) status of *Dryabalanops aromatica* after Garibaldi and Turner (2004). Color of fields refer to the possible fulfillment of the CKS criteria, e.g., Green = possibly fulfilled, Red = possibly not fulfilled, and gray = no information available (na).

		Borneo								Johore	Sumatra
		Kayans	Dusun	Punan	Kenyah	Sibops	Iban	Hulu	Malanau	Jakuns	Batak
1) Intensity, type and multiplicity of use	Is this species used routinely and in large quantities? Does this species have multiple uses?	Camphor crystals, oil, Camphor used as tribute to the deceased (3)	Used to be found in large quantity in the early 20th century (6). Not known to have multiple uses	na	na	na	na	na	na	Camphor crystals, Camphor oil, used as medicine	Camphor was used at burial of the deceased so that they "might have the spirit gift of power in the next world" (4)
2) Naming and terminology in language	Does the language incorporate names and specialised vocabulary?	A "peculiar language" is used during harvest (3)	A special language was used during Camphor collection (6)	"Many tribes"... must use 'camphor language'(2)	na	na	Special language used (2)	Special language called `Pantang Kapur` where `Pantang` means forbidden or taboo (1)	Camphor language used (2)	Camphor language used (1). The region Kapur Barus named after Camphor (1).	An "artificial language" is spoken during harvest (4). Minyak Kapur named as a special place for camphor harvest (1)
3) Role in narratives, ceremonies or symbolism	Is it featured in narratives and or ceremonies, dances, songs or as a major symbol?	Omens are observed before harvest expedition (2, 3). Camphor used as tribute to the deceased (3)	Plenty of folklores, taboos and customs associated with camphor collection (6)	na	na	na	Dressed up in... "finest war clothes" during camphor harvest (2)	na	na	Commonly associated with omens, beleifs and taboos. A "bisan" or spirit presides over the camphor tree (1)	Regarded as an earthly copy of the heavenly Tree of Fate (4). Harvest festival celebrated with drums and dancing (4)
4) Persistence and memory of use in relation to cultural change	Is the species ubiquitous in the collective cultural consciousness and frequently discussed?	na	Frequently discussed in the early 20th century. By 1980s, it has almost faded from the collective memory (6)	na	na	na	na	na	na	na	In 1922 "the old men disapprove modern neglect of ancient customs" (4)
5) Level of unique position in culture	Is it difficult to replace with other available native species?	Camphor laurel (*Cinnamomum camphora*) produce "Chinese camphor" but the distribution of this species does not overlap with that of *Dryobalanops aromatica*. Furthermore, camphor crystals are "a peculiarity of the Borneo camphor" (2)								Camphor laurel, "Chinese camphor" with another distribution	Camphor laurel, "Chinese camphor" with another distribution
6) Extent to which it provides opportunities for resource acquisition from beyond the territory	Is used as a trade item for other groups?	Tribute of camphor paid to Java. Camphor sold to the Malay and Chinese (2, 3). Hire Punans as guides for camphor collection (2).	Was sold to Chinese traders for 5-20 dollars/ kati in early 20th century (6).	Traded to the Chinese for various goods. Also traded to other natives (2)	Hire Punans as guides and helpers for the camphor collection, which are later traded to the Chinese (2).	Hire Punans as guides and helpers for the camphor collection, which are later traded to the Chinase (2).	Hire Punans as guides and helpers for the camphor collection, which are later traded to the Chinese (2).	na	na	Sold to the Chinese at Kwala indau (1)	na

Table 2
Assessing Flagship Status of *Dryobalanops aromatica* (After Jones and Entwistle 2002).

Sl. No.	Criteria	Assessment	Explanation
1.	Geographical distribution	Yes	Native to Borneo, Malaya, Sumatra (POWO, 2023)
2.	Conservation status	Yes	*Dryobalanops aromatica* is listed as globally vulnerable under criteria A2cd of the IUCN Red List (Barstow and Randi, 2018). It is also listed on the Malaysian red list as near threatened (NT) for Sabah and Sarawak and Least Concern (LC), for Peninsular Malaysia (Chua et al., 2010).
3.	Ecological role	Yes	Key component of Kapur forests that are named after the species. Unlike many other canopy tree species in lowland tropical forests, *D. aromatica* can be locally very abundant which provides unique conditions for a multitude of other tree species (Foxworthy 1932; Vincent 1961; Norafida et al., 2013). Unlike most other dipterocarps, *D. aromatica* flowers and fruits regularly (Appanah, 1981), supporting pollinators and wildlife.
4.	Recognition	Yes	Well known. Frequently recollected in the popular culture
5.	Existing usage	Yes	On 16 Dec 1981, Malaysia issued an 80c Postage stamp, depicting *D. aromatica*. (http://stampdata.com/stamp.php?id=223873)
6.	Charisma	Yes	Bowen-Jones and Entwistle recognize that charisma is a subjective criterion. We feel *D. aromatica* is indeed charismatic.
7.	Cultural significance	Yes	The species is possibly an understudied Cultural Keystone Species (Table 1)
8.	Positive associations	Yes	The plant is reported to be cultivated in the forest gardens of West Kutai District, Indonesia (Apuy et al., 2017).
9.	Traditional knowledge	Yes	Associated communities possess local knowledge on camphor crystals; The Batak Toba of North Sumatra use the sap and leaves for treating Injury, malaria, abdominal pain (Silalahi et al., 2019); local people in Gunung Leuser National Park, Indonesia use the plant to treat cold, flu, leprosy and ringworm (Elliott and Brimacombe 1986)
10.	Common names	Yes	Kapur (Apuy et al., 2017), Kapur Barus (Elliott and Brimacombe 1986), Kapur Singkel, Kapur bukit, Kapur peringii, Kapur anggi, Keladan (Aswandi and Kholibrina 2021); Betiting (punan) (Cesard, 2007). kayu asup (Brunei's Dusun) (Kershaw 2020)

camphor crystals developing in the wood (Lake and Kelsall 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). Historical uses of the camphor tree include the use of bark and wood for construction of houses (Lake and Kelsall 1894); fruit kernel powder was used in local remedies (Soerianegara and Lemmens 1993). Furthermore, the literature report that the camphor tree had multiple uses for various local communities: the Kayans of Borneo, Jakuns of Johor, and Batak of Sumatra (Table 1). Today, camphor is used as a source of aromatic oil for the flavor, fragrance, food, cosmetics and pharmaceutical industries (Burkill et al., 1966; Le et al., 2017; Suhaimi and Najua, 2020). Camphor is used for its preferable scent in religious ceremonies, in perfumery and aromatherapy, as an ingredient in cooking, and for medicinal purposes (Suhaimi and Najua, 2020). Natural camphor is also used as the template for producing synthetic variants (Ponomarev and Mettee 2017). Camphor timber is highly valued for construction because of its attractive pale brown color, and is used locally for the construction of walls and floors of houses. Overall, we find that the camphor tree has the potential for multiple uses, but there are uncertainties to what extent the tree is currently used in the local cultures (Table 1).

Naming and terminology in language

The second criterion assesses the prominence accorded to the species in the local language. One of the key feature of the camphor tree and its uses in local cultures is its clear language tangents (Lake and Kelsall 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). Multiple authors mention a special language variety once used by local communities during camphor harvest (Lake and Kelsall 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). Our review reveals that at least six cultures from Borneo, Johor, and Sumatra were using this elite language variety (Table 1), but this custom may have been even more widespread. Furness (1902) reports that "Many tribes" used this language during camphor harvest and adds that this "curious custom prevails throughout Borneo, and in the Malay Peninsula also". This language variety was called "Pantang Kapur" by the Orang Hulu where "*Pantang*" means forbidden or tabooed, and refers to the fact that the use of everyday language is forbidden during the camphor hunt (Lake and Kelsall 1894). For instance, the Melanau word for to return is 'muli', but in the presence of a camphor tree they use 'beteku'; 'to hide' in the Melanau language is 'palim' but when on a camphor hunt they use 'krian'. Lake and Kelsall (1894) also report that it is not only the camphor hunters that have to speak the "Pantang Kapur", but also the community members staying at home and not participating in the hunt. Almost all tribes use the term 'Paji' for camphor-hunting (Furness 1902), indicating networking and sharing of this elite language variety. Although we could not track down the original reference, there are reports stating that camphor is mentioned in poems/literature in foreign countries. Lake and Kelsall (1894) report that camphor is mentioned in the poems of Imru-l-kais, an Arabian prince who lived in Hadramant, by the Gulf of Aden, in the sixth century.

Role in narratives, ceremonies or symbolism

The third criterion assesses the cultural value of a species beyond its provision of resources or monetary valuation. Species that have made it into narratives, ceremonies and symbolism of a culture are considered culturally significant to that culture. The camphor tree scores high for this criterion, at least for five local cultures. For example, borneol was traditionally used by Kayans of Borneo and Bataks of Sumatra in the ceremonial purification of dead bodies, (Table 1). In Sumatra, the camphor tree was regarded as an earthly copy of the heavenly Tree of Fate (Schoff 1922). Harvesting of camphor was associated with district ceremonies and symbolism (Furness 1902). Furness also reports Iban camphor collectors dressing up in their finest war clothes before going on camphor hunt. Traditionally, there were also omens associated with camphor harvesting that has to be observed for a favorable camphor harvest. Furness (1902) writes: "before setting out for the depths of the jungle where the camphor trees grow, the Kayans first look for a bird known to them as 'Isit'—a Spider hunter, (*Arachnoihera longirostris* or *Anthreptcs malaccencis*); should it be seen flying across their path, from right to left, the omen is not good, there will be poor luck in their search; if it is seen flying in the opposite direction, there will be good luck". This omen must then be followed by favorable omens communicated by the red hawk, the rain bird and the barking deer. Lastly, camphor hunters must look for a certain snake, 'batang limu' that has to be killed, "should it escape, they may as well return home; they will find no camphor, even though all the other omens have been auspicious".

Persistence and memory of use in relation to cultural change

Historical written accounts record that the camphor tree and its products were once culturally significant to various local cultures (Lake and Kelsall 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). Although camphor harvest is mentioned by local informants from Borneo as late as the 1950s (Sellato 2002), and Sumatra in the early 21st century (Aswandi and Kholibrina 2021), many of the camphor rituals and ceremonies could possibly be disappearing in many local cultures. In the early twentieth century, Schoff (1922) reported that "the old men disapprove modern neglect of ancient customs" and that the elders fear such neglect may result in the felling of low-yielding camphor trees. We have not come across any twenty-first century record of the persistence

of the camphor harvest rituals, or the use of the special language variety in contemporary cultures. There are however evidence that the tree is still valued in some local communities, as it is grown in traditional forest gardens (Apuy et al., 2017), and used as a remedy for treating various illnesses (Elliott and Brimacombe 1987; Silalahi et al., 2019). Reports also indicate that camphor is still harvested in some regions (Aswandi and Kholibrina 2021). These evidence occuring through time signals some persistence and resistance to cultural change (Kazancı et al., 2021). Contemporary records across the region for persisting uses and memories of uses, however, are lacking.

Level of unique position in culture

The fifth criterion assesses the irreplaceability of the species in the respective cultures. Although camphor oil is also obtained from *Cinnamomum camphora*, the yield from *D. aromatica* is of superior quality. China had its own camphor extracted from *C. camphora* (L.) J.Presl. Yet, the best quality of Bornean camphor was exported to China where it was worth hundred times the cost of Chinese camphor (Lake and Kelsall, 1894), while an inferior quality was bartered with merchants from India (Gujarat and Bengal) (Nicholl 1979). Furthermore, geographical distribution of *C. camphora* does not overlap with *D. aromatica*, and consequently, cannot be considered as a substitute for *D. aromatica*.

Evidence also suggests that the camphor tree had a unique position in local cultures incomparable to other economically important species. Beccari (1904) reports that other forest trees used by local communities such as the tapang (*Koompassia excelsa*), the minuang (*Octomeles sumatrana*), the mingris (Dialium sp.), and the plai (Alstonia, sp.) were common tribal property, and could not be felled by an individual. This was not the case with the camphor trees, or its yield (Lake and Kelsall, 1894), which belonged to the finder of the tree (Beccari 1904). Contemporary records that could have helped us to determine the uniqueness of the species for today's cultures are lacking.

Extent to which it provides opportunities for resource acquisition from beyond the territory - Is it used as a trade item for other groups?

Historically, camphor trade was quite prominent. Camphor was mentioned by Marco Polo as exported from Southeast Asia to the Middle East since the 6th century (Polo 1845). Furness (1902) and Nicholl (1979) report Chinese camphor trade with local communities in Borneo (Fig 1). Lundqvist (1949) mention Dayaks trading camphor in Nunokan, Borneo, possibly with Arabic traders. Even in the 1950s, Bornean camphor was a rare and highly valuable commodity (Césard 2007). At least four local cultures had once traded camphor to foreign traders, viz., the Dayaks, Kayans and Punans of Borneo, and Jakuns of Johor (Table 1). There is also evidence suggesting that camphor was harvested and traded by many more tribes than mentioned above. For example, both Hose et al. (1912) and Furness (1902) report that the Punans are knowledgeable in Camphor harvest. Furness (1902) further writes that "The chief camphor workers are the Punans, who are either hired as guides and helpers by the Kayans, Kenyahs, Sibops, or Ibans, or else they collect the camphor themselves and barter it with the other natives, who in turn sell it to the Chinese". Historical accounts also suggest that the trade was well established and partly industrialized. Traders were reportedly using copper devices perforated with holes of different sizes to sort camphor crystals into different grades (Lake and Kelsall, 1894). Dutch reports show camphor production for the whole of Southeast Borneo ranging from 20 kg to 200 kg per year in the late 1920s, and camphor was still mentioned by local informants in the 1950s (Sellato 2002). Today, camphor is used as a source of aromatic oil in the flavor, fragrance, food, cosmetics and pharmaceutical industries (Burkill et al., 1966; Le et al., 2017). The camphor tree is still a valuable timber species. Nevertheless, its endangered status might limit the extent to which it is used. We find that the camphor tree scores high for this criterion.

Assessing flagship status

We assessed the flagship status of *D. aromatica* using the framework proposed by Bowen-Jones and Entwistle (2002). This framework deploys 10 different assessment criteria to gauge a species' suitability as flagship for conservation. Our assessment indicates that the species has high potential to be used as a flagship species in its native range of Borneo, Malaya, and Sumatra (POWO, 2023). The species is suitable as a flagship species for conservation and restoration of the Kapur forest type; it is also suitable for conservation of the broader mixed dipterocarp forests type. We provide detailed information for each of the assessment criteria below (summary of our assessment is provided in table 2).

Geographical distribution

A charismatic flagship species also assumes ecological importance when it is native to the region of concern. *Dryabalanops aromatica* is native to Borneo, Malaya, and Sumatra (POWO, 2023), which makes it a candidate flagship species for the region. However, the species is known to occur only in certain localities of the distribution range, but where it occurs, it can be abundant (Foxworthy 1932; Vincent 1961; Ashton 1967; Kachi et al., 1995; Norafida et al., 2013), forming a special forest type known locally as Kapur forests (Norafida et al., 2013). Based on the geographical distribution, we judge *D. aromatica* as a suitable flagship candidate for conservation of Kapur forest type in particular.

Conservation status

Popular flagship species are usually species with threatened populations. But the concept may also be applied to species that represent a special type of habitat. Greater awareness and popularity of the species in comparison to rare species may make them suitable flagship species. *Dryobalanops aromatica* is listed as 'globally vulnerable' under criteria A2cd of the IUCN Red List (Barstow and Randi, 2018). It is also listed in the Malaysian Red List as 'Near Threatened' (NT) for Sabah and Sarawak, 'Least Concern' for Peninsular Malaysia (Chua et al., 2010) and is a priority for conservation in certain regions (Aswandi and Kholibrina 2021). The species can nevertheless be abundant locally in its preferred habitat where it forms distinct Kapur forests (Norafida et al., 2013). As *D. aromatica* is a vulnerable species that also can occur abundantly in patches with distinct ecological roles in such areas, we judge it as a suitable flagship species.

Ecological role

The benefits of a flagship species concept can be amplified by adopting a species that play a pivotal ecological role in the landscape. Although the contribution of individual Dipterocarp species to a broader range of taxa is not well known (but see, Axelsson et al., 2022), mixed Dipterocarp forests support a wide range of associated taxa such as insects (Sakai et al., 1999; Axelsson et al., 2022), birds (Engstrom et al., 2020), and mammals (Charles 1996; Chapman et al., 2018). *Dryobalanops aromatica* also possesses special ecological features that makes it important in some forest types and regions. Unlike many other canopy tree species in lowland tropical forests, *D. aromatica* can be locally abundant which provides unique conditions for many other tree species (Foxworthy 1932; Vincent 1961; Norafida et al., 2013). Unlike most other dipterocarps, *D. aromatica* also flowers and fruits regularly, almost annually (Appanah, 1981), supporting pollinators and wildlife feeding on the fruits. The flowering is typically rich and known to attract swarms of bees, mainly *Apis* and *Trigona* species, which forage for the nectar and pollen (Appanah, 1981). Based on the ecological assessment that highlights *D. aromatica* as an important component of the highly diverse Dipterocarp forest of southeast Asia and in particular for the Kapur forest type, we find that *D. aromatica* is a suitable flagship species within its native range.

Recognition

The taxa used as a flagship should be well known to the target

audience, and should be distinctive and not readily confused with other species (Bowen-Jones and Entwistle 2002). Because *D. aromatica* is a source of high quality camphor, it is well-known at local and global levels. The epithet 'aromatica' indicates that all parts of this tree are strongly aromatic, which together with the special characteristics of purple brown color and scaly bark, distinguishes the tree from others in the forest (Mohamad et al., 2018). The species is also frequently recollected in the popular culture (Ting 2015; Wu 2020). During the XXI IUFRO conference hosted by Malaysia in 2000, a postal stamp depicting the tree was issued. We find that *D. aromatica* is a popular species locally, an attribute that positions it as a flagship species within its native distribution.

Existing usage

A species that is used as a mascot for another cause may not be suitable as a flagship for conservation, especially if the previous use is in direct conflict with the conservation agenda. Although there are commercial interests in *D. aromatica* and that the tree may be used as a symbol for camphor products, we are not aware of any use that would disqualify it as a flagship candidate. The postal stamp issued by IUFRO depicting the tree is of synergistic value here, as the overarching agenda of IUFRO is to promote sustainable forest practices and the theme of this conference was "Interconnecting Forests, Science and People".

Charisma

Although flagship species have traditionally been charismatic mammals or birds, charisma is a subjective assessment criterion (Bowen-Jones and Entwistle 2002). For most people, the Giant panda is more charismatic than any tree species. Nevertheless, *D. aromatica* has characteristics that could make it charismatic. 'Crown shyness' is an interesting feature that occurs in dense *D. aromatica* stands where the crowns of individual trees do not touch each other (Halle and Ng 1981). This is a distinguishing feature of Dipterocarp trees, and the phenomenon have raised interest in the scientific community, as well as among the general public, with some people considering this as an "awe--inspiring natural phenomenon" (Ting 2015). Due to its special characteristics, it is also suggested to enhance the attractiveness of a site for tourists (Mohamad et al., 2018). Its cultural significance (Table 1) that captures 'the imagination of the public' (Walpole and Leader-Williams 2002), helps the tree satisfy the charismatic criteria of flagship species.

Cultural significance

The cultural significance of a species can offer strong incentives for conservation. Species that are represented in folklore, traditions and other cultural uses can reinforce conservation or enhance the cultural relevance of restoration (Bowen-Jones and Entwistle 2002; Axelsson and Grady 2022). With support from our CKS assessment (Table 1), we find that *D. aromatica* scores high for this criterion. The species is possibly an understudied Cultural Keystone Species, with lingering uncertainties about cross-cultural usages and the persistence in relation to cultural change.

Positive associations

Negative associations of species impede our capability to raise incentives for conservation. *Dryobalanops aromatica* has strong positive associations with local communities. Traditionally, camphor harvest was sacred and associated with distinct ceremonies and symbolism (Furness 1902). Furness (1902) reports Iban camphor collectors dressing up in their finest war clothes before going on camphor hunting. In Sumatra, the camphor tree was regarded as an earthly copy of the heavenly Tree of Fate (Schoff 1922). To what extent these symbolisms are linked with the species today is unknown to us. However, the species is reported to be cultivated in the forest gardens of West Kutai District, Indonesia (Apuy et al., 2017). Local communities also use tree products for enhancing their daily lives: The Batak Toba of North Sumatra use the sap and leaves for treating injury, malaria, and abdominal pain (Silalahi et al., 2019); local people in Gunung Leuser National Park, Indonesia use the plant to treat cold, flu, leprosy and ringworm (Elliott and Brimacombe 1987). There are also evidence that camphor is still harvested in some regions (Aswandi and Kholibrina 2021). These contemporary uses signal positive association which makes *D. aromatica* a flagship species.

Traditional knowledge

Active local knowledge on species provides opportunities to build conservation actions, thereby enhancing the effectiveness of a species as a flagship. Much of the contemporary local knowledge is possibly not reported in literature due to paucity of studies. Yet, records indicate local knowledge prevalence. For example, the use of the tree in the traditional forest gardens (Apuy et al., 2017), may provide valuable information about the management and propagation of the species. A powder of the fruit kernel was used in local remedies (Soerianegara and Lemmens 1993), which implies knowledge on how to acquire seeds, and its organoleptic properties. Aswandi and Kholibrina (2021) report recording information from ten local camphor collectors when developing conservation actions for *D. aromatica* in Sumatra.

Common names

The local names given to a species can reinforce its flagship status, provided the meanings or interpretations do not have negative connotations (Bowen-Jones and Entwistle 2002). The common names of *D. aromatica* are Borneo camphorwood and Kapur, from its camphor; the distinctive forest type is known as kapur forests (Norafida et al., 2013). We are not aware of any negative connotations associated with these names, and given the many positive associations of the species, it is unlikely that such names exist.

Discussion

Our aim was to use written accounts and historic testimonies to assess if contemporary research has followed up on the historical leads on the cultural importance of the camphor tree. We found that the camphor tree possesses attributes related to all six criteria of the CKS framework. However, no report exists for all six criteria from a specific culture, which is understandable due to the historical timeline of the reports (pre-2004, mostly), and it is currently hard to assess to what extent the tree conforms to the persistence criterion. Our results are consistent with the report of Reyes-Garcia et al. (2023), that most culturally important species are data deficient. The data-deficiency for *D. aromatica* despite its popularity spanning across centuries, calls for an urgent need for participatory surveys. Our review also highlights *D. aromatica* as a possible flagship species suitable for reinforcing restoration and conservation. Below, we discuss the trends emerging from our review, and flag possible research questions for future field studies.

Linguistic heritage associated with D. aromatica

The pronounced, and possibly under-reported spiritual significance of *D. aromatica* can be inferred from the language and ritual context. Many local communities employ a 'ritual language' while harvesting culturally important plant resources. Ritual languages are highly conserved codes of communication (Graburn 1984), meant for occasions deserving utmost sanctity. For the Trobrianders of Papua New Guinea, the most important period of the year is *milamala*, the harvest festival. During this festival, the people sing songs in Biga Baloma, the ritualistic variety of the Kilivila language. Biga Baloma is the 'language of spirits of the dead', and is comprehensible only to select members of the community (Senft 1996). Similarly, harvest of camphor from *D. aromatica* was historically associated with rituals, omens, and special clothing, as well as the use of a special language (Lake and Kelsall 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). The ritual language associated with camphor collection offers 'elite closure', a social

mobilization strategy employed by powerful elites in a community to propagate their power and social and economic privileges through language choices (see Myers-Scotton 1993). Ritual languages are context-specific linguistic varieties, suitable for use only in specific contexts. The camphor language with its elite stature protected the economic interests of those proficient in local knowledge related to camphor tree and harvest. However, doing so, it also restricted access to the tree from the larger populace, in the absence of which, the species would have been overexploited in the past. This is in line with Schoff (1922) who reports the fear of elders that neglecting old customs associated with camphor harvest may result in overexplotation or felling of low-yielding camphor trees. To what extent such neglect may have contributed to population decline is unknown. It is likely that the shift in economic potential of the species from camphor to timber since the 1950s could have driven population declination. Also, another plausible consequence of the shift in economic potential is that the cultural requirement for elite closure and ritualistic languages disappear. With this in mind, we ask: *what are the consequences of the loss of this language variety? Are there community members still proficient in the ritualistic language? If so, what are the factors that have contributed to the maintenance of this elite language variety?*

Is D. aromatica a CKS in the contemporary world?

Our assessment shows *D. aromatica* as an understudied, but a strong contender for being a CKS to many communities within its distribution range. Evidences indicate that the tree is a valued species to some contemporary communities: it is grown in traditional forest gardens (Apuy et al., 2017), and used as remedy for treating various illnesses (Elliott and Brimacombe 1987; Silalahi et al., 2019). More modern and industrialized uses include the use of camphor as a source of aromatic oil in the flavor, fragrance, food, cosmetics and pharmaceutical industries (Burkill et al., 1966; Le et al., 2017; Suhaimi and Najua, 2020). Nevertheless, we could not find any literature pointing to persistence and memory of use in relation to cultural change, the fourth criteria in the CKS framework. There are a few literature supporting continued camphor harvest in certain regions in the 21st century (Aswandi and Kholibrina 2021). But most reports are historical claims from late 19th century or early 20th century (Lake et al. 1894; Furness 1902; Beccari 1904; Hose et al., 1912; Schoff 1922). To what extent the special practices are still an active part of local cultures is unknown to us. Although our review highlights written historic accounts as valuable starting point for cultural assessments of species, the lack of contemporary data is a clear limitation that needs to be overcome in future studies.

We have not come across any detailed information pertaining to the persistence of the camphor harvest rituals or use of the special language in contemporary cultures. As early as in 1922, Wilfred H. Schoff reported "the old men disapprove modern neglect of ancient customs" and that such negligence may result in felling of trees with poor camphor yield (Schoff 1922). Many of the rituals and ceremonies mentioned in relation to camphor harvest are likely to be impoverished in contemporary local cultures which in turn may affect feelings of cultural belonging. Participation in rituals are known to escalate endorphin levels and promote social bonding (Charles et al., 2020). Rituals can aid in revitalizing cultural traditions, as exemplified by the Odawa Indians who revived their traditions and rituals to enhance community bonding (Pflug 1996). In this context, we raise the question *what are the implications of the loss of camphor harvest rituals for the respective communities; are there social incentives for local communities to revitalize camphor rituals?* Although economic value alone does not explain a species' cultural importance (Cristancho and Vining 2004), the immense value of camphor tree to the local communities (of Johor) in the 1890s could be understood from the record that it was acceptable for a stronger contender to murder a successful camphor collector and covert his camphor harvest (Lake and Kelsall, 1894). In the context of the diminishing economic relevance, we do not know the current levels of cultural importance attached to the species. For those persisting cultural values, it would be relevant to know *what are the factors sustaining the cultural importance of this endangered species?*

Cultural Keystone Species are potential flagship species

Steering conservation using flagship species provides incentives for engaging the local populace in conservation and restoration of landscapes (Bowen-Jones and Entwistle 2002; Axelsson and Grady 2022). Although CKS may live up to many of the cultural aspects of the flagship species assessment (i.e., cultural significance, traditional knowledge, existing use, and recognition etc.), a CKSspecies need not be ecologically important (Cristancho and Vining, 2004; Bowen-Jones and Entwistle, 2002) although there are many such examples (Yadav et al., 2013; Franco et al., 2014b). The flagship species concept in application is often biased towards charismatic megafauna and it is important to consider the capability of CKS trees to captivate the attention of local communities. By providing undue emphasis on megafauna, the conservation community foregoes cost-effective opportunities to conserve landscapes using charismatic trees. Including CKS trees into restoration and reforestation across large areas of degraded landscapes (i.e. Bonn Challenge, The trillion tree campaign etc.) could also increase the cultural significance of restored forests (Axelsson and Grady 2022). Bowen-Jones and Entwistle (2002) discuss how the Mayan communities of Toledo District, southern Belize successfully used *Ceiba pentandra*, the silk cotton tree, as a flagship species to conserve Golden Stream Corridor Preserve. Similarly, the cultural significance of the Koa tree (*Acacia koa*) is currently used as incentive for restoration of an endangered forest type in Hawaii (Axelsson and Grady 2022). With support of our flagship species assessment, we conclude that *D. aromatica* is a suitable flagship species for conservation and restoration of the Kapur forest type that it defines, and potentially also for mixed Dipterocarp forests.

Conclusion

The need for documenting and revitalizing cultural connections is urgent for species threatened with declining populations and extinction. Loss of culturally important species hamper their cultural uses and disrupt cultural evolution. Our review highlights that written accounts of species are usefull starting points to identify possible CKS. Such species could then be pursued further in collaboration with local communities. Our assessment shows that even a species such as the camphor tree that has centuries of known use, has not been understood fully from the perspective of contemporary cultures. The existing literature indicates that the tree could be a CKS to multiple communities, but comprehensive data is lacking. As a CKS, the tree is also a suitable flagship species for the camphor forests it defines. Efforts to document should pay attention to *inter-community, and intra community dynamics of knowledge on the species, and its varying cultural importance across temporal and spatial scales*.

Author's contribution

EPA formulated the initial idea. Both authors contributed equally in compiling literature, and writing.

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Authors declare no conflict of interest.

Data availability

No data was used for the research described in the article.

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