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Beyond the Pharmacopoeia: To what extent is trade for “TCM” limited to official TCM taxa?

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ABSTRACT

The global trade in wildlife affects ~24% of terrestrial vertebrates, and demand for traditional medicinal materials, especially for traditional Chinese medicine, is a high profile driver. At present the relative extent to which demand for wild-animal-origin medicinal materials arises from different markets (OTCM, zhongyi and CMP, see companion paper) within “TCM” is unknown. We wished to populate the above categories, revealing the numbers and types of species involved, to provide the first consolidated description of the diversity of animal species potentially able to be used for different facets of “TCM”, an overview of their conservation status, and an initial estimate of the degree to which existing trade feeds into these different facets of “TCM”. We found that the number and diversity of wild-animal-origin medicinal materials listed as available for use in “TCM” differ markedly between the Pharmacopoeia of the People’s Republic of China (representing OTCM) - which currently lists 70 wild species - and the Medical Fauna of China, representing zhongyi - which lists 2275 animal species. Our findings indicated a substantial trade - both imports to, and exports from China - of “TCM” medicinal materials from wild animal taxa listed in the Medical Fauna of China but not listed in the Pharmacopoeia, and also of species for which there is no prior textual support, including species potentially being traded as substitutes for listed species. We recommend working with TCM practitioners to enact the targeted substitution of sustainably sourced plant-based medicinal materials for the currently-used animal-origin materials. We suggest that this should initially target the 70 OTCM species, as well as inferred OTCM species and selected genera likely to be imported as substitutes, to strike a balance between keeping the focus of the required research narrow, while targeting the taxa most likely to be traded.

1. Introduction

The global trade in wildlife affects ~24% of all extant terrestrial vertebrate species on Earth (Scheffers et al., 2019), and is known to

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be a major driver of species extinctions and animal welfare abuses (e.g. Baker et al., 2013; Challender et al., 2015; Dutton et al., 2013; Fernandes-Ferreira et al., 2012; Grieser-Johns and Thomson, 2005; Pires and Moreto, 2011; Sodhi et al., 2004). The global trade serves a number of sources of consumer demand, among which a high profile driver is the use of plants and animals for traditional medicines (Baker et al., 2013). Among traditional medicines, “Traditional Chinese Medicine” (“TCM”) represents a suite of hugely valuable economic markets, predicted to reach 5 trillion yuan (approximately 1 trillion USD) by 2030 (Market Insider, 2016), with the accompanying concern that this will increase already severe pressures on wildlife (e.g. Hinsley et al., 2020).

The negative impacts for species conservation, and individual animals’ welfare, of species use in “TCM” are detailed in a large and growing literature that links demand for traditional medicinal and healthcare ingredients with global declines in species abundance (e.g. Pantel and Chin, 2009; Challender, 2011; Challender et al., 2014; Nijman et al., 2016; Nowell and Xu, 2007; Goodrich et al., 2015; Davis et al., 2019; McClenachan et al., 2016), and with the capture, transport, captive breeding, slaughter and sale of wild animals under conditions that give rise to negative animal welfare impacts (Fuller et al., 2018; Green et al., 2020). To address conservation and animal welfare issues driven by demand, solutions increasingly incorporate marketing campaigns aimed at influencing the purchasing decisions of consumers, and / or testing whether consumers’ attitudes to the consumption of specific products are amenable to being altered (e.g. Moorhouse et al., 2020; Dalberg, 2012; Courchamp et al., 2006; Veríssimo and Wan, 2019). The ultimate goal of such campaigns is to lower demand for products and materials that are damaging to wildlife, and / or to promote those that are not (e.g. Moorhouse, 2020; Macdonald et al., 2021). Achieving these goals depends critically upon understanding the nature of the target audience, especially with respect to their receptiveness to different approaches and messaging (e.g. Moorhouse et al., 2017, 2020; Veríssimo and Wan, 2019; Olmedo, Sharif and Milner-Gulland, 2018; Veríssimo et al., 2018), because different segments of consumer populations are likely to respond differently to different types of message (Moorhouse et al., 2020; Veríssimo and Wan, 2019; Olmedo, Sharif and Milner-Gulland, 2018). Moorhouse et al. (in press) argue that with respect to animal-origin medicinal materials, what species conservation and animal welfare professional communities term Traditional Chinese Medicine (or “TCM”) in fact comprises several distinct facets. Official TCM (OTCM) comprises traditional Chinese medicine, particularly as practised by doctors and professionals in hospitals and large clinics. The animal-origin medicinal materials used for OTCM are typically restricted to those listed in the Pharmacopoeia of the People’s Republic of China (hereafter “Pharmacopoeia”).

These represent a curated subset (amounting to 70 species, see below) of the medicinal materials used in the broad medical field of Chinese medicine, here termed *zhongyi*, that have a history of use that is recorded in pre-twentieth century texts (folk practice descriptions and scholarly treatises, which list >2200 such species, see below) (see Moorhouse et al., in press). CMP (Chinese medicine and pharmaco-therapy) represents a neoliberal and biotechnologised extension to, and some departure from both TCM as it was originally conceived in the 1950s, and *zhongyi*. Importantly, it incorporates medicinal materials that may be biotechnologised, novel, and which have little or no prior textual support, and/or the levels of consumption of which are not driven primarily by practitioners diagnosis and treatment, but rather by consumer demands that arise from outside of the doctor-patient relationship (e.g. through social media advertising and self-diagnosis) - notwithstanding that modern OTCM has also now incorporates some CMP elements and practices (Moorhouse et al., in press). Please note that while we here focus on trade to meet demand deriving from different elements of “TCM” (OTCM, *zhongyi* and CMP) in the People’s Republic of China (PRC), “TCM” is consumed in many other countries to which many of our findings will equally apply (e.g. Hsu, 2009).

At present it is unknown to what extent the international trade in wildlife is driven by the need to supply medicinal materials for the animal-origin species within OTCM, as opposed to those used in *zhongyi*, or CMP. Our goals in this paper are threefold. First we wish to derive lists of wild animal species used for OTCM and *zhongyi*, as presented in the appropriate texts, and to ascertain the conservation status and legal status (via any listing on the Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES - or the People’s Republic of China’s List of Fauna Under Special State Protection - LFSSP) of the species on those lists, and to establish whether the species are found in (and are therefore able to be sourced from) the PRC. Second we wish to identify, from the CITES trade database, imports and exports of animal species to and from the PRC that represent trade intended to supply “TCM” medicinal materials. Thirdly we wish, where possible, to distinguish whether a given trade is intended to supply species for use in OTCM, *zhongyi* or CMP. Doing so will provide an initial description of the diversity of animal species currently potentially able to be used for different facets of “TCM”, an overview of their conservation status, and an initial estimate of the degree to which existing trade feeds into different facets within “TCM”.

2. Methods

2.1. Assigning animal-origin medicinal materials to categories of “TCM”

We wished to reveal the how animal-origin medicinal materials available for use differed between different facets of “TCM”. To achieve this we derived lists of animal species recorded in the texts describing medicinal materials for OTCM and *zhongyi*. We assume that species unlisted in either, but still traded for “TCM” constitute some degree of neologism, and therefore represent a facet of CMP.

We populated the list of OTCM medicinal materials from the Pharmacopoeia, which is formulated and promulgated in accordance with Law of the People’s Republic of China on Pharmaceutical Administration, and belongs to the PRCs most authoritative national drug standard system (National Medical Products Administration, 2019). The Pharmacopoeia lists two types of medicinal materials: traditional Chinese medicines (plant-origin and animal-origin medicinal materials), and patent medicines (chemical medicines and biological products that may also include animal-origin materials).

At the time of writing there have been ten updates to the original 1953 edition of the Pharmacopoeia, of which the latest was a revision in June 2020, implemented on December 30, 2020. Our initial list for analysis was compiled from the 10th edition of the

Pharmacopoeia (CPC, 2015) and then updated during writing to reflect changes made in the 2020 edition. For a given medicinal material the Pharmacopoeia provides the Chinese name and English name of the medicinal material, its Latin binomial, the medicinal animal (i.e. the common name of the taxon in Chinese) and medicinal part (of that taxon – e.g. “gall bladder” or “whole skin”). To these we added the English common name of the taxon. For OTCM prescriptions we collated animal medicinal materials, medicinal part and dosage.

The list of zhongyi medicinal materials (i.e. those available for use in the broad medical field of zhongyi, which has a long, still ongoing history incorporating multiple sources of tradition and knowledge, from scholarly texts to folk medicine) was derived from the Second Edition of the Medicinal Fauna of China (hereafter MFC; Li et al., 2013). The MFC describes animal-origin medicinal materials recorded in ancient Chinese herbal books, but also medicinal species newly introduced from folk and ethnic minorities, and is considered to be the most complete professional reference book collating information on medicinal animals (Li et al., 2013). For each medicinal material we collected the phylum, class, order, family, and species of the animal from which it is derived, as well as its Chinese name, common name, medicinal part and whether it is currently captive bred. The taxonomic classifications provided in the MFC were cross-checked with the following reference sources: for mammals, Chinas Mammal Diversity and Geographic Distribution (Jiang et al., 2015); for birds, A Checklist on the Classification and Distribution of the Birds of China (Third Edition) (Zheng, 2017) and BirdLife International Data Zone (<http://datazone.birdlife.org/home>); for reptiles, A revised taxonomy for Chinese reptiles (Cai et al., 2015) and The Reptile Database (<http://www.reptile-database.org/>); for amphibians, Amphibian Species of the World: an Online Reference (<https://amphibiansoftheworld.amnh.org/index.php>) and World Amphibian Database (<https://amphibiaweb.org/>); for fishes FishBase (<https://www.fishbase.se/search.php>); for invertebrates the Global Biodiversity Information Facility (GBIF) (<https://www.gbif.org/>).

For both the OTCM and zhongyi lists, we collated information about whether each taxon was endemic to China, its level of conservation endangerment (domestic and international), as well as its level of protection (domestic and international). The former information was derived from the China Species Red List (Vol. I Red List) (Wang and Xie, 2004), China Species Red List (Vol. III Invertebrates) (Wang and Xie, 2005), Red List of Chinas Vertebrates (Jiang et al., 2016) and IUCN Red List of Threatened Species (valid from March 2020) (<https://www.iucnredlist.org/>). The latter was derived from the LFSSP, 1989/ 2021 (<http://www.forestry.gov.cn/main/3954/content-1063883.html>) and CITES (valid from January 2020) (<https://www.speciesplus.net/>).

2.2. Assessing the scale of imports to, and exports from, China of animal species for use in traditional Chinese medicine

We wished to derive lists of CITES listed taxa imported to, and exported from, China for use as “TCM”. A key difficulty in doing so lay in the quality of evidence required to substantiate the underlying purpose of a given trade of a given species (i.e. to determine whether the trade was intended to supply a “TCM” medicinal material, as opposed to representing any different purpose). Initially we downloaded all import and export records from the CITES trade database (<https://trade.cites.org/>) for the period 2008–2018, inclusive. We then iteratively filtered these as described below to include only those likely to have been traded for traditional Chinese medicinal use. CITES database terms indicates the form (e.g. skins, eggs, bones, bodies, specimens), and source (e.g. wild, captive-bred, confiscations) of any given record, which depending on the wider context may constitute evidence for use for “TCM”. Given that many species are potentially able to be used as medicinal materials (see Results), but that a large number of other potential commercial uses also exist for a given taxon, our approach was to derive a conservative list of records that included only those for which a high degree of evidence existed that a given trade was intended to supply “TCM” medicinal materials. To do so we employed separate, tiered systems to filter export and import records.

2.3. List of exports

To establish our initial candidate list of export records we retained only records with the following trade terms, which potentially indicate use as medicinal materials: “medicine”, “specimen”, “derivatives”, “bodies”, “extract”, “powder”, “musk”, “oil”, “bones”, “horn”, “scales”, and “gall/gall bladder”. A high likelihood of a given taxon being exported as medicinal “TCM” was assigned if the export term was “medicine”, or if the taxon was present on our lists of zhongyi or OTCM (see Supplemental Tables 1, 2) and the export term indicated a form appropriate for the derived medicinal material. Records were excluded if the taxon had a known use in Western medicine (derivatives and extracts from macaque monkeys, for example, were excluded on this basis; Eudey, 2008).

To account for potential novel medicinal uses of taxa (i.e. taxa not included in existing lists of zhongyi or OTCM, but which were nevertheless exported as medicinal materials for “TCM”), we retained records where the export term was “medicine”, where there was no known Western medicinal use, but where the taxon was not listed in the Pharmacopoeia or MFC. Species traded for traditional medicine, but unlisted in these texts are likely to represent some facet of CMP, potentially in the form of species substitutions for other taxa listed in these texts.

2.4. List of imports

To establish our initial candidate list of import records we removed any for which the trade term indicated that the reason was unlikely to be medicinal. Records with the following terms were removed: carvings / bone carvings (for Anthozoa, Bivalvia, Mammalia, Reptilia), tusks, ivory carvings and pieces (Elephantidae), jewellery (Anthozoa, Aves, Mammalia, Reptilia), caviar (Actinopteri), cloth (Mammalia), eggs (Actinopteri), fur products (Mammalia), garments (Aves, Mammalia, Reptilia), leather products (Actinopteri, Mammalia, Reptilia), rugs (Mammalia), shoes, skin/skin pieces (Reptilia), unspecified. Retained records were then filtered by the taxa

Table 1

Species exported from China between 2008 and 2018 with sufficient evidence to link the export purpose to use in traditional medicine. Shown is a summary of the trade terms associated with the exports and the volume of exports of species listed in the Pharmacopoeia (OTCM), MFC (zhongyi T.P. Moorhouse *et al.*

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species), and unlisted species. Data source: CITES trade database. UU = units unknown.

Species exported	Medicine	Musk	Derivative	Bodies	Extract	Powder	Bone pieces	Bones	Horn	Gall	Gall bladder	Scales	Oil
Official TCM (OTCM, 9 taxa)													
Reeves turtle (<i>M. reevesii</i>)	17,178 kg		1592 kg			23 kg							
Saiga antelope (<i>S. tatarica</i>)	1415 kg								1699 kg				
Common seahorse (<i>H. kuda</i>)	64.7 kg		322 kg	614 kg									
Flat-faced seahorse (<i>H. trimaculatus</i>)	105.5 kg		56.7 kg	146 kg									
Great seahorse (<i>H. kelloggi</i>)	73.7 kg			105 kg									
Leopard (<i>P. pardus</i>)	1.8 kg		17.1 kg				60	40					
Spiny seahorse (<i>H. hirtix</i>)			48.2 kg	28.8 kg									
Siberian musk deer (<i>M. moschiferus</i>)	39.3 kg	13.8 kg	5.9 kg			0.9 kg							
Red deer (<i>C. elaphus</i>)	4.95 kg												
Inferred Official TCM (OTCM, 6 taxa)													
Asian black bear (<i>U. thibetanus</i>)	0.02 kg, 392UU		0.098 kg, 0.8 L, 4,717UU			4,717UU				1.9 kg, 10 ml			
Pangolin species (<i>Manis spp.</i>)	457UU		2.1 kg, 2,369UU			0.014 kg						0.45 kg, 381UU	
Bear (<i>Ursus spp.</i>)	9.6 kg, 105 ml, 1,943UU		1.4 kg, 1,932UU		200 ml					48 g, 22UU	1		
Brown bear (<i>U. arctos</i>)	118UU		0.04 kg, 67UU		15 ml					0.01 kg	2		
Sun bear (<i>H. malayanus</i>)	200UU		0.4 kg										
Chinese pangolin (<i>M. pentadactyla</i>)	11.4 kg											12UU	
Zhongyi species (10 taxa)													
Seahorse (<i>Hippocampus spp.</i>)	322 kg, 125 ml, 20,881UU		0.5 kg	222 kg, 13,172UU	3.5 kg								
Musk deer (<i>Moschus spp.</i>)	82.8 kg, 4,610UU, 125 ml	65 kg, 40.8UU	13.4 kg, 350 ml, 14,050UU										12 g
Tortoises (Testudinidae spp.)	3264 kg, 1,168UU		82.8 kg, 25 ml, 8,601UU			0.53 kg							
<i>Panthera</i> spp.	2,664UU, 236 ml		3,900UU, 322.1 kg				40UU, 60UU						
Asian box turtle (<i>Cuora</i> spp.)	3UU		3 kg, 1,482UU		2UU	0.2 kg							
Tiger (<i>P. tigris</i>)	0.4 kg, 0.2 L, 1,372UU												
Marine turtles (<i>Cheloniidae</i> spp.)	37UU		1.04 kg, 618UU			618UU							
Chinese stripe neck turtle (<i>M. sinensis</i>)						179 kg							
Tortoises (<i>Indotestudo</i> spp.)	48UU		3UU										
Chinese box turtle (<i>C. trifasciata</i>)	50UU												
Unlisted (7 taxa)													
Siamese crocodile (<i>Crocodylus siamensis</i>)	411,600UU		130,000UU, 127 kg		1 L								
Oldams leaf turtle (<i>Cyclemys oldhamii</i>)	1,200UU												
Great Asian pond turtle (<i>Heosemys grandis</i>)	480 kg		174UU										

(continued on next page)

Table 1 (continued)

Species exported	Medicine	Musk	Derivative	Bodies	Extract	Powder	Bone pieces	Bones	Horn	Gall	Gall bladder	Scales	Oil
Rhinoceros (Rhinocerotidae spp.)	59UU		201UU										
Big belly seahorse (<i>H. abdominalis</i>)			3 kg, 30 ml	202UU									
Hunan soft shelled turtle (<i>Pelodiscus axenaria</i>)	40UU		5UU			100 bottles							
Hedgehog seahorse (<i>H. spinosissimus</i>)	90.5 kg			50 kg, 52UU									

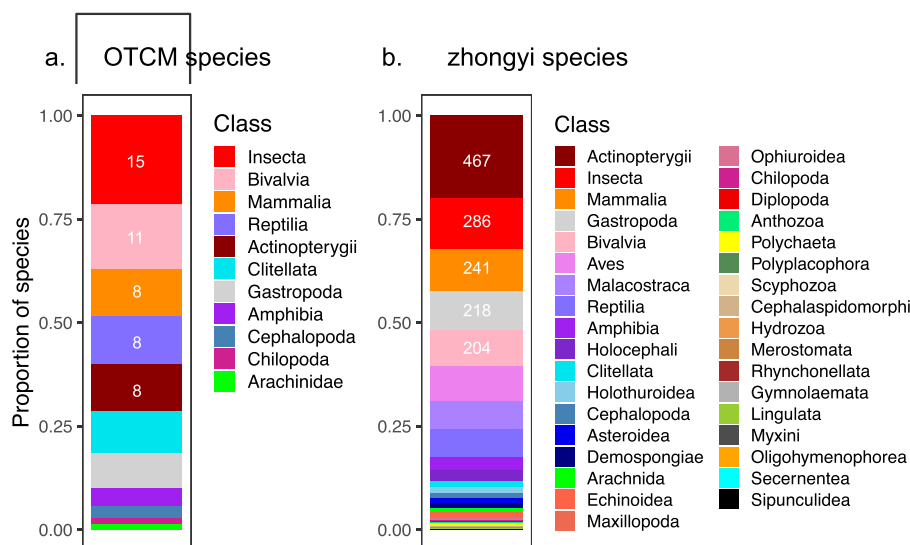


Fig. 1. Diversity of classes of animals on a) the OTCM list (2020 Edition) and b) the list of zhongyi species. Numbers show the number of species within each class of animal. See [Suppl. Material 1](#) for complete list.

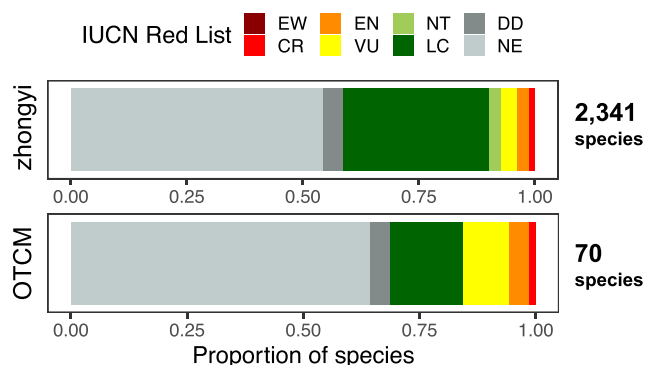


Fig. 2. Conservation status of the species on the OTCM list and list of zhongyi species, according to the IUCN Red List. Data shows the proportion of species under each Red List category. DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered; NE, not evaluated.

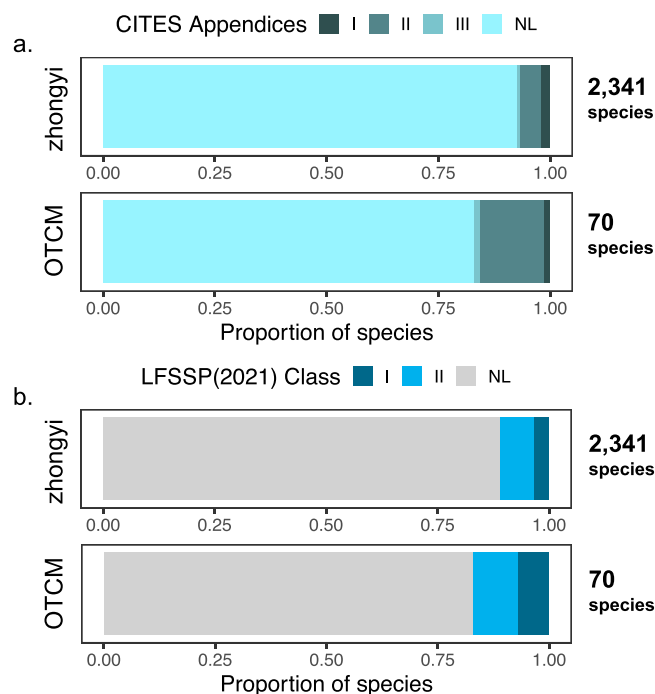


Fig. 3. Proportion of species on the OTCM (2020) list and list of zhongyi species, recorded a) in the CITES appendices (I, II, III) and b) in the LFSSP 2021 appendices (Class I, II). NL = not listed.

present on our lists of potential OTCM and zhongyi medicinal materials (see [Supplemental Tables 1, 2](#)): if a given import was not associated with a species listed as used in zhongyi or OTCM in [Supplemental Tables 1 and 2](#) it was excluded. Given that evidence for species substitutions arose from the export data (see Results) we made exceptions to these exclusions if a given record plausibly represented a species substitution – i.e. a given species was not listed in the Pharmacopoeia or MFC but belonged to the same genus as a species that was listed. This long list was then refined by contrasting the import terms (i.e. the form in which the species was recorded as being imported, e.g. bodies or derivatives) for each taxon against the medicinal part used in TCM (see [Table 1](#)) and against other known commercial uses of the species. We ascribed a high likelihood of a taxon being imported for traditional medicinal use when “medicine” was specified as the import term, or where the import term identified the correct medicinal part for the OTCM or zhongyi usage, and where no alternative commercial uses for that part were discovered.

2.5. Convictions for wildlife crime within the PRC, related to supply of medicinal materials for TCM

As far as possible we wished to ground the above trade data in evidence that a given species was traded for the purpose of supplying medicinal materials for “TCM”. To this end, and following methods reported in [Shao et al. \(2021\)](#), we accessed depositions of court judgements within the PRC, archived at China Judgements Online (<https://wenshu.court.gov.cn/>) between 2014 and 2018, to determine which species were represented as being illegally traded for medicinal use, and to assign these species to their respective facets of “TCM”.

3. Results

3.1. Animal species listed in the Pharmacopoeia

The 2015 revision of the Pharmacopoeia listed 71 wild animal species used in OTCM, representing 11 classes, 25 orders, and 34 families ([Supplementary Table 1](#)). In 2020 this list was reduced to 70 species because *Manis pentadactyla* (Chinese pangolins) were removed. The most represented class was insects (15 species; 21.4%), followed by bivalves (11 species; 15.7%), reptiles (8 species; 11.4%), mammals (8 species; 11.4%), and Actinopterygii (ray-finned fishes, including pipefishes and seahorses from the order Synbranchiformes, which contained all eight of the listed species; 11.4%) ([Fig. 1](#)).

In addition to the 70 species explicitly listed in 2020, there were at least seven species the use of which was able to be inferred from their listing as patent ingredients included in the medicinal formulas, in both 2015 and 2020. For example, “bear bile” is included as an ingredient in thirteen preparations, which implies the use of one of three species known to be used for this purpose: *Ursus thibetanus* (IUCN Red List Vulnerable), *Ursus arctos* (Least Concern), *Helarctos malayanus* (Vulnerable). Similarly, three leopard species (Clouded

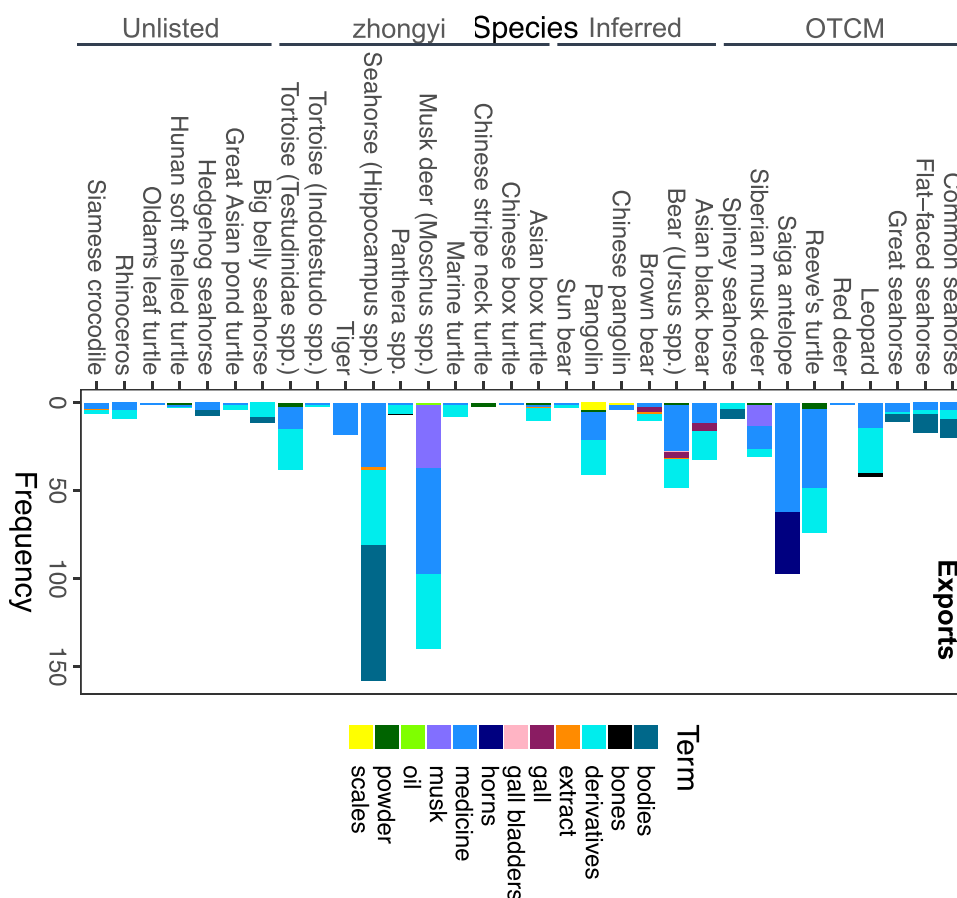


Fig. 4. Species exported from China between 2008 and 2018 with sufficient evidence to link the export to use for “TCM”. Shown is the number of records of exports from China between 2008 and 2018 for each species (frequency) broken down by CITES export term (including only those terms relevant to traditional medicine for each species).

leopard, *Neofelis nebulosa*, Vulnerable; Leopard, *Panthera pardus*, Near Threatened; Snow leopard, *Uncia uncia*, Endangered) are inferred to be OTCM, despite not being explicitly listed, because “leopard bone” is a patent ingredient in three preparations in the 2015 and 2020 revisions of the Pharmacopoeia. In addition, in 2020, despite the Critically Endangered Chinese pangolin *Manis pentadactyla* being removed from the explicit official list, the use of pangolins (*Manis* spp.) was still able to be inferred, because “pangolin” was retained as a patent medicinal ingredient in eight preparations in the 2020 Pharmacopoeia (Supplemental Table 1). We deal with these inferred species separately when examining import and export records.

Sixty five (92.3%) species on the OTCM list have extant wild Chinese populations, and one of these is endemic to China (the Blister beetle, *Mylabris cichorii*). The five species that do not have extant wild populations in China are the Saiga antelope (*Saiga tatarica*, extinct in the wild in China), red deer (*Cervus elaphus*), sheeps ear abalone (*Haliotis ovina*), blacklip abalone (*Haliotis ruber*), and one species of bee (*Apis mellifera*).

Eleven (15%) species on the OTCM list are threatened with extinction according to the IUCN Red List: one is Critically Endangered (Saiga antelope), three are Endangered (forest musk deer, *Moschus berezovskii*; alpine musk deer, *Moschus sifanicus*; Reeves turtle, *Mauremys reevesii*), and seven are Vulnerable. An additional eleven are considered Least Concern and three are Data Deficient. For the remaining two thirds of listed species ($n = 45$, 64.3%) the conservation status has not been evaluated by the IUCN (Fig. 2). Ten vertebrate species on the OTCM list are listed on the Red List of China’s Vertebrates (Jiang et al., 2016) of which three are Critically Endangered (Tokay gecko, *Gecko gecko*; forest musk deer; Siberian musk deer, *Moschus moschiferus*), three are Endangered (king ratsnake, *Elaphe carinata*; Chinese moccasin, *Agkistrodon acutus*, Reeves turtle), two are Least Concern and one is extinct in the wild (Saiga antelope) (Supplementary Table 1).

Twelve (17.1%) species on the OTCM list are listed in CITES appendices: ten (14.3%) on Appendix II, 1 (1.4%) on Appendix III and one (red deer) on Appendix I/II/III (Fig. 3). The LFSSP 2021 lists 12 of the OTCM species. Of these six are afforded a higher level of protection within China than internationally (Reeves turtle, LFSSP 2021 Appendix II, compared to CITES Appendix III; Saiga antelope, forest musk deer, alpine musk deer and Siberian musk deer, all LFSSP 2021 Appendix I compared to CITES Appendix II; Sika deer, *Cervus nippon*, Appendix I of the LFSSP 2021 and unlisted by CITES). Three species on the OTCM list were uplisted from LFSSP

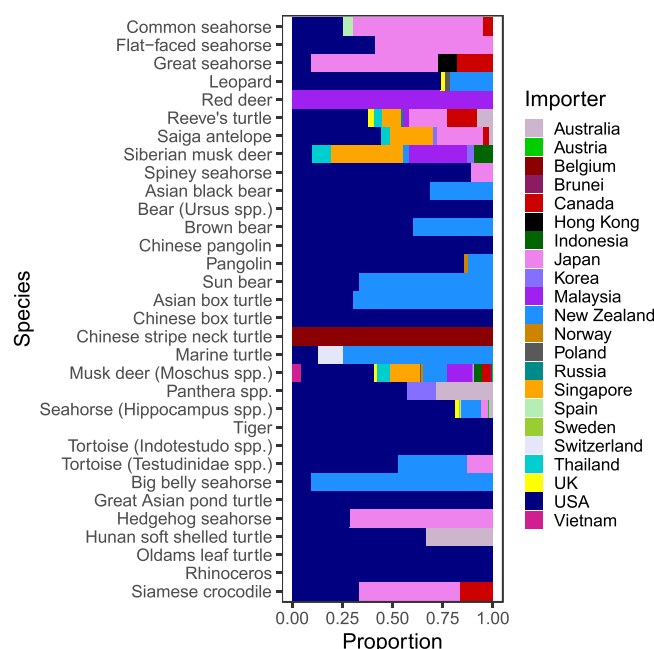


Fig. 5. Species exported from China between 2008 and 2018 with sufficient evidence to link the export to use for “TCM”. Shown is the importer countries of the exports for each species (including only exports of terms relevant to traditional medicine for each species).

Appendix II to Appendix I in 2021 (forest musk deer, Siberian musk deer and alpine musk deer), and six were added to LFSSP Appendix II (Reeves turtle and five species of seahorse, *Hippocampus* sp.). One species (red deer) was removed from the LFSSP appendices in 2021 (see [Supplementary Table 1](#)).

3.2. Animal species listed in the Medical Fauna of China (MFC)

The MFC lists 2275 animal species and 66 sub-species, representing 35 different taxonomic classes, 156 orders and 448 families. Actinopterygii is the most represented class (467 species; 19.9%), followed by insects (286 species; 12.2%), mammals (241 species; 10.3%), gastropods (218 species; 9.3%), bivalves (204 species; 8.7%) and birds (195 species; 8.3%) ([Fig. 1](#)). Approximately half the species listed were vertebrates (1199 species; 51.2%), belonging to eight different taxonomic classes, the most represented being Actinopterygii, followed by mammals, reptiles, birds and amphibians.

Of the 1199 vertebrate species on this list of zhongyi species, 96.6% (1159) have extant populations in the wild in China, of which 138 (11.9%) are endemic. And of the 1142 invertebrate species on the zhongyi list, at least 75% (856) have extant wild populations in China, of which 21 (2.5%) are endemic, and at least 14.4% (165) of invertebrate species are not present in the wild in China.

A total of 170 (7.3%) species is internationally threatened with extinction: 79 (3.4%) are Vulnerable, 62 (2.6%) Endangered, 30 (1.3%) Critically Endangered, and one species is extinct in the wild (Père David's Deer, *Elaphurus davidianus*). Approximately a third of species (31.4%; $n = 736$) were Least Concern, 2.6% ($n = 61$) are Near Threatened, and 4.6% ($n = 102$) are Data Deficient. The conservation status of greater than half of the species (1272; 54.3%) has not yet been evaluated by the IUCN ([Fig. 2](#)). According to Chinas Red List, 278 (11.9%) species on the zhongyi list are threatened with extinction in China, 93 (3.4%) are Vulnerable, 132 (5.6%) Endangered, 53 (2.3%) Critically Endangered, and one (white stork, *Ardea Ciconia*) is regionally extinct ([Suppl. Material 1](#)).

Of the zhongyi species 173 (~7%) are listed on CITES appendices: 47 (2%) on Appendix I, 113 (4.8%) on Appendix II and 13 (0.6%) on Appendix III ([Fig. 3](#)). LFSSP (2021) appendices list 272 (11.2%) of the species: 83 (3.5%) on Appendix I and 179 (7.6%) on Appendix II ([Fig. 3](#)). The 2021 revision of the LFSSP represents an increase from 149 of these species (6.4%) listed in the 1989 LFSSP.

3.3. Exports of CITES-listed animal species representing trade in traditional Chinese medicine

Between 2008 and 2018, a total of 8239 records of exports from China was reported to CITES, involving 477 different taxa, with 396 animals identified to species level. After initial exclusions the long list of exported taxa potentially involved in the trade in TCM medicines and medicinal materials comprised 127 taxa. Of these 15 were taxa listed in the 2020 Pharmacopoeia (13 identified to species), 40 were listed in the MFC (29 identified to species) and 72 (48 identified to species) were not listed in either text.

Sufficient evidence existed to link the export purpose to use as “TCM” for 32 of the above 127 taxa ([Table 1](#); [Fig. 4](#)). Of these nine were species listed in the 2020 Pharmacopoeia. Six taxa were not explicitly listed in the 2020 Pharmacopoeia, but their products were listed as constituents of patent medicines, and so their use for OTCM can be inferred. Ten taxa were either able to be directly identified as listed in the MFC, or belonged to a higher classification containing species listed in the MFC. Seven taxa were unlisted in either text

Table 2

Species imported to China between 2008 and 2018 with sufficient evidence to link the import to use in “TCM”. Shown is a summary of the trade terms associated with the imports recorded and volume of import. Data source: CITES trade database. UU = units unknown.

Species imported	Medicine	Derivative	Specimen	Bodies	Extract	Musk	Bones	Horn	Skeleton	Powder	Skull	Gallbladder	Gall	Live	Oil	Swimbladder	Meat	Shell	Scales	Skin
OTCM (6 taxa)																				
Tokay gecko (<i>Gekko gekko</i>)				1,510,739																
Flat-faced seahorse (<i>H. trimaculatus</i>)				1727 kg, 780 UU																
Common seahorse (<i>H. kuda</i>)				1312 kg, 880 UU																
Great seahorse (<i>H. kelloggi</i>)				249 kg, 1 UU																
Saiga antelope (<i>S. tatarica</i>)	1 UU	4.1 kg						6.9 kg		2.65 kg	220									
Siberian musk deer (<i>M. moschiferus</i>)						137 kg														
Inferred OTCM (2 taxa)																				
Brown bear (<i>U. arctos</i>)	250 kg											15	3.1 kg	72						
Asian black bear (<i>U. thibetanus</i>)													3 UU	15						
Zhongyi species (2 taxa)																				
Burmese python (<i>P. bivittatus</i>)					1500 kg							30 kg			13,250 kg					
Tiger (<i>P. tigris</i>)	1 UU			56			1 UU							101						
Unlisted (Potential species substitution for OTCM – 20 taxa)																				
Giant pangolin (<i>Manis gigantea</i>)																		7245 kg	3000 kg	
Tree pangolin (<i>Manis tricuspis</i>)														210				7452 kg		
Sunda pangolin (<i>Manis javanica</i>)																		2800 kg		
Hedgehog seahorse (<i>Hippocampus spinosissimus</i>)				1752 kg + 873 UU																
West African seahorse (<i>Hippocampus algiricus</i>)				380.3 kg + 33 UU					55 kg + 1,316 UU											
Tiger tail seahorse (<i>Hippocampus comes</i>)														1480						
Pangolin (<i>Manis</i> spp.)																		1250 kg		
Big-belly seahorse (<i>Hippocampus abdominalis</i>)				6.5 kg + 50 UU										430						
Long-snouted seahorse (<i>Hippocampus reidi</i>)														256						

(continued on next page)

Table 2 (continued)

Species/imported	Medicine	Derivative	Specimen	Bodies	Extract	Musk	Bones	Horn	Skeleton	Powder	Skull	Gallbladder	Gall	Live	Oil	Swimbladder	Meat	Shell Scales	Skin
Lion (<i>Panthera leo</i>)				166UU			52UU		4UU		22								
Long-tailed pangolin (<i>Manis tetradactyla</i>)														200				1 kg	
Pacific seahorse (<i>Hippocampus ingens</i>)														60					
Slender seahorse (<i>Hippocampus guttulatus</i>)														60					
Barbours seahorse (<i>Hippocampus barbouri</i>)														50					
Seahorse (<i>Hippocampus</i> spp.)				50UU															
Knysna seahorse (<i>Hippocampus capensis</i>)														30					
Mountain zebra (<i>Equus zebra</i>)																			19UU
Musk deer (<i>Moschus</i> spp.)	8UU					0.95 kg													
Onager (<i>Equus hemionus</i>)	8UU																		
Temminicks pangolin (<i>Manis temminckii</i>)				2UU														1 kg	
Unlisted (potential species substitutions for zhongyi taxa- 16 taxa)																			
Russells viper (<i>Daboia russelii</i>)		201,550UU	760 ml + 40,439UU		8,692UU														
Amboina box turtle (<i>Cuora amboinensis</i>)														188,978					
Hermanns tortoise (<i>Testudo hermanni</i>)														45,372					
Reticulated python (<i>Python reticulatus</i>)		30 kg	9,990UU								60UU	44 kg + 60UU		1236			27,650 kg + 25,015UU		
Greek tortoise (<i>Testudo graeca</i>)														17,224					
Marginated tortoise (<i>Testudo marginata</i>)														7976					
Checkered keelback (<i>Xenochrophis piscator</i>)																	300UU		5,105UU
Asian forest tortoise (<i>Manouria emys</i>)														5111					
Chinese cobra (<i>Naja atra</i>)		10 mg												3400					
Keeled box turtle (<i>Cuora mouhotii</i>)														460					
Gulf sturgeon (<i>Acipenser oxyrinchus</i>)																			

(continued on next page)

Table 2 (continued)

Species/imported	Medicine	Derivative	Specimen	Bodies	Extract	Musk	Bones	Horn	Skeleton	Powder	Skull	Gallbladder	Gall	Live	Oil	Swimbladder	Meat	Shell Scales	Skin
McCords box turtle (<i>Cuora mccordi</i>)														71		1UU + 135 kg			
Monocled cobra (<i>Naja kaouthia</i>)		41 ml																	
Yellow-headed box turtle (<i>Cuora aurocapitata</i>)														7					
Indochinese box turtle (<i>Cuora galbinifrons</i>)														3					
Pans box turtle (<i>Cuora pani</i>)														2					
Unlisted (4 taxa)																			
Rhinoceros (<i>Rhinocerotidae</i> spp.)									21UU										
Javan rhinoceros (<i>Rhinoceros sondaicus</i>)									4UU										
Indian rhinoceros (<i>Rhinoceros unicornis</i>)									3UU										
Rhinoceros (<i>Rhinoceros</i> spp.)									2UU										

(Table 1; Fig. 4).

The nine species listed in the Pharmacopoeia were *Cervus elaphus* (4.95 kg of medicine exported), *Hippocampus histrix* (48.16 kg derivatives; 28.75 kg bodies), *Hippocampus kelloggi* (73.71 kg medicine; 105.44 kg bodies), *Hippocampus kuda* (64.66 kg medicine; 322.08 kg derivatives, 613.95 kg bodies), *Hippocampus trimaculatus* (105.51 kg medicine; 56.68 kg derivatives; 145.65 kg bodies), *Mauremys reevesii* (17,177.51 kg medicine; 1592.98 kg derivatives; 23 kg powder), *Moschus moschiferus* (39.25 kg medicine; 5.85 kg derivatives; 0.9 kg powder; 13.77 kg musk), *Panthera pardus* (leopard: 1.83 kg medicine; 17.09 derivatives; 40 bones; 60 bone pieces), *Saiga tatarica* (1414.95 kg medicine; 1699.28 kg horns) (Table 1).

Four of the six inferred OTCM taxa (i.e. those listed as patent ingredients) were resolved to species: *Manis pentadactyla* (11.44 kg medicine, 12 units unknown, hereafter "UU", scales); *Helarctos malayanus* (sun bear: 200 UU medicine; 0.375 kg derivatives); *Ursus arctos* (118 UU medicine; 15 ml extract; 0.04 kg and 67 UU derivatives; 0.01 kg gall; 2 gall bladders); *Ursus thibetanus* (0.02 kg and 392 UU medicine; 0.098 kg and 820 ml and 4717 UU derivatives; 4717 powder UU; 1.87 kg and 10 ml gall; 1 gall bladder). Two taxa were resolved only to genus: (*Manis* spp.) (457 UU medicine; 2.06 kg, 2369 UU derivatives; 0.014 kg powder; 0.45 kg, 381 UU scales); *Ursus* spp. (9.62 kg + 105 ml+1943 UU medicine; 200 ml extract; 1.42 kg+1932 UU derivatives; 48 g, 22 UU gall; 1 gall bladder) (Table 1).

Of ten taxa listed in the MFC, three were resolved to species: *Cuora trifasciata* (Chinese box turtle: 50 UU medicine); *Mauremys sinensis* (Chinese stripe necked turtle: 179.1 kg powder); *Panthera tigris* (413 g and 236 ml and 1372 UU medicine). A further five were resolved to genus; and two only to family, but all potentially represented species listed in the MFC. Those resolved to family were: Cheloniidae spp. (marine turtles: 37 UU medicine; 1.035 kg and 618 UU derivatives; 618 UU powder), and Testudinidae spp. (tortoises: 3264.41 kg and 1168 UU medicine; 82.79 kg, 25 ml and 8601 UU derivatives; 0.53 kg powder). Those resolved to genus were: *Cuora* spp. (3 UU medicine; 2 UU extract; 3.0 kg and 1482 UU derivatives; 0.21 kg powder), (*Hippocampus* spp.) (3.45 kg extract; 322.41 kg, 125 ml, 20,881 UU medicine; 0.53 kg derivatives; 222.13 kg, 13,172 UU bodies), *Indotestudo* spp. (tortoises: 48 UU medicine; 3 UU derivatives); (*Moschus* spp.) (82.76 kg, 4610 UU, 125 ml medicine; 12 g oil; 13.44 kg + 350 ml+14,050.5 UU derivatives; 64.96 kg, 40.78 UU musk), *Panthera* spp. (2664 UU, 2.25 kg, 236 ml medicine; 3900 UU, 322.08 kg derivatives; 40 and 60 UU bone pieces) (Table 1).

Six species and one higher taxon (identified to family) were unlisted in either the Pharmacopoeia or the MFC, but were likely to have been exported as "TCM" medicinal materials. These were *Crocodylus siamensis* (411,600 UU medicine, 1 L extract; 130,000 UU, 127 kg derivatives), *Cyclemys oldhamii* (Oldams leaf turtle: 1200 UU medicine), *Heosemys grandis* (great Asian pond turtle: 480 kg medicine; 174 UU derivatives), *Hippocampus abdominalis* (big belly seahorse: 2.992 kg, 30 ml derivatives; 202 UU bodies), *Hippocampus spinosissimus* (hedgehog seahorse: 90.48 kg medicine; 49.99 kg, 52 UU bodies), *Pelodiscus axenaria* (Hunan soft shelled turtle: 40 UU medicine; 5 UU derivatives; 100 bottles of powder), Rhinocerotidae spp. (rhinoceros: 59 UU medicine; 201 UU derivatives). With the exception of Rhinocerotidae spp., each of these species belonged to a genus containing a species that was listed in either the Pharmacopoeia or the MFC, suggesting that the export represented a substitution for a listed species. Of all the above exported taxa, six did not have extant wild populations in China. These were *Cervus elaphus*, *Saiga tatarica*, *Crocodylus siamensis*, *Heosemys grandis*, *Hippocampus abdominalis*, and Rhinocerotidae spp., but all were recorded as having been imported during the same period. With regards to the destination countries of the exports of the above taxa, the relevant terms were exported to 22 different countries in Asia (Brunei, Thailand, Vietnam, Hong Kong, Indonesia, Japan, Korea, Malaysia, Singapore), Australasia (Australia, New Zealand), Europe (Austria, Belgium, Norway, Poland, Russia, Spain, Sweden, Switzerland, UK), and North America (Canada, USA) (Fig. 5).

3.4. Imports of CITES-listed animal species to supply materials for traditional Chinese medicines

Between 2008 and 2018, 20,927 imports of animals to China were reported to CITES, involving 1091 different taxa, with 989 identified to species. After exclusions, the long list of taxa imported potentially for use as "TCM" medicinal materials comprised 99 species. Of these, sufficient evidence existed to link the import to use in traditional medicine for ten (Table 2, Fig. 6): six OTCM, listed explicitly in the Pharmacopoeia, two inferred OTCM, and two listed only in the MFC.

Six species were listed in the Pharmacopoeia (great seahorse *Hippocampus kelloggi*, common seahorse *Hippocampus kuda*, flat-faced seahorse *Hippocampus trimaculatus*, tokay gecko *Gekko gekko*, Saiga antelope *Saiga tatarica* and Siberian musk deer *Moschus moschiferus*). The medicinal part of the three species of seahorse is the whole body (see Supplemental Table 1). All seahorses were imported as bodies in substantial quantities: 249 kg of the great seahorse bodies, 1727 kg of flat-faced seahorse bodies, and 1389 kg of common seahorse bodies (Table 1). Internet searches revealed no competing commercial uses of seahorse bodies outside of "TCM". Similarly, 137 kg of *Moschus moschiferus* musk (the relevant medicinal extract) was imported, and imports of *Saiga tatarica* included 2.65 kg of "powder", 220 skulls, 4.126 kg of "derivatives" and 6.87 kg of horns (Table 2, Suppl. Material 2). For this latter species horns are a relevant medical part, with no alternative commercial use being discovered. Imports of *Gekko gekko* comprised 1510,739 UU bodies (the relevant medicinal part), and these imports are likely to have serviced demand for "TCM" (TRAFFIC, 2011).

The derivatives of two imported species were listed as patent ingredients in the 2020 Pharmacopoeia, representing inferred OTCM. These were *Ursus arctos* (brown bear) and *Ursus thibetanus* (Asian black bear). The medicinal parts of the two *Ursus* species are gall bladder, fat, brain, muscle, bone, meat, palm. Relevant imports of *Ursus arctos* comprise 250 kg of medicine, 15 gall bladders, 3.146 kg of gall and 72 live specimens. For *Ursus thibetanus* these were 3 UU of gall, and 15 live specimens.

Two imported species were listed only in the MFC, representing species likely to have been used for zhongyi. These were *Panthera tigris* (tiger) and *Python bivittatus* (Burmese python) (Table 2, Fig. 6). Of *Panthera tigris*, the medical part is bone and so relevant imports were 1 UU of medicine, 56 bodies, 101 live tigers and 1 UU of bone. The medicinal parts of *Python bivittatus* are fat, bile, flesh, skin, blood, and "film". Relevant imports comprised 1500 kg of extract, 30 kg of gall bladder, and 13,250 kg of oil (used for skincare; e.g. Health Benefits, 2021).

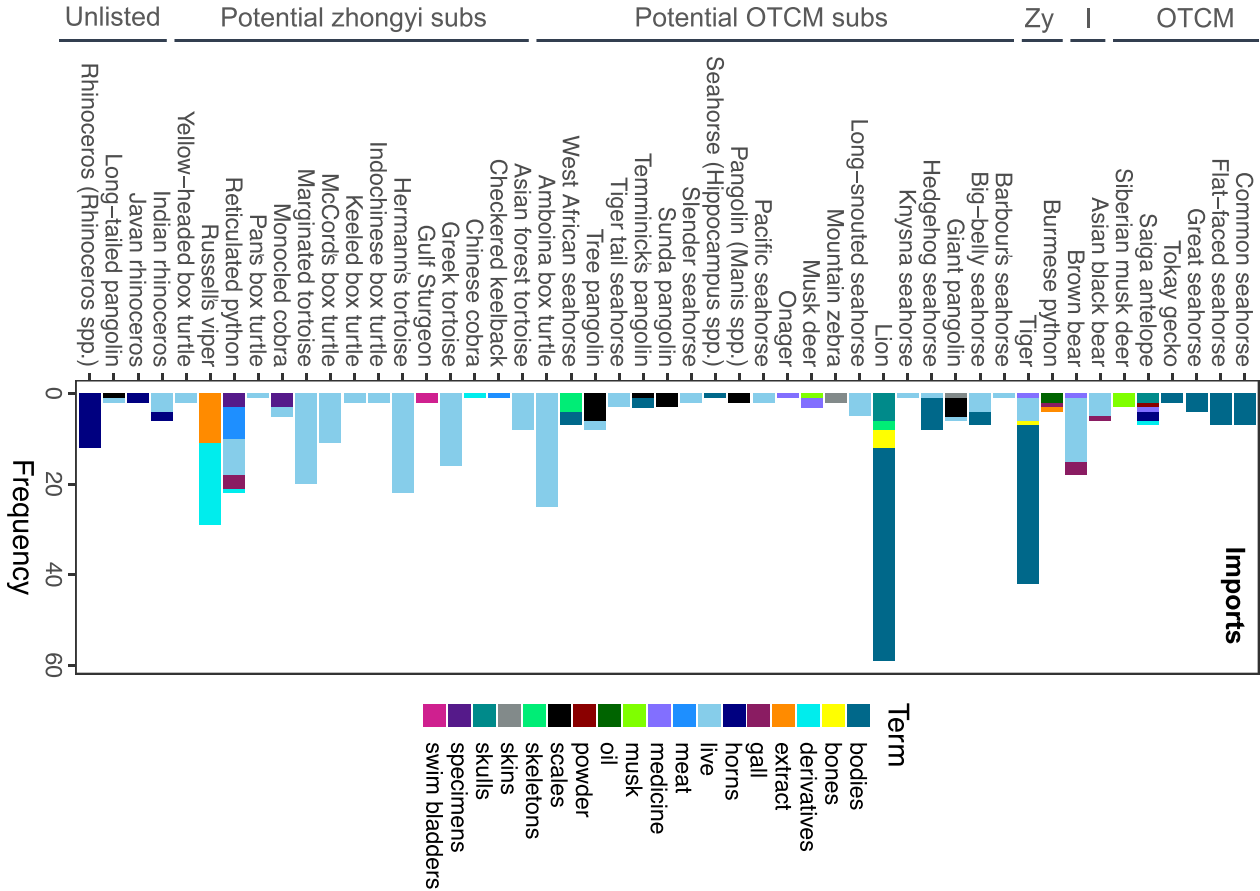


Fig. 6. Species imported to China between 2008 and 2018 with sufficient evidence to link the import to use for “TCM”. Shown is the number of import records for each species (frequency) broken down by CITES import term (including only those terms relevant to traditional medicine for each species).

A further two species and two higher taxa were unlisted in either the Pharmacopoeia or MFC, but are known to be primarily traded as medicinal materials (Cheung et al., 2021a, 2021b). These were *Rhinoceros sondaicus* (Javan rhinoceros), *Rhinoceros unicornis* (Indian rhinoceros), *Rhinoceros* spp. and Rhinocerotidae spp. The medicinal part of *Rhinoceros* species is horn. Relevant imports comprise 4 UU horns of *Rhinoceros sondaicus*, 3 UU horns of *Rhinoceros unicornis*, 2 UU horns of *Rhinoceros* spp. and 21 UU horns of Rhinocerotidae spp. We include these species because rhinoceros was listed in the 1963 edition of the Pharmacopoeia, and so has prior textual support.

3.5. Imports of CITES-listed animal species as potential substitutes for OTCM or zhongyi listed species

Imports of seventeen species and three higher taxa were plausibly intended as a species substitution for an OTCM species (i.e. were not themselves listed in the Pharmacopoeia, but belonged to the same genus as species that were listed). The seventeen species comprised nine seahorse species (*Hippocampus* spp., Table 2), five pangolin species (*Manis* spp., Table 2), lion (*Panthera leo*), mountain zebra (*Equus zebra*), Onager (*Equus hemionus*). The three higher taxa were *Moschus* spp., *Hippocampus* spp., and *Manis* spp. (see Table 2). Relevant imports of the *Hippocampus* species include 430 live and 6.5 kg + 50 UU bodies of *Hippocampus abdominalis*, 380.3 kg + 33 bodies and 55 kg + 1316 UU skeletons of *Hippocampus algiricus*, 50 live *Hippocampus barbouri*, 30 live *Hippocampus capensis*, 1480 live *Hippocampus comes*, 60 live *Hippocampus guttulatus*, 60 live *Hippocampus ingens*, 256 live *Hippocampus reidi*, 1752 kg + 873 bodies of *Hippocampus spinosissimus*, 50 bodies of *Hippocampus* spp. The medicinal part of pangolin is scales and so relevant imports of the pangolin species were 3000 kg of skins and 7245 kg of scales of *Manis gigantea*, 2800 kg of scales of *Manis javanica*, 2 bodies and 1 kg of scales of *Manis temminckii*, 200 live and 1 kg of scales of *Manis tetradactyla*, 210 live and 7452 kg of scales of *Manis tricuspis*, 1250 kg of scales of *Manis* spp. The medicinal part of *Panthera leo* is bone and so relevant imports were 166 bodies, 4 skeletons, 52 UU of bones, and 22 skulls. Of *Moschus* spp. the medicinal part is musk and so relevant imports comprise 0.953 kg musk and 8 UU medicine. Of the two *Equus* species, skin is the medicinal part and relevant imports comprised 19 UU of skins of *Equus zebra* and 8 UU of medicine of *Equus hemionus*.

Sixteen imported species were unlisted in either the Pharmacopoeia or the MFC but were plausibly imported as substitutes for species listed in the MFC. These were *Acipenser oxyrinchus* (Gulf sturgeon), six species of box turtles (*Cuora* spp., Table 2), *Daboia russelii* (Russell's viper), *Manouria emys* (Asian forest tortoise), *Naja atra* (Chinese cobra), *Naja kaouthia* (Monocled cobra), *Python reticulatus* (Reticulated python), *Testudo graeca* (Greek tortoise), *Testudo hermanni* (Hermann's tortoise), *Testudo marginata* (Marginated tortoise), and *Xenochrophis piscator* (Checkered keelback).

The medicinal part of *Acipenser oxyrinchus* is dry swim bladder and so relevant imports were 135 kg + 1 UU swim bladders. Of the six *Cuora* species, the medicinal part is plastron and carapace. Relevant imports comprised 188,978 live *Cuora amboinensis* specimens,

Table 3

Details of 65 China Judgements Online cases describing crimes involving wild animals where the use of a species for medicinal purposes was recorded as the motivation.

Species	Text	usage claimed by the offenders	Number of cases	Case code (s)
<i>Accipiter gentilis</i>	MFC	NA	1	8
<i>Accipiter nisus</i>	MFC	NA	2	13,35
<i>Asio flammeus</i>	MFC	NA	1	52
<i>Asio otus</i>	MFC	NA	1	55
<i>Aviceda leuphotes</i>	Unlisted	NA	1	35
<i>Budorcas taxicolor</i>	Unlisted	Stomach pain	1	11
<i>Buteo japonicus</i>	MFC	Rheumatism	1	56
<i>Centropus bengalensis</i>	MFC	Rheumatism	4	6,32,40,53
<i>Chelonoidis carbonarius</i>	Unlisted	NA	1	23
<i>Chrysolophus amherstiae</i>	MFC	NA	1	59
<i>Crocodylus siamensis</i>	Unlisted	NA	2	21,44
<i>Cuora trifasciata</i>	MFC	Skin disease	1	29
<i>Gekko gekko</i>	Pharma-copoeia & MFC	Bronchitis	6	3,16,27,36,39,45
<i>Glaucidium brodiei</i>	MFC	Cough	1	41
<i>Glaucidium cuculoides</i>	MFC	Dizziness	1	7
<i>Macaca mulatta</i>	MFC	NA	1	18
<i>Macaca thibetana</i>	Unlisted	Mental disease	2	24,51
<i>Manis pentadactyla</i>	Pharma-copoeia & MFC	Medicine inducer; Neck pain	10	1,9,10,37,42,49,60,62,63,64
<i>Moschus chrysogaster</i>	Pharma-copoeia & MFC	Stomach pain; Hypertension	3	22,28,50
<i>Naja atra</i>	Unlisted	NA	1	25
<i>Naja naja</i>	MFC	Medicine inducer	1	20
<i>Nycticebus bengalensis</i>	MFC	NA	1	61
<i>Otus lettia</i>	MFC	NA	6	26,33,34,46,47,57
<i>Otus scops</i>	MFC	NA	2	31,48
<i>Paguma larvata</i>	Unlisted	NA	1	4
<i>Przewalskium albirostris</i>	MFC	Rheumatism	1	17
<i>Python bivittatus</i>	MFC	NA	3	12,54,58
<i>Tetraogallus himalayensis</i>	Unlisted	NA	2	15,43
<i>Tyto capensis</i>	MFC	NA	2	2,30
<i>Ursus thibetanus</i>	MFC	Rheumatism	2	5,38
<i>Varanus salvator</i>	MFC	NA	2	14,19

7 live *Cuora aurocapitata*, 3 live *Cuora galbinifrons*, 71 live *Cuora mccordi*, 460 live *Cuora mouhotii* and 2 live *Cuora pani*. Other uses exist for *Cuora* imports, including for shell carving and exotic pets (Stanford et al., 2020), and an unknowable proportion of the above may have been intended for these uses. We include *Cuora* spp. here, however, in light of the substantial quantities of exports of medicine derived from members of this genus (see above). The medicinal part of *Daboia russelii* is whole body and relevant imports were 201,550 UU derivatives and 8692 UU extract. Of *Manouria emys*, the medicinal part is plastron and carapace. Relevant imports were 5111 live specimens. The medicinal part of the two *Naja* species is whole body and venom and so relevant imports comprised 10 mg derivatives of *Naja atra* and 3400 live and 41 ml specimens of *Naja kaouthia*. Imports of *Python reticulatus* were 60 gall bladders, 44 kg + 60 UU of gall, 1236 live specimens, 30 kg derivatives, 9990 UU of specimens, 27650 kg + 25015 UU of meat (the medicinal part is fat, gall bladder, meat, skin, blood, and “film”). The medicinal part of the three *Testudo* species is plastron and carapace and so relevant imports comprised 17,224 live specimens of *Testudo graeca*, 45,372 live *Testudo hermanni* and 7976 live *Testudo marginata*. Of *Xenochrophis piscator*, the medicinal part is whole body and relevant imports comprised 300 UU meat and 5105 UU skins.

Imports of the above originated from 46 different countries in Asia, Australasia, Europe, Africa, and North America.

3.6. Court judgements

Between 01/01/2014 and 31/12/2018, China Judgements Online archived 5509 judgement documents for crimes involving wild animals (Shao et al., 2021). Among these judgements the use of a species for medicinal purposes was recorded as the motivation in 65 cases, in which animals were involved in illegal hunting, smuggling and/or domestic trafficking (Table 3). These 65 cases involved 31 different species, of which three were listed in the Pharmacopoeia and MFC both, 20 were listed only in the MFC and eight were listed in neither text (Table 3). As a percentage of total cases, 53.8% (35 cases) involved species in the MFC (most prominently eight cases involving two species of *Otus*, scops owl); 29.2% (19 cases) involved species in the Pharmacopoeia (most prominently 10 cases involving *Manis pentadactyla*); and 16.9% (11 cases) involved species listed in neither text (Table 3). OTCM species accounted for 9.6% of the species involved but 29.2% of the cases. For MFC species these figures were 64.5% and 53.8%, and for unlisted species these figures were 25.8% and 16.9%, respectively. OTCM species were therefore over-represented in numbers of cases.

The 65 cases resulted in penalties being awarded to 72 offenders, which varied in severity from exemption from criminal liability to fixed-term imprisonment. In one instance in 2014, one female offender was sentenced to 12 years in prison for illegally transporting 84 geckos (listed in both the Pharmacopoeia and the MFC), claiming they were intended as medicinal ingredients for her personal use. In 2018, a 73-year-old male was sentenced to 16 years in jail for illegally hunting 19 greater coucals (*Centropus sinensis*, listed only in the MFC) using noose traps near his home and selling them at a rural market as medicinal remedy for rheumatism (Table 3).

4. Discussion

The number and diversity of wild-animal-origin medicinal materials available for use in “TCM” differ markedly between OTCM, as listed in the Pharmacopoeia of the People’s Republic of China - which currently lists 70 wild species - and broader Chinese medicine, zhongyi, as described in the Medical Fauna of China - which lists 2275 animal species, of which the majority are likely to be wild sourced. Different TCM practitioners will preferentially draw their information from different sources, dependent on their approach. As an example, Moorhouse et al. (in press) found that of 11 TCM practitioners asked to name their sources of knowledge about TCM, six who practised in large cross-community institutions (e.g. TCM hospitals in major cities) referred to modern TCM texts twice as often as to traditional texts, whereas those who worked in single community venues (e.g. drugstores in rural locations) referred to traditional texts three times more often than to modern texts. In this context, the Pharmacopoeia is a modern text, whereas the MFC incorporates information drawn from a variety of traditional sources (Li et al., 2013). Such textual differences may clearly translate into real-world impacts on different species potentially of conservation and animal welfare concern that are traded, given that this trade is driven by demand for medicinal materials that arises from practitioners, providers and consumers.

A key objective of this study was to provide preliminary evidence of the extent to which the global trade in wild animals might be driven by demand arising from different facets of “TCM”. Ascribing intentionality for use in “TCM” to a particular trade record was simpler in practice for export records than for import records, because the accompanying trade term (e.g. “medicine”, “extract”, “powder”) typically excluded other potential uses. We firmly attributed exports from China for use as “TCM” to materials derived from 32 species (Table 1). Of these, nine species (28.1%) were explicitly listed in the Pharmacopoeia. Of the remaining 23, six (18.8%) were inferred OTCM (three species and one genus of bears - exported as gall-based medicines - and two species of pangolins, exported as medicines, derivatives or powder; Table 1). A further 10 (34.4%) represented zhongyi materials, listed in the MFC, but not the Pharmacopoeia. Seven (18.8%) were unlisted in either the Pharmacopoeia or the MFC.

These findings indicate a potentially substantial export trade from China in traditional medicines derived from wild animal taxa that are not explicitly listed in the Pharmacopoeia (i.e. those taxa listed as patent medicinal ingredients, or listed in the MFC), as well in taxa that are unlisted in either the Pharmacopoeia or the MFC - and which are therefore likely to have little or no prior textual support for their use. In our data this latter category comprised one species of crocodile, three species of turtle and two species of seahorse (Table 1). Each of these belonged to genera that contained another species listed in the MFC, which suggests that these exports may have represented species substitutions, creating medicinal materials to be used in place of those from listed species. Debate surrounds whether it is legitimate within TCM to substitute a species for a similar one with no prior history of usage. Moorhouse et al. (in press) presented opinions on this question from three respondents of whom two (a Professor at a Chinese Medical University and a doctor from a single community drugstore) stated that species of the same genus as existing medicinal animals are part of TCM and able to be used as such, and one of whom (a pharmacist at a TCM hospital) stated that species with no direct textual precedent were not TCM.

Regardless, our data indicate that such substitutions are likely to occur, and knowingly or unknowingly, be traded as "TCM" medicinal products, despite having no direct textual precedent.

Estimating the relative size of the official, inferred, unofficial and unlisted trades from the export data was problematic due to the incomplete nature of many CITES records (e.g. [Challender et al., 2021](#)). By weight CITES exports of the nine OTCM taxa totalled 23,555.4 kg, of which 18,793.0 kg (79.8%) was products from Reeves turtle and 3114.0 kg (13.2%) were from Saiga antelope and 1000.7 kg (4.2%) were of common seahorse ([Table 1](#)). By comparison the majority of recorded exports of the inferred official, zhongyi and unlisted taxa had unknown units ([Table 1](#)), making direct comparisons impossible. Taking as an example *Crocodylus* spp. exports, these comprised 127 kg of derivatives, 1 L of extract, and 411,600 unknown units of medicine. The latter could plausibly represent 412 g, 412 L, 411,600 kg or 411,600 L, all with very different implications for the estimated size of the trade. A minimum estimate from our data, excluding all unknown quantities, is 5344.5 kg of products derived from species unlisted in the Pharmacopoeia. Of these approximately 32.4 kg were inferred OTCM, 4688.6 kg were from species listed in the MFC and 623.5 kg were unlisted, potentially species substitutions (see [Table 1](#)).

Taken together the above may indicate that the majority of the "TCM" exports we recorded were of medicines from OTCM species, but that a substantial minority (perhaps a fifth) derived from taxa outside of the Pharmacopoeia. The majority of the above represented end products, and so the weight of animal-origin raw material they represent is likely to be orders of magnitude larger. An unknown proportion of this material will have been wild caught. Large scale captive breeding within China does occur, for example of bears for bear bile, tigers ([EIA, 2020](#)) and of both turtles and crocodiles for a number of purposes, including the production of crocodile oil ([Chinese Academy of Engineering, 2017](#)). Such farming continues despite the Chinese government recently moving to close enterprises that farm wildlife for food ([Zhou et al., 2020](#); [Yang et al., 2020](#)). Similarly there are an estimated one million tortoise and turtle breeding enterprises, farms and farmers in China, with over 50 species of turtle industrially captive bred, numbers of which tripled between 2006 and 2015–342,000 tonnes per annum ([Chinese Academy of Engineering, 2017](#)). This latter is plausibly reflected in the quantities of *Heosemys* sp. medicine reported as being exported (480 kg). The export of non-native seahorses and rhinoceros products, however, may be more likely to indicate an illicit trade unreported to CITES.

Of 20,927 imports to China reported to CITES between 2008 and 2018, sufficient evidence existed for ten species listed in either the Pharmacopoeia or the MFC to determine with a high degree of confidence that the trade was intended to provide medicinal materials for "TCM". Of these species, six were listed in the Pharmacopoeia (three species of seahorses, Tokay geckos, Saiga antelope, and Siberian musk deer), with a further two (black and brown bears) able to be inferred as servicing OTCM as a result of bear bile powder being listed as a patent medicine ingredient in the 2020 edition of the Pharmacopoeia ([Table 2](#)). The remaining two species were found only in the MFC (tiger and Burmese python) and therefore represent zhongyi materials, albeit that tiger was formerly listed in the Pharmacopoeia, ending with the 1977 edition. Taken together these findings support the conclusions from the export data, in indicating the existence of a trade in medicinal species not specifically listed in the Pharmacopoeia.

The imported quantities of the above species were substantial: the combined imported weight of products from these ten species was 18,471.8 kg, of which < 20% (3438.7 kg) was for species listed in the Pharmacopoeia (these figures, however, exclude 1510,739 bodies of Tokay geckos, an OTCM species for which no weights were provided but which even if transported dried could still weigh tens of thousands of kilos). The remainder comprised 253.2 kg for inferred OTCM (the bear species) and 14,780.0 kg of products ("extract" and oil) derived from the Burmese python.

Our export data indicated that unlisted species were traded as substitutes for species listed in the Pharmacopoeia and/or the MFC ([Table 2](#)). We accordingly extended our import records search to include unlisted species within genera that contained species listed in these texts. We found a total of 36 unlisted taxa ([Table 2](#)) likely to have been imported as substitutes for medicinal materials from listed species. The imported quantities of these were also substantial. Imports of substitutes for species listed in the Pharmacopoeia included 2193.8 kg of unlisted *Hippocampus* (seahorse) species and 21,749.0 kg of scales and skins of unlisted *Manis* (pangolin) species. Substitutes for MFC species included 135.0 kg of swim bladders of *Acipenser oxyrinchus*, 44.0 kg of gall and 30.0 kg of derivatives of *Python reticulatus*. Live specimens imported comprised 1236 live *Python reticulatus*, 70,572 *Testudo* species, 189,421 of *Cuora* species, all of which have alternate uses in trade, but medicines from all of which were exported from China during the same period.

Taken together the above evidence indicates the existence of an abundant trade not only in species listed in the Pharmacopoeia and MFC, but also in species unlisted in either text but which are nonetheless traded for the purposes of supplying medicinal materials for "TCM". This finding is corroborated by data from court judgements, which comprise prosecutions of people illegally trading a diversity of "TCM" materials amounting to 31 different species, the majority of which were listed in the MFC, eight of which were unlisted, and only three of which were listed in the Pharmacopoeia. Illegal trade involving these three latter species, however, constituted the majority of cases. The key finding of our study, therefore, supports that of [Moorhouse et al. \(in press\)](#), that OTCM represents only one facet of "TCM", that different practitioners and consumers adhere to different facets, and that the markets they stimulate do drive a substantial global trade in wild animal species and their derivatives. A considerable proportion of this global trade is illegal (\$7.8–20 billion of an estimated \$30.6–42.8 billion annually; ([Haken, 2011](#); [Pires and Moreto, 2011](#)), and whether legal or not for a given species or individual, featuring in this trade is associated with a raised probability of detrimental conservation and animal welfare outcomes ([Macdonald et al., 2021](#)). A related point is that a proportion of medicinal materials are derived from species protected under the Wildlife Protection Law in the PRC (e.g. leopard bone, pangolin scales). These materials are able to be sourced from existing stocks, and this reason has been provided to explain the ongoing use of these materials by pharmaceutical manufactures ([White, 2021](#)). Our data, however, show that imports of many protected species (including tiger, rhinoceros and pangolin; [Table 2](#)) continue.

Uncovering evidence linking the global trade to use of species for "TCM" was complicated by a number of circumstances, principal among which was that a substantial proportion of the relevant wildlife trade passes unrecorded, either because the trade is wholly illicit or because the trade in many taxa is inconsistently recorded regardless of its legality ([Macdonald et al., 2021](#)). In this study we

focused on CITES records because these data are easily available, and reflect both legal trade and re-exports of seized illicit cargoes. These data are, however, limited only to species listed by CITES, and so will fail to represent an unknown but plausibly large proportion of trades in relevant taxa, particularly those in the MFC (of which only ~7% are listed in CITES appendices) or which are unlisted. Similarly there are well established limitations to using CITES records (e.g. multiple records for a single import shipment, see [Chalender et al., 2021](#)), and we framed our conclusions and estimates of relative quantities to acknowledge these.

Our approach of creating a conservative list of imports and exports avoided potential difficulties when species could be traded for several uses, not necessarily related to "TCM". This approach, however, required us to discount a large number of live imports, and imports of body parts that potentially could have been intended for use as medicinal materials. As examples, 534,703.9 kg of *Strombus gigas* shells, 3400 live *Naja atra*, 1111,324 live *Ptyas mucosus* (oriental ratsnake) were imported, which have potential uses as medicinal materials, but all of which also have alternative uses in the carving or pet trades. All species with existing alternate uses were discounted unless exported as medicines during the same period, or unless a body part specific to the medicinal use was listed (for example the above *Acipenser* swim bladders represent a single record amid many imports of caviar from this species). We therefore are likely to have systematically underestimated the size and diversity of many imports related to "TCM", and our remaining results represent a minimal estimate of the diversity of trade for "TCM".

4.1. Conclusions and implications for managing species conservation and animal welfare impacts

Official TCM permits the usage, for medicinal materials, of 70 wild animal species, as recorded in the 2020 Pharmacopoeia. By contrast pre-modern zhongyi comprises > 2200 wild animal origin species, as recorded in the Medical Fauna of China. While direct comparisons could only be approximate, our data suggest that the majority of the international trade in wildlife for medicinal materials is likely to be in OTCM species, but that a large proportion of imports and exports were also of zhongyi species, or of species unlisted in either the Pharmacopoeia or MFC (i.e. those with no prior textual support). Our data suggest that these latter are likely to represent species substitutions, which may or may not be legitimate from "TCM" practitioners' or scholars' perspectives ([Moorhouse et al., in press](#)), and to some extent represent a neologistic extension to "TCM" ([Hsu, 2009](#)). In practical terms the existence of a trade in species unlisted in these texts suggests that a growing number of wild animal species globally is viewed to some extent as able to be exploited for "TCM". Trade can be positive, neutral or negative for a species' conservation ([Macdonald et al., 2021](#)), but time and research effort is required to ascertain the impacts of a given trade, and to monitor changes over time. The extensive nature of the above trade for "TCM" medicinal materials increases the scope and complexity of such research. From an animal welfare perspective, the welfare of all individuals, whether wild caught or farmed is likely to be compromised to at least some degree ([Kikuchi, 2012](#); [Rizzolo, 2020](#)).

We investigated the above with a view to understanding what interventions may be required or available to mitigate the negative species conservation and animal welfare consequences that arise from the use for "TCM" of some species. It is clear from our findings that the explicit listing or otherwise of a species in the Pharmacopoeia currently does not directly correlate with the scale of the trade for "TCM" in that species: while the trade in species in the Pharmacopoeia appears marginally larger than that in species listed in the MFC or in unlisted species, our data indicate the existence of extensive trade in these zhongyi and unlisted (potentially substitute) species. This is unsurprising given that the use of some species not explicitly listed in the Pharmacopoeia can nonetheless still be inferred if they are listed in the Pharmacopoeia as ingredients in patent medicines - as appears to have occurred for many species of pangolins and three species of bears - and because many practitioners, their clientele/patients and consumers do not use only species listed as OTCM, but also incorporate those listed in other texts (e.g. [Moorhouse et al., in press](#)), or those that are popular/ socially desirable (e.g. as CMP). As an example of the latter, rhinoceros horn is currently listed in neither the Pharmacopoeia or MFC, but is nonetheless traded to supply materials for "TCM" ([Cheung et al., 2021a, 2021b; Table 2](#)).

We argue that mitigating both species conservation and animal welfare impacts is likely to require the targeted substitution of sustainably sourced plant-based medicinal materials for the currently-used animal-origin materials. [Moorhouse et al. \(in press\)](#) suggest engaging with OTCM practitioners to achieve this. Our data suggest that initially targeting the 70 OTCM species, as well as inferred OTCM species and selected genera likely to be imported as substitutes (e.g. *Hippocampus*, *Manis*; [Table 2](#)), may strike a balance between keeping the focus of the research required into plant-based alternatives relatively narrow, while targeting the taxa most likely to be traded. Initial research suggests that such plant-origin substitute materials are available (e.g. <http://tawap.org/>), and could be deemed acceptable by both practitioners and consumers ([Moorhouse et al., 2020](#); [Moorhouse et al., in prep](#)).

There is likely to be disagreement between various actors on which species and products are untenable for trade based on conservation / animal welfare and, indeed public health concerns. However, in situations where the trade in a given species is deemed undesirable, it is important to note that regulatory mechanisms alone will not be sufficient, but must be accompanied with enforcement action and human behaviour change initiatives of the type we propose above ([Macdonald et al., 2021](#)). A key requirement for any attempt to mitigate these impacts, therefore, is likely to be buy-in from the extended community of TCM doctors, scholars, professionals, providers and consumers (see [Moorhouse et al., in press](#) for further discussion).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.gecco.2021.e01906](https://doi.org/10.1016/j.gecco.2021.e01906).

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