Received: 7 March 2025 | Revised: 10 November 2025 | Accepted: 11 November 2025

DOI: 10.1002/ppp3.70154

RESEARCH ARTICLE

Plants People Planet PPP Open Access

Conservation status of species used in the UK herbal medicine industry

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Funding information
Leverhulme Trust; University of Leeds

Societal Impact Statement

Given the ongoing biodiversity crisis, sustainable use and management of medicinal plants is critical. We assessed the conservation status, threats and conservation actions of 298 species sold by UK suppliers to medical herbalists. We found that most species used are unevaluated, representing a gap in conservation knowledge, and of those with assessments, biological resource use and agriculture were the two key threats. More comprehensive evaluation of the extinction risk of medicinal plants is needed, and sustainable management of threatened species, especially through sustainability schemes such as FairWild, would also be beneficial.

Summary

- Collection of medicinal plants from the wild has been implicated in the decline of target species abundance in their natural habitats and possible local extinction. However, conservation status differs widely between species used in herbal medicine. Here, we conduct a broad survey of herbal remedies to evaluate the extent to which species involved are at conservation risk.
- We created a list of 298 species used in herbal remedies commonly available from online retailers in the United Kingdom. The list was cross-referenced with IUCN and CITES databases to evaluate the extent to which traded species are considered to be threatened, including particular threats faced by the species.
- We found that 203 (68.1%) of species used in the UK herbal medicine market are unevaluated by the IUCN. Of the 95 species that had been evaluated, 13 (13.7%) were in categories of Near Threatened (NT) or higher. The most common threats to endangered species were intentional exploitation as biological resources and threats from agriculture relating to non-timber crops. Only seven species (2.4% of the total) are featured on CITES.
- The results show that medicinal plants supplying the UK herbal medicine industry lack comprehensive conservation evaluations. Whilst the overall number of endangered species in trade is low, this number may rise if more evaluations are carried out.

- We have included a list of species which may be more sustainable alternatives for 11 species that are of conservation concern. We also recommend that herbalists and suppliers increase sourcing from sustainability schemes such as FairWild. Additional work is required to further detail knowledge about the trade of medicinal plants in the WHM industry.

KEYWORDS

biodiversity, conservation, health, herbal medicine, IUCN

1 | INTRODUCTION

Medicinal plants are of critical importance as a source of medicinal treatments to many people globally, and in some regions, particularly in the Global South, are one of the primary sources of healthcare (World Health Organization, 2013). Medicinal plants not only have practical utility in medicine but also have ecological value, economic use in support of livelihoods and cultural value (Knapp, 2019; Schaal, 2019; Ticktin, 2004). In addition, medicinal plants are often sought out as remedies in the treatment of several conditions such as hormonal, digestive and allergic disorders in the Global North (NIMH, 2020; World Health Organization, 2013). The medicinal plant trade internationally has been valued at US$940B as of 2014 (Mofokeng et al., 2022). These markets provide income for several stakeholders across supply chains, from harvesters and farmers to wholesalers and traders. In the Global South, environmental income is thought to represent 28% of household incomes (Angelsen et al., 2014), and the trade in medicinal plants represents an important source of income for a range of people in this industry (Hilonga et al., 2019; Pyakurel et al., 2018). Additionally, the use of medicinal plants is culturally significant, as plants used medicinally can be associated with traditional ecological knowledge (TEK) specific to the culture in which they are used (Salim et al., 2019) or can be used to treat culturally significant folk illnesses (Petersen et al., 2015), and so conservation of medicinal plants has a cultural importance as well.

Despite their economic, medicinal and cultural value, medicinal plant species are often threatened by a range of anthropogenic stressors, particularly overharvesting (Williams et al., 2013). Whilst some threat analyses have focussed predominantly on the risks posed by local (Jusu & Sanchez, 2014) or industrial extraction (Campos & Albuquerque, 2021), broader studies implicate a range of locally relevant stressors including agriculture, natural hazards and firewood collection (Gafna et al., 2017; Ganie et al., 2019). In addition, authentication issues can cause incorrectly identified medicinal plants entering the market, which can cause issues with both safety (Chen et al., 2014) and conservation (Balaji & Parani, 2022). However, sustainable management of medicinal plants is hindered by a lack of information about particular plant species. There are estimated to be around 400,000 plant species globally, though this figure is debated (Heywood, 2017). Of these about 5.45% are assessed by the IUCN, though the IUCN suggests this figure is more like 7% because they consider the estimated number of plant species to be lower (Heywood, 2017). Based on the 25,791 species of plants that are documented as having a medicinal role at the time, Howes et al. (2020) noted that 5411 (21.0%) have been evaluated by the IUCN and 723 (13.4%) of those evaluated species are considered endangered (Howes et al., 2020). The current figure for documented species of medicinal plants according to Kew's Medicinal Plant Names Service (MPNS) is 39,112, but the number of those species that have assessments is unknown (Kew Science, 2024a). Data deficiency is a recurrent challenge in case studies in the literature, for example, where only small numbers of taxa are assessed from among a larger total number of species that have been studied (Bello et al., 2019), or individual species of plants that are generally regarded as threatened not appearing on the Red List due to a lack of information (Khan et al., 2016). The simple lack of information means that actors in the herbal medicine trade cannot make informed choices concerning the sustainability of that trade. As a result, there is a need to link the species that are actually involved in trade with the conservation literature, and to incorporate the feedback of experts (such as WHM practitioners), in order to support evidence-based decisions concerning sustainable development of this large and growing industry.

Considering the ongoing biodiversity crisis (Rull, 2022), and that many medicinal plant species, especially those which are traded, have been regarded as threatened by overexploitation in the literature (Khan et al., 2016; Tali et al., 2015; Williams et al., 2013), it is important to understand the range of plants used by practitioners of WHM and how they are affected by overharvesting and other threats to their populations. These herbal products can be imported into the United Kingdom under two different categories, either as plant parts or as herbal remedies (Department for Environment, Food, and Rural Affairs, 2025; HM Revenue & Customs, 2012), and this will affect the extent to which conservation legislation affects them. This study aims to explore the following research questions: Firstly, how much do we know about the extinction risk of species used by medical herbalists in the United Kingdom and what is the status of these species on the IUCN Red List? Secondly, what are the main threats posed to species used by medical herbalists in the United Kingdom? Thirdly, what conservation actions are being taken to prevent declines in populations of threatened WHM species and to protect them from further depletion? Fourthly, what role does CITES play in protecting threatened WHM species in international trade? And fifthly, what sustainable alternatives exist to endangered species within the UK herbal medicine trade?

2 | MATERIALS AND METHODS

Data was collected from three of the main online suppliers of medicinal plants to UK WHM practitioners, identified on the basis of the first author's professional experience. None of the three suppliers sampled appeared to be using FairWild or other similar sustainability schemes, as far as their public websites demonstrate. However, in terms of Good Manufacturing Practice (GMP), suppliers have GMP data demonstrating that they follow good safety and manufacturing protocols. One is a member of the HerbMark scheme, which involves auditing of herbal manufacturers to assure manufacturing standards for 'quality and effectiveness' in herbal medicine products supplied to practitioners (BHMA, 2022). Data regarding liquid and dried products were collected and collated in a spreadsheet, listing the binomial name given, common name, strength, volume and any organic accreditation. The list of binomial names associated with medicines was checked against databases of botanical nomenclature—Plants of the World Online (PotW) and World Flora Online (WFO). For fungal species, Species Fungarum was used to check nomenclature. Additionally, because of unorthodox naming conventions in the herbal medicine industry, the Kew Medicinal Plant Names Service (MPNS) was used to check the names given by suppliers. The nomenclature used by herbalists does not always use the current name for a species, and herbal products are often sold under the more familiar synonyms rather than accepted names. For some products listed, such as 'Squill Oxymel', a traditional preparation of *Drimia maritima* (L.) Stearn in honey (Nejatbakhsh et al., 2017), the correct binomial had to be confirmed using MPNS, as the phrase 'Squill Oxymel' would not yield a result in the IUCN Red List. Likewise, *Aloe capensis* is the name given to a preparation of *Aloe* sp. in pharmacopoeias, not a binomial name for a specific plant, though we do refer to it as if it were (Irving, 2016). As such, this species was not included in the binomial list for analysis. The species listed from the MPNS that are commonly sold as *Aloe capensis* were listed instead (viz., *A. ferrox* Mill., *A. vera* (L.) Burm.f., *A. spicata* L.f. and *A. africana* Mill.), since products sold as *Aloe capensis* could be made from any of these other species (Kew Science, 2024b).

This final version of the species list was used with the R package 'rredlist' (Gearty and Chamberlain, 2016) to generate a data frame with Red List data from the IUCN API about all listed taxa. Data gathered in this way included Red List status, assessment date and author, criteria under which assessment was made, population trend, threats, narratives on identification, rationale for listing, geographic range, population, population trend, habitats, conservation measures, use in trade, countries of occurrence, common names and growth forms.

In addition to this, we extracted narrative data from the IUCN database. The types of narrative data were identification, taxonomy notes, rationale, geographic range, population, population trend, habitats, threats, conservation measures, use and trade. Since the focus of this research is on the extinction risk of medicinal plants used by UK-based herbalists, these data were reviewed to understand the reasoning for Red Listing and the role trade and medicinal use plays in the risk to extinction of these plants. Whilst IUCN threat categories for each species provide a high-level summary of the role various threats play in the extinction risk to these plants, the narratives from the IUCN assessments provide qualitative data, which gives a nuanced understanding of the role each threat plays and to what extent, if any, trade and medicinal use is a factor that threatens extinction to these taxa.

Each species was also searched manually on the checklist of CITES species (CITES, 2025), to gather information specific to trade in these species, including under which Appendix the plants were covered, whether this was a specific species or the entire genus of a plant, and what specific regulations were in place under CITES with regard to the trade in various species. These data could then be cross-referenced with the data from the IUCN to give information about how threatened species which are internationally traded are protected by CITES.

To determine the extent of specific threats, the threat codes assigned by the IUCN for each species were recorded at various levels of the hierarchy of threat codes, ranging from general codes (e.g. 5—Biological resource use) to more specific (e.g. 5.2—gathering terrestrial plants, 5.2.1—Intentional use [species is the target]). From these data, we calculated the number of species assigned to each category.

To gain a greater understanding of the quantity of knowledge about medicinal plant conservation, specific to medicinal plants used by UK herbalists, the literature around this subject was also investigated. To add another dimension of characterisation, the R package 'rscopus' (Muschelli, 2015) was used to automate a literature search using the search terms '"species name" AND conservation' and then report the number of papers generated, which match these keywords for each species. This search gave broad information about the number of papers related to the keyword 'conservation' for each species and allows for a preliminary assessment of which species are well studied in the academic literature, and how this relates to IUCN and CITES assessment.

Finally, we include a list of herbs which may be sustainable replacements for any threatened species based on a number of herbal reference texts, research articles and the EU Monographs, all referenced in Table 1. Remedies were sought that were recommended for the same ailment, or with the same actions, as that for which an endangered species was currently available, and the replacement was checked to ensure that it was not endangered.

3 | RESULTS

3.1 | Red list categorisation

The total number of species in the final list of taxa was 298 (see Dataset S1 for a full list). Of these, most ($n = 293$) were plant species, with fungi (4), lichen (1) and algae (1) also being present among taxa for sale as medicinal products in the WHM trade. For brevity, this study will refer to 'medicinal plants', but this term encompasses all species (including non-plant species) which appear. The number of plants with IUCN assessments and those non-assessed is shown in Figure 1 below. There were 203 taxa which were non-assessed, and 95 assessed on the IUCN

TABLE 1 Threated medicinal plants and nonthreatened possible alternatives. Note that not all species are currently used in UK herbal medicine. As such, these are indicative of plants that are mentioned in literature as sharing the same role as a threatened species and are not clinical suggestions for prescription. In addition, these are broad, symptomatic suggestions and do not take into account a holistic approach.

Threatened species (IUCN status)	Medicinal uses	Possible alternative (IUCN status)	Medicinal uses
Commiphora wightii (Arn.) Bhandari (CR)	Inflammation, diabetes, rheumatism, arthritis and obesity (Cunningham et al., 2018)	*Galega officinalis* L. (LC) *Galium aparine* L. (NE) *Iris versicolor* L. (LC)	Hypoglycaemic (Hoffmann, 2003) Obesity—traditional (Bartram, 1998) Antiobesity, anti-inflammatory (Bartram, 1998)
Ginkgo biloba L. (EN)	For promoting circulation, particularly to the brain and improved mental function (particularly in elderly) (Bartram, 1998)	*Salvia rosmarinus* Spenn. (LC)	Improves circulation, specifically to peripheries (Hoffmann, 2003)
Juglans cinerea L. (EN)	Constipation associated with hepatic conditions, stimulates flow of bile, skin condition and haemorrhoids (Bartram, 1998)	*Malva sylvestris* L. (LC) *Centaurium erythraea* (LC), *Artemisia vulgaris* L. (LC). *Geranium maculatum* L. (NE)	Constipation (Mousavi et al., 2021) Bile (Bartram, 1998) Haemorrhoids (Hoffmann, 2003)
Aesculus hippocastanum L. (VU)	Haemorrhoids (Wood, 2008)	*G. maculatum* L. (NE)	Tonifying astringent (Hoffmann, 2003)
Cinnamomum verum J. Presl (VU)	Traditionally used for 'mild, spasmodic gastrointestinal complaints', bloating, flatulence and mild diarrhoea (European Medicines Agency, 2011)	*Mentha x piperita* L. (NE) *Matricaria chamomilla* L. (LC) *Foeniculum vulgare* Mill. (LC)	Spasmodic digestive pain, bloating, diarrhoea (Wood, 2008) Diarrhoea, mild digestive conditions (Wood, 2008) Antispasmodic, relieves flatulence (Hoffmann, 2003)
Hydrastis canadensis L. (VU)	Used in treatment of a number of infections in various bodily systems (Edwards et al., 2015) Also used to support mucous membranes and in cases of catarrh (Hoffmann, 2003)	*Althaea officinalis* L. (LC) *Inula helenium* L. (LC) *Allium sativum* L. (NE)	Soothing mucous membranes (Hoffmann, 2003) Catarrh (Hoffmann, 2003) Antimicrobial (Wood, 2008)
Picrasma excelsa (Sw.) Planch (VU)	Anthelmintic (Bartram, 1998)	*Betonica officinalis* L. (LC)	Used in treatment of intestinal parasites (Wood, 2008)
Saraca asoca (Roxb.) W.J.de Wilde (VU)	Larvicidal, anti-nephrolithiatic, anticancer activity, dermo-protective activity, CNS depressant, brain tonic, anti-menorrhagic, antiasthmatic (Rathod & Ghante, 2021)	*Daucus carota* L. (LC) *Avena sativa* L. (NE) *Alchemilla vulgaris* L. (LC)	Kidney stones (Hoffmann, 2003) Exhaustion from mental strain, stress, improves concentration and memory (Wood, 2008) Menorrhagia (Hoffmann, 2003)
Fraxinus excelsior L. (NT)	Used traditionally for mild joint pain to increase urinary flow for flushing in mild urinary tract illness (European Medicines Agency, 2012)	*Betula pubescens* Ehrh. (LC) *Taraxacum offcinale* F.H.Wigg. (LC)	Joint pain (listed as *B. alba* L.) (Wood, 2008) Diuretic (Bartram, 1998)
Handroanthus impetiginosa (Mart. ex DC.) Mattos (NT)	Internal: Digestive conditions, anti-inflammatory. External: Skin conditions, boils, eczema and psoriasis (Edwards et al., 2015)	*M. sylvestris* L. (LC) *Betula pendula* Roth (LC)	Digestive conditions (anti-inflamatory) (Mousavi et al., 2021) Skin conditions (listed as *B. alba*) (Wood, 2008)
Pulsatilla vulgaris Mill. (NT)	Antispasmodic, nerve relaxant, alterative (Bartram, 1998)	*Melissa officinalis* L. (NE), *Nepeta cataria* L. (LC). *Artemisia vulgaris* L. (LC), *N. cataria* L. (LC). *G. aparine* L. (LC)	Diaphoretic, antispasmodic (Hoffmann, 2003) Nervines (Hoffmann, 2003) 'Lymphatic swellings' (Wood, 2008)

Abbreviations: CR, critically endangered; DD, data deficient; EN, endangered; LC, least concern; NE, not evaluated; NT, near threatened; VU, vulnerable.

Red List. Of those which were assessed with a conservation status, Least Concern (LC) was the biggest group ($n = 75$), followed by Data Deficient (DD, $n = 7$), Near Threatened (NT, $n = 5$), Vulnerable (VU, $n = 5$), Endangered (EN, $n = 2$) and Critically Endangered (CR, $n = 1$).

3.2 | Population trends

Population trend from IUCN assessments was analysed. Populations of most ($n = 41$) species were stable, with others decreasing (18),

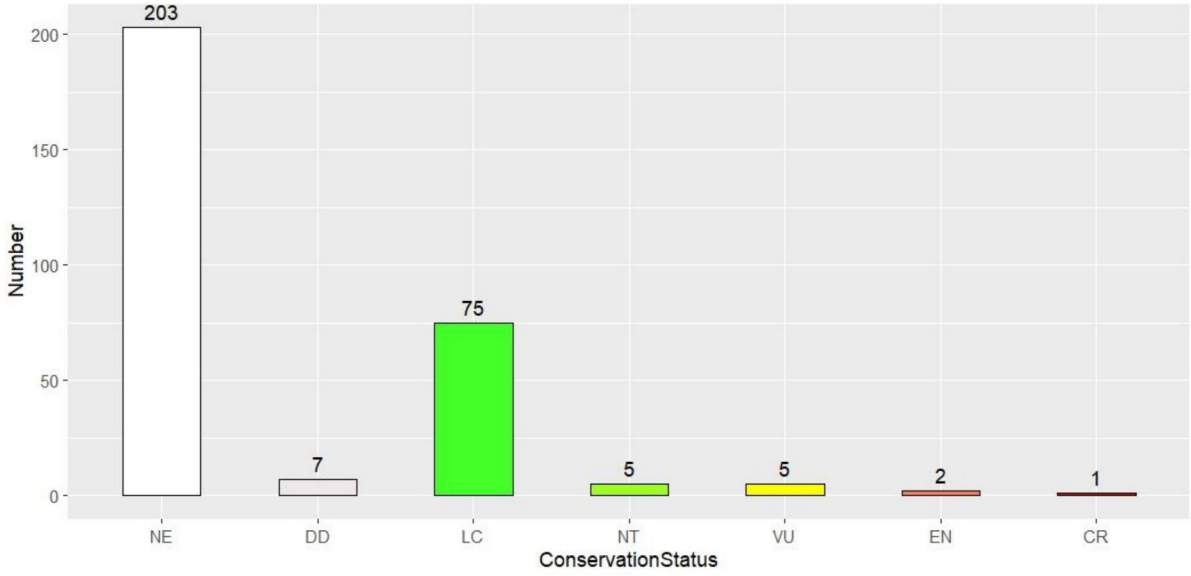

FIGURE 1 Bar chart showing the number of species in each category of the IUCN red list. CR, critically endangered; DD, data deficient; EN, endangered; LC, least concern; NE, not evaluated; NT, near threatened; VU, vulnerable.

TABLE 2 The threatened species, IUCN status, population status and number of papers on conservation found.

Species	Family	IUCN status	Population status	Papers on conservation
Aesculus hippocastanum L.	Sapindaceae	VU	Decreasing	22
Cinnamomum verum J. Presl	Lauraceae	VU	Unknown	40
Commiphora wightii (Arn.) Bhandari	Burseraceae	CR	Decreasing	37
Fraxinus excelsior L.	Oleaceae	NT	Decreasing	142
Ginkgo biloba L.	Ginkgoaceae	EN	Unspecified	88
Handroanthus impetiginosus (Mart. ex DC.) Mattos	Bignoniaceae	NT	Decreasing	23
Hydrastis canadensis L.	Ranunculaceae	VU	Decreasing	21
Juglans cinerea L.	Juglandaceae	EN	Decreasing	37
Ophiocordyceps sinensis (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones and Spatafora	Cordycipitaceae	VU	Decreasing	78
Picrasma excelsa (Sw.) Planch	Simaroubaceae	VU	Unspecified	2
Platycladus orientalis (L.) Franco	Cupressaceae	NT	Unknown	100
Pulsatilla vulgaris Mill.	Ranunculaceae	NT	Unknown	11
Saraca asoca (Roxb.) W.J.de Wilde	Fabaceae	VU	Unspecified	23

Abbreviations: CR, critically endangered; DD, data deficient; EN, endangered; LC, least concern; NE, not evaluated; NT, near threatened; VU, vulnerable.

unknown (27), increasing (4) or 'NA' (4). Most species with decreasing populations ($n = 11$, 61.1%) were Least Concern. Some species, such as *Asparagus cochinchinensis* (Lour.) Merr., which is listed as DD and had an unknown population trend, were suggested by the narrative from the IUCN assessment to be threatened by overexploitation in some of its range, with more information from across the entire range being needed to assess the broader trend. This species narrative suggests that even among species with unknown population trends, there is concern that some taxa may have declining populations.

Additionally, *Achillea millefolium* L. is also listed as LC with an unknown population trend, yet the IUCN report narrative on population trends suggests that the population may be declining in part of the range. This is based on data gathered from the IUCN for a regional assessment which covered the United States, Canada and Mexico. This noted regional population decline highlights the fact that even plants which are assessed as Least Concern need to be monitored carefully, as population decline may lead to increased extinction risk over time.

Table 2 shows the population status of medicinal plants with IUCN assessments, which have been evaluated as having an extinction risk of NT or higher. All species populations are either declining (7), unknown (3) or unspecified (3). The difference here between 'unknown' and 'unspecified' is whether the IUCN data states specifically that the population trend is unknown or simply provides no data for this category.

3.3 | Threat code analysis

All identified WHM plants listed under IUCN threat code 5.2 'Gathering terrestrial plants' ($n = 19$) were listed in subcode 5.2.1 'Intentional use (target is the species)'. This is the subcode that would be expected for deliberate gathering of medicinal plants from 'wild' areas for a specific purpose (whether medicinal or otherwise). No species appeared in any of the other threat subcodes (i.e., 5.2.x) within this broader category of 'Gathering terrestrial plants'. Nineteen species were listed under 5.2.1, which is the highest number of species assigned to a single threat code and therefore the greatest single threat. To give this context, 137 different assignments to threat codes are mentioned so this number represents only 13.9% of the total number of mentioned threats for taxa in this study. Therefore, whilst the gathering of plants for intentional use is the biggest single threat, most threats are unrelated to the gathering of terrestrial plants.

For the highest level threat codes, 'Biological resource use' is the second largest threat to the plant species listed among the data for this study, of those which have threat codes assigned (Figure 2). 'Biological resource use' has fewer ($n = 36$) reports than 'Agriculture & aquaculture' ($n = 41$). Other contributing threats facing medicinal plants within the context of this study are 'Invasive species and other problematic species, diseases & pests' ($n = 20$), 'Climate change and severe weather' ($n = 14$) and 'Natural systems modification' ($n = 13$).

3.4 | Conservation actions

Of the species in threat categories of NT or higher, most (9) had conservation actions in place (Dataset S2). Only one species (*Ginkgo biloba* L.) did not have any listed conservation actions, according to the IUCN data; however, the narrative here notes that the species has been in cultivation for several centuries. Three species (*Picrasma excelsa* (Sw.) Planch., *Platycladus orientalis* (L.) Franco and *Saraca asoca* (Roxb.) W.J.de Wilde) were listed as 'unknown' in terms of conservation actions. For the nine species with conservation actions, presence in an ex situ collection, or presence in a Protected Area (PA), were the most frequently cited. For species with conservation actions in place, most authors of IUCN reports recommended further actions, often focussing on the role that enhanced governance, enforcement or legislative protections may play in conservation (see Supporting Information for details of conservation actions).

3.5 | Cites

Of the 298 species in this study, seven species were listed on CITES Appendix II: *Aloe africana* Mill., *Aloe ferox* Mill., *Aloe spicata* L.f., *Handroanthus impetiginosa* (Mart. ex DC.) Mattos, *Hydrastis canadensis* L., *Panax ginseng* C.A.Mey. and *Rhodiola rosea* L. Of those on CITES, three were also IUCN assessed—*Ha. impetiginosa*, *Hy. canadensis* and *R. rosea*.

3.6 | Existing conservation literature availability

The literature search yielded data about the number of publications referencing conservation for each species of the 298 in this study. Of these, many had few publications, with 24 species being associated with zero papers and 21 species associated with one paper published on conservation. Some species were represented by very high numbers of publications. Notable here is *Zea mays* L., which was represented by 4257 results. The reason for this comparatively high number of results is due to the context in which 'conservation' is used for this species—referring mainly in literature to water conservation in agriculture.

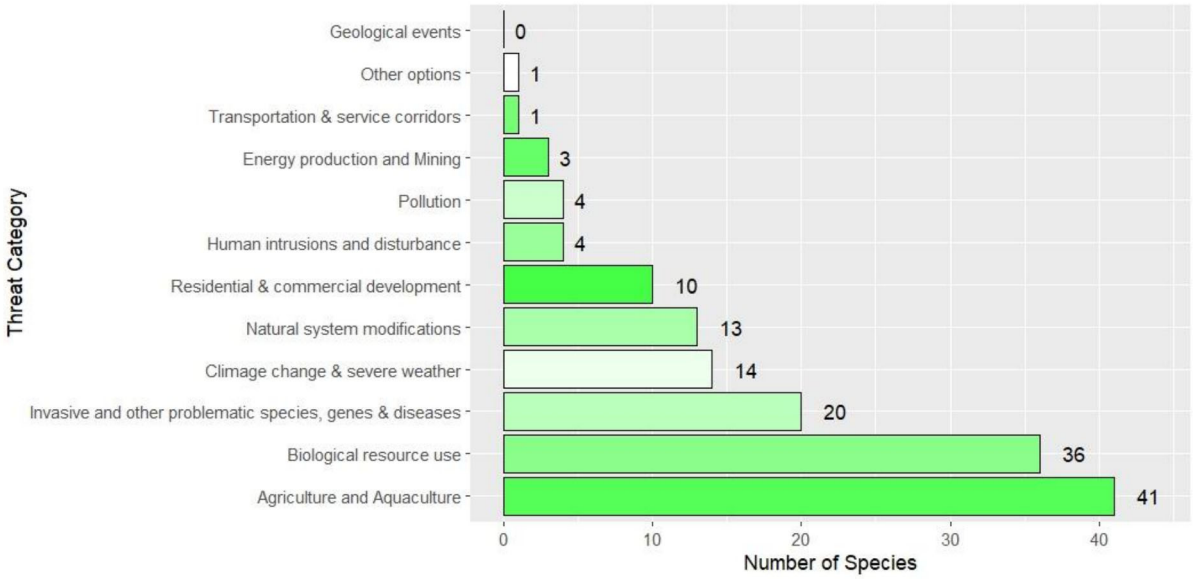

FIGURE 2 The number of species of medicinal plant available for sale in UK online retailers recorded in each of the IUCN threat categories.

3.7 | Alternative species and sustainable substitution

We were successfully able to suggest multiple species as possible sustainable alternatives for endangered species based on reference to common herbalism texts, although these suggestions are purely based on reported therapeutic effects and would require consultation with a herbalist prior to prescription (Table 1).

4 | DISCUSSION

Our results provide important insights into the sustainability of medicinal plants that are traded through online marketplaces in the United Kingdom. We demonstrate that a minority of species has been assessed for their conservation status and a small proportion of those assessed species are known to be of conservation concern. For those that have been assessed, agriculture and harvesting are the primary threats. Whilst some species have received a great deal of research and are subject to conservation measures, there are cases where medicinally important plants have been neglected by research and have no documented conservation strategy. Finally, a small number of medicinal plants used in the UK herbal medicine trade are CITES listed. Below, we explore how these findings can inform the future sustainability of the UK herbal medicine trade.

4.1 | IUCN assessment

We demonstrate that a minority of species has been assessed for their conservation status and a small proportion of those assessed species are known to be of conservation concern. We find that most species involved in the UK herbal medicine trade had no assessment from the IUCN, and some of those assessed were Data Deficient. Whilst Heywood (2017) suggested that plants in general have between 5% and 7% of an approximate number of total species assessed by the IUCN, and Howes et al. (2020) find that 21.0% of medicinal plants globally have been evaluated, this study found that 31.9% of plants sold in the UK herbal medicine trade have been evaluated. This higher figure than previously reported suggests that medicinal plants have better representation on the IUCN Red List than plants in general and that those plants used in well-established systems of trade may be a particular focus. Whist there is still data deficiency, some of this will be because species (such as *Taraxacum officinale* F. H. Wigg. and *Lamium album* L.) are seen as commonly occurring weeds in the United Kingdom and not in need of extinction risk assessment. However, some species, such as *Schizandra chinensis* (Turcz.) Baill. and *Harpagophytum procumbens* (Burch.) DC. ex Meisn., are internationally traded species which have no assessment yet, and other species may have been inaccurately assessed (Campbell, 2012). These latter species are the kind for which Red List assessments should be prioritised. Existing literature also suggests issues of misuse and inaccuracy in red listing (Campbell, 2012; Do et al., 2018; Tomasini, 2018). Since herbalists are engaging with these species regularly, including them in the Red Listing process could be of benefit in tackling these issues.

Whilst some species have received a great deal of research and are subject to conservation measures, there are cases where medicinally important plants have been neglected by research and have no documented conservation strategy. The literature search showed that species which are listed in categories of Near Threatened or higher on the IUCN Red List are not necessarily well represented in literature on conservation.

4.2 | Conservation actions and the 'knowing-doing gap'

The 'Knowing-doing Gap' is a term used (Cunningham et al., 2016) to describe the way in which, despite having knowledge of the threats to a species, there is often a gap observed between what we know and what is put into action. In many cases throughout this study, though conservation actions were in place for threatened species, these were simply the presence of the plant in ex situ collections in botanic gardens or having part of their range in a protected area (PA). Protected areas have been established as a strategy for the preservation of biodiversity and have been regarded as 'essential' in conserving it (Watson et al., 2016). Despite their widespread use, PAs face several challenges in various contexts, relating to climate change (Thomas et al., 2012), encroachment on indigenous lands (Lee, 2016), poaching (Massé, 2020) and gaps in biodiversity coverage (Le Saout et al., 2013). Other papers have highlighted that unsustainable gathering of non-timber forest products (NTFPs) does take place within PAs (McGraw et al., 2010).

4.3 | Threats to medicinal species conservation

For those that have been assessed, agriculture and harvesting are the primary threats. Given that threat code 5.2.1 was the largest single threat subcode (13.9%), the level of threat from overexploitation of medicinal plants is significant. Other literature (Shaltout & Bedair, 2022; Tali et al., 2015) covers the extent to which overexploitation plays a part in the decline of medicinal plant species, and this study echoes these findings. Overexploited threatened species are sold by suppliers to UK herbalists. The extent to which herbalists utilise these species and the popularity in practice cannot be ascertained, though, by this study, and understanding the attitudes of herbalists to overexploited species in their own practice represents an area of potential future study.

Other studies relating to medicinal plant overharvesting and conservation of other medicinal plant species have mentioned a diversity of threats, including agricultural threats such as livestock overgrazing and loss of habitat from encroaching agriculture (Khan et al., 2016; Tali et al., 2015). In addition, supporting the assertion by other authors that there are a variety of threats, other notable threat codes included

those covering invasive species and diseases ($n = 19$), a notable threat for particular species such as *Fraxinus excelsior* L. (Coker et al., 2019), and climate change ($n = 12$), which has been highlighted as having a number of different effects not only on conservation but also on the efficacy and local availability of medicinal species (Applequist et al., 2020).

Literature supports a broad nexus of threats affecting the efforts to conserve plant species in general, especially considering the ongoing biodiversity and climate crises (Nic Lughadha et al., 2020). In the case of medicinal plants and other NTFPs, biological resource use is often a part of the picture (Darbyshire et al., 2017), which is less common with less useful or economically beneficial taxa, so it plays a unique role for these specific plants that it would not otherwise have.

4.4 | Range of species and international trade

Many of the species used by medical herbalists in the United Kingdom are native or have been naturalised for so long that they are common in many areas of the country, and this is evident from the list of species generated to inform this study. These species can be cultivated easily in the United Kingdom or harvested from wild populations. Many other species on the list generated from online traders are plants which would be difficult, if not impossible, to cultivate in the United Kingdom (e.g. *Handroanthus impetiginosus*, *Harpogaphytum procumbens* and *Azadirachta indica* A.Juss.), and do not occur as either native or naturalised plants and so would be impossible for herbalists to access without international trade.

4.5 | CITES and red listing

Finally, a small number of medicinal plants used in the UK herbal medicine trade are CITES listed. Of the species listed in this study, only seven species are covered by CITES, and only two species are listed on both CITES and the IUCN Red List: *Handroanthus impetiginosus* (NT) and *H. canadensis* (VU). Of these two, *Ha. impetiginosus* is not on CITES because of medicinal use, but because of use for timber, and it is the logs and timbers whose trade is restricted. *Hy. canadensis* is the only plant listed in this study under the threat code 5.2.1 (relating to biological resource use of a plant species, where the species is the intended target) to also feature on CITES.

5 | CONCLUSION

Of those which have been assessed, most are Least Concern, though this does not preclude declining populations among these taxa. The threats to these assessed species are likewise varied, though the largest threats seem to come from agriculture, including grazing by livestock and encroachment of agricultural land, as well as biological resource use, specifically overexploitation of targeted species. For threatened species, conservation actions are often in place, particularly in the form of legal protections, use of protected areas and presence in ex situ collections such as botanic gardens, though further measures have been called for by IUCN assessors. Medicinal plants, which are sold by UK-based suppliers for use by medical herbalists come from a variety of sources. Many of these species are unevaluated by the IUCN Red List, and their extinction risk is unknown. CITES plays a role in limiting the export of some medicinal species; however, few species used by herbalists are listed on CITES. Careful sourcing of medicinal plants, utilising sustainability schemes such as FairWild where possible, would be beneficial for practitioners and suppliers alike in ensuring that the supply chain moves towards greater sustainability.

Whilst overexploited species are being sold by suppliers to UK herbalists, this gives little in the way of detail about what is going on in this part of the supply chain. We know that these species are used, but we do not know how popular these plants are with UK-based herbalists. There is likely to be some sale of these products to the market of medical herbalists because there would be no commercial incentive to offer them if this was not the case. The extent of popularity among herbalists remains unknown, and their attitudes to and knowledge of the various issues in the trade chains and how they affect purchasing choices remain unstudied. This is significant because it will give more data about how the UK market of medical herbalists interacts with these taxa, and what choices herbalists are making in relation to medicinal plant species, which are at risk of extinction. This could be investigated in future research through the use of market audits, or surveys of current WHM practitioners. Additionally, whilst we know the country of origin for threatened species from IUCN assessments, we do not have data that reflects whether these are areas of commercial exploitation or if there are merely countries within a species' extent of occupancy. This is another area where further work and more detailed data gathering would be beneficial to create a more nuanced picture.

AUTHOR CONTRIBUTIONS

Design of the research: Isabella Flowers, Christopher Hassall and Jon C. Lovett. *Performance of the research*: Isabella Flowers and Christopher Hassall. *Data analysis, collection or interpretation*: Isabella Flowers and Christopher Hassall. *Writing the manuscript*: Isabella Flowers, Christopher Hassall and Jon C. Lovett.

ACKNOWLEDGEMENTS

IF is supported by a Leverhulme Trust PhD studentship through the University of Leeds Extinction Studies Doctoral Training Programme.

CONFLICT OF INTEREST STATEMENT

I.F. is a qualified medical herbalist. The authors declare no other conflicts of interest

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the Supporting Information of this article.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Flowers, I., Lovett, J. C., & Hassall, C. (2026). Conservation status of species used in the UK herbal medicine industry. *Plants, People, Planet*, 1–10. https://doi.org/10.1002/ppp3.70154