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Review

Ethnopharmacological field studies: A critical assessment of their conceptual basis and methods

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We dedicate this article to the memory of our friend and colleague Prof. Nina Etkin (Hawai'i), who passed away on 27 Jan, 2009. She was a brilliant scholar and keen advocate for multidisciplinary approaches in ethnopharmacology.

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ABSTRACT

Ethnopharmacology as a well-defined field has a relatively short history, but for centuries researchers have been interested in the observation, description, and experimental investigation of indigenous drugs and their biological activities. Today, such articles are published in a variety of journals among which the *Journal of Ethnopharmacology* has a prominent position as well as in book monographs. As any other area of scientific endeavour, this field requires a critical and engaged discussion about the conceptual basis, the relevant methods and the overall standards necessary for excellence. Here we review recent ethnopharmacological field studies in order to highlight achievements and future needs for improving the quality of such studies. The basis for this review is 40 field studies published in the years 2007 and 2008 in the *Journal of Ethnopharmacology*. Researchers need to have a clear vision for what and how they want to achieve a conceptually and methodologically sound approach and as in all disciplines adherence to internationally recognized methodological standards is essential. Here we review not only the basic conceptual requirements but also the minimal methodological (i.e. botanical, anthropological/historical, ethnomedical) standards and ways how to quantify ethnopharmacological information. Future uses of such information both in the context of experimental research and in applied projects highlight the multiple roles of such data generated in ethnopharmacological field studies. This review cannot be a book of recipes on how to conduct such research but *highlights minimal conceptual and methodological requirements for use in future projects.*

Contents

Abbreviations: CBD, convention on biological diversity; F_{IC}, index of informant consensus; IAR, informant agreement ratio; TEK, traditional ecological knowledge.

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1. Introduction

In 1979 the *Journal of Ethnopharmacology* started with the ambition to be a '. . . multi-disciplinary area of research, concerned with the observation, description, and experimental investigation of indigenous drugs and their biological activities' (Rivier and Bruhn, 1979).

Such studies have a long tradition in the field and, for example, the knowledge about North American Indian plant use was documented in great detail most importantly during the 19th and 20th centuries (Moerman, 1998). Similarly, some researchers have studied the use of pharmaceuticals from the perspective of patients (pharmaceutical anthropology, Van der Geest, 1987), a topic which is not covered here.

Within what now amounts to nearly 30 years, one constant element of the *Journal of Ethnopharmacology* has been studies focusing on the local and traditional use of medicinal plants. Early accounts provide rich and purely descriptive overviews on peoples' use of such plants (e.g. Schultes, 1979). In this review we focus on studies of plant (and to a lesser degree fungi and animal) derived products which are used in any part of the world as a medicine (ethnopharmacology).

Reviewing, for example, the 40 largely field-based ethnopharmacological studies published during 2007 and 2008 in the journal, a focus on descriptive[1] field studies becomes apparent, as exemplified in these four characteristic statements:

- '. . . *collecting* and *documenting* indigenous knowledge on medicinal plants may add information to the valuation of biodiversity and to forward suggestions for its sustainable use and conservation' (Wondimu et al., 2007).
- 'The aim of this study is to *collect i*nformation about the traditional medicine of this region before it is completely lost.' (Kültür, 2007)
- 'The purpose of this survey was to *document* useful medicinal plants with a clearly defined therapeutic context of being used to treat infectious disorders' (Maregesi et al., 2007).
- '. . . this study was undertaken in order to compose detailed *documentation* on wild medicinal flora, its ecological status and usage based on ethnobotanical knowledge in a locality with the most diverse flora and vegetation—Kopaonik Mountain.' (Jarić et al., 2007)

(All emphasis by the authors of this paper.)

These diverse authors all agree on the urgent need for documenting such knowledge and presenting it to the international audience. It is also clear that, from the beginning such descriptive accounts have formed one basis for a critical analysis of medicinal plant usage (e.g. Moerman, 1979). This raises a much broader and more fundamental issue: it is now widely accepted that scientific research should be hypothesis driven and that research should clearly answer those research questions which result from a given hypothesis (i.e. a preliminary idea which is to be tested empirically and which may or may not be falsifiable in a Popperian sense, Gertsch, 2009). Data-driven research, on the other hand, generally results in the generation of hypotheses and therefore can be considered a preliminary and complementary step to hypothesis-driven research, but in itself is often not considered 'hard science' (Kell and Oliver, 2004). Ethnopharmacology is, by definition, multi-disciplinary/transdisciplinary. Following Stamos (2007), we argue that science and scientific theories – and especially ethnopharmacology – by definition have to integrate different clusters of knowledge domains. This allows us both to interpret new knowledge (i.e. generated in a field study) in the context of a wider conceptual framework, and to test concepts (hypotheses) derived empirically from previous research. Clearly, field-based research is not an area where the Popperian doctrine of falsifiability can be applied (Stamos, 2007). Of course, in all cases exactness when describing our experiences is essential.

At the same time, we have to ask ourselves: 'What do we (as a scientific community) want to achieve with ethnopharmacological, ethnobotanical and ethnopharmaceutical field studies?' Documentation is an essential basis, but is this sufficient to justify such research? Purely descriptive accounts of all the plants used in some village in some part of the world may well simply be seen as forming a "cabinet of curiosities." We argue that *we do not do justice to the potential of such research if we simply list such local and traditional uses*. In this review we suggest some conceptual and methodological minimal standards for ethnopharmacological field studies and want to highlight the need for a systematic interpretation (as compared to a simple description) in such studies. Excluded from this comparative analysis are historical studies (e.g. Giorgetti et al., 2007; Lev, 2007; Mendes and Carlini, 2007; Odonnea et al., 2007).

In very general terms, research follows a broadly similar scheme moving from the initial idea and the planning of a project, to data collection and storage, and finally to the analysis and publication or use of such data. These three steps are interconnected and in fact, certain parts are conducted simultaneously.

2. Developing a project

2.1. Developing a field study—the conceptual framework and hypothesis testing

The 40 studies in Table 1 largely focus on broad descriptions of the local and traditional uses of plants. About a quarter of them focus on one or two specific groups of diseases like malaria or diabetes, or on gynaecological conditions. Three studies present the results of ethnoveterinary projects (Yineger et al., 2007; Farooq et al., 2008; Hussain et al., 2008), a fast developing area of ethnopharmacological investigations. All studies were conducted in regions with a long track record of ethnobotanical studies and especially on the Indian subcontinent, Ethiopia in Italy, Spain and Brazil, where much previous research has already been conducted.

In the initial steps, a detailed assessment of such previous studies in the region or neighbouring areas, and in areas which have used a methodology that is of relevance to the authors, allows for a basic assessment of those research questions that will be pertinent to the planned project. While certainly a well-known aspect of science, this conceptual or regional basis is often not discussed in detail (or even mentioned at all) in the studies cited in Table 1. In a broader context, people use plants as an essential element for energizing and repairing themselves, an element deeply embedded in our evolution. Especially in the case of traditional crops and medicines, this may now be historical information that people no longer use. In Table 1 some core statements about the researcher's rationale (goals) for conducting the project and publishing it have been summarized. While descriptive in nature, all articles highlight one or another important scientific concerns and problems:

- How does local and traditional knowledge account for the use of the environment and questions of sustainability?
- How can this knowledge be assessed (evaluated) in the context of biomedicine or phytochemistry?
- What is the role of specific taxa in a society?

[1] While preparing the final corrections of this article (January 2009) several methodologically robust studies appeared in the *Journal of Ethnopharmacology* and we would like to draw the attention to these works: Ruysschaert et al. (2009) (Suriname Maroons), Molares and Ladio (2009) (Mapuche of Argentina).

Table 1
A comparison of ethnobotanial and ethnopharmaceutical studies published in the *Journal of Ethnopharmacology* in terms of main objectives, quantification, general study design and potential further use of information gathered.

Country	Main objective(s)*	Quantification of plant usage	Other relevant data/evaluation parameters	Therapeutic categories	Authors' assessment of study's implications/potential further uses of this information	Authors
Africa						
Ethiopia	The objective of this study was to *document* and *analyse* local knowledge regarding the use of plants for the treatment and prevention of various human ailments in three sociocultural groups, namely the peoples of Shinasha, Agew-Awi and Amhara, residing in selected districts of the Metekel and Agew-Awi administrative zones of the Benishangul-Gumuz and Amhara administrative regions of Ethiopia, respectively	Selection of the most frequently cited species	Short information on habitat	Broad	*In situ* and *ex situ* conservation measures	Giday et al. (2007)
Ethopia	'. . . collecting and documenting indigenous knowledge on medicinal plants may add information to the valuation of biodiversity and to forward suggestions for its sustainable use and conservation'	Preference ranking for the most frequently used medicinal plants	Valuation of biodiversity and to forward suggestions for its sustainable use and conservation	Broad	Conservation of knowledge, involvement of local populations, valuation of biological resources	Wondimu et al. (2007)
Ethopia	Document the indigenous knowledge on utilization, management and conservation status of ethnoveterinary medicinal plants	Number of recorded use reports		Ethnoveterinary uses	Conserve and ensure the sustainable use of these resources	Yineger et al. (2007)
Kenya	Collect information from local populations concerning the use of Nandi Forest medicinal plants; verify the sources of medicinal plants used and determine the relative importance of the species surveyed	Analysis based on the number of species per botanical family used		Broad	The most important plants used by Nandi people and on medicinal plants for possible on-farm conservation. Since most of them are shrubs and herbs, they grow fast and therefore can provide a continuous supply of the medicinal products. When household needs are met the surplus can be sold for income generation. Domestication of medicinal plants is a suitable option for optimizing resource utilization, as well as decreasing overdependence on wild habitats	Jeruto et al. (2008)
Morocco	Inventory of medicinal plants that grow and/or are available	Frequency of recorded use for target indications		Hypertension and diabetes	Preserve this knowledge for future generations	Tahraoui et al. (2007)
Nigeria	Inventory of plants used by traditional healers	Number of respondents reporting use	Analysis of healers' diagnostic criteria and general assessment of outcome; General comparison with similar studies in the country	Diabetes mellitus	Further experimental investigation	Abo et al. (2008)
Nigeria	Identification and documentation of medicinal plants used by the indigenes of Akwa Ibom State	Performance index (relationship between the 'specific flora' and the 'global flora')	Relative importance of diseases in terms of citations (of species), comparison with uses outside of the area of study	Broad	Veritable source of information for practitioners of traditional medicine esp. based on the government's interest in incorporating traditional and western medical practice into the healthcare delivery system	Ajibesin et al. (2008)
Tanzania	'The purpose of this survey was to *document* useful medicinal plants with a clearly defined therapeutic context of being used to treat infectious disorders.'	Frequency of mention	Assessment of importance in the context of infectious diseases	Infectious diseases	If these drugs in their crude forms have curative properties in societies using them, scientific studies could lead to isolation of active principles or compounds that can serve as templates for the synthesis of modern drugs, or preparation of standardized herbal products	Maregesi et al. (2007)
Uganda	'This study *documents* the medicinal plants used by 13 villages in the subcounties surrounding the Sango bay ecosystem . . . in central Uganda'	Frequency of recorded use		Broad	Phytochemical and pharmacological studies are needed Community-based conservation strategies (including home medicinal plants gardens)	Ssegawa and Kasenene (2007)
Uganda	Documentation *of* the medicinal plants used in one ecosystem	None		Gynaecology (inducing labour)	Scientific investigations that can provide guidance in setting up health policies in the reproductive health care, as well as collaborative approaches involving traditional medical practitioners such as traditional birth attendants, is long overdue	Kamatenesi-Mugisha and Oryem-Origa, 2007

Table 1 (*Continued*)

Country	Main objective(s)*	Quantification of plant usage	Other relevant data/evaluation parameters	Therapeutic categories	Authors' assessment of study's implications/potential further uses of this information	Authors
Uganda	Document herbal medicines (HMs) used in the treatment of malaria as well as the existing knowledge, attitudes and practices related to malaria recognition, control and treatment in Budiope county	Questionnaire survey, number of use reports	This study focuses on the knowledge about malaria, its causation, symptoms, traditional and biomedical treatments	Malaria		Tabuti (2008)
The Americas						
Brazil	Documentation of traditional knowledge (healing practices using wild and native plants) since it is now 'fast disappearing due to modernization and the tendency to discard their traditional lifestyle allied to the strong anthropism to the environment.' There urgent need to study and document this precious knowledge of this area	No, only of number of uses in disease categories	Information on mode of preparation	Broad incl. toxic spp.	Potential for studying 'their chemical constituents and/or biological activities.'	Agra et al. (2007)
Brazil	Analysis and comparison of species sold on a market and testing of a series of hypothesis	RI value	Therapeutic role, potential toxicological risks	Broad	Markets are dynamic systems. The study offers a critical assessment of their current and future role	de Albuquerque et al. (2007)
Brazil	Comparison of zootherapeutic practices of fishing communities	ICF	Cluster analysis for comparative purposes	Broad	Conservation of species and knowledge, respect differing views of the value of wildlife	Alves and Rosa (2007)
Brazil	Documentation of knowledge/survey of use of plants with weight loss purpose	No	Correlation between popular use and biological properties	Weight loss	Confirmation of other reports on species used in this therapeutic area; 'some' species deserve further study for studies	Dickel et al. (2007)
Ecuador	'The ethnobotanical survey outlined in this paper gave us *a complete picture* about the natural remedies used by the inhabitants of the provinces of Loja and Zamora-Chinchipe in southern Ecuador.'	No	Quantification according to uses of taxa in therapeutic groups, therapeutic applications of main families	Broad	Conservation of knowledge. More detailed studies about the use of medicinal plants and on biological activity of the most promising plants	Tene et al. (2007)
Guatemala	Explore Q'eqchi perceptions, attitudes, and treatment choices related to women's health	Number of female and male informants citing the species	Screening for estrogen receptor and serotonin receptor binding	Gynaecology: *in vitro* tests in estrogen and serotonin bioassays	A better understanding of Maya medical beliefs and cultural concepts surrounding women's health, while the experimental laboratory results support their empirical use by the Q'eqchi. There is a need to further investigate these and other herbal treatments remedies, and underscore the need and value of government programs and initiatives that support such endeavours . . . contributing to Guatemala's national effort to improve public health measures in rural areas through the documentation of Maya medical practices	Michel et al. (2007)
Nicaragua	Document the use of medicinal plants by Rama midwives on the island of Rama Cay	Use reports (number of midwives who reported this species)	Detailed account of ethnopharmaceutical aspects (preparation, use, habitat, origin, etc.)	Midwifery	Stimulate further ethnobotanical and ethnopharmacological research on this subject in Nicaragua and elsewhere	Coe (2008)
Peru	'. . . the present research aimed to *identify* medicinal plants species used by the population of Canta and *document* the traditional medicinal knowledge associated with the use of these plants.'	No	Very short comparison with other regions	Broad	Comparison with neighbouring cultures shows considerable homogeneity, potential for study of those species not previously investigated phytochemically	De-la-Cruz et al. (2007)
Asia						
China (P.R.)	'. . . look into medicinal plants that are used by local people for curing various ailments' focusing on plants available on local markets in Yunnan	None	Assessment in terms of cultivated/wild, discussion of sustainability	Broad	Potential conservation issues (due to high demand). Further study of substitution 'to ensure its impact on local medical systems and biodiversity.' Indicator for monitoring plant biodiversity	Lee et al. (2008)

China (P.R.)	Collect information on the use of medicinal plants by the Hakka living in Guangdong. Document valuable knowledge represented by Hakka herbal medicine	Use reports	Relative number of species per family, assessment of frequency of species per category of medical use, comparison of Hakka and non-Hakka usage of medicinal plants, information on form of application; Bioactive constituents and clinically relevant pharmacological data related to hepatitis or liver protection	Broad	Unrecorded information may be lost forever. There is an urgent need both to record this valuable Hakka medicinal knowledge and to encourage its transfer to the next generation	Au et al. (2008)
China (P.R.)/Thailand	Study the effect of geographic separation of ethnic groups on local knowledge of medicinal plants used by Akha people in Thailand and China, who were separated 100–120 years ago	Number of use records per disease category in the two region of study, Comparison between Chinese and Thai Akha communities	Statistical analysis of differences and similarities in medicinal plant tradition (uses) between Chinese and Thai Akha	Broad	The Akha have had to apply their knowledge using a different set of species (ecological divergence)	Inta et al. (2008)
India	'. . . *record* the indigenous knowledge of Natuvaidyulu on plants to treat asthma.'	No	Comparison of some plants with clinical uses of the spp.	Asthma	Further critical ethnobotanical, phytochemical and pharmacological investigation of plants of the tribals of Andhra Pradesh	Savithramma et al. (2007)
India	'. . . assess the present status medicinal plant and to *document* the new information on medicinal plants used for the treatment of cold, cough and fever by the traditional Amchis of Ladakh.'	No, only of uses in disease categories	Plant parts used and herbal formulations	Cold, cough and fever	Proper phytochemical evaluation of selected plant species for the discovery of biologically active novel chemical compounds as a starting point for the development of new drugs and conservation of endangered plant species through *ex situ* and *in situ* conservation	Ballabh and Chaurasia (2007)
India	Highlight the new or lesser known medicinal uses of plant bioresource along with validation of traditional knowledge	Number of plants in specific categories of use	Uses in other region (ethnobotanical information) and existing phytochemical information	Broad	Open new vistas for the researchers to carryout in-depth phytochemical and pharmacological investigations	Singh and Lal (2008)
India	None stated	–	Screening for biological activity (testing for toxin-neutralizing effects)	Snake bites	None stated	Samy et al. (2008)
India	Document the new ethno-medico-botanical information and traditional use of medicinal plants against kidney and urinary disorders, and thus to conserve the rapidly disappearing traditional knowledge system of Amchis of Ladakh	None	Comparison of formulations used, number of species per 'formulation,' number of species used in each disease category., Information on collection and storage procedures, uses of plants against kidney and urinary disorder, preparation methods, combinations, doses, mode of administration, precautions and duration of treatment	Kidney and urinary disorders	Preserving and developing the traditional systems of medicine, and thus help to improve the health care of tribal population	Ballabh et al. (2008)
Indonesia	Elucidate the roles of herbal medicine in treatment of illnesses and to report medicinal plants and their uses, comparing with those mentioned in the encyclopaedic book series of Plant Resources of South-East Asia (PROSEA)	Quantification of all plant uses compared to other treatment alternatives	The research focuses on an assessment of peoples' response to illness episodes, includes ethnomedical aspects	Broad	Comparison with existing data published by PROSEA highlight discrepancies and similarities	Roosita et al. (2008)

Table 1 (*Continued*)

Country	Main objective(s)*	Quantification of plant usage	Other relevant data/evaluation parameters	Therapeutic categories	Authors' assessment of study's implications/potential further uses of this information	Authors
Jordan	The objective of the present survey is to *elaborate on the number, status, method of use and indication of ethnically important medicinal and herbal plant species* prevailing in Ajloun Woodland Reserve	ICF	Reported other local uses	Broad	Very general (developing efficacious remedies for various diseases)	Aburjai et al. (2007)
Jordan	Collect information from local population concerning the use of medicinal plants of the Mujib region; identify the most important medicinal plants used; determine the relative importance of the species surveyed and calculate the informant consensus factor (F_{IC}) in relation to medicinal plant use	F_{IC}		Broad	This ethnopharmacological inventory adds to the databank of medicinal plants used in traditional medicine an exhaustive list which can be targeted to search for new drugs. Moreover and as the collaborative use of both the F_{IC} and the UV allows for more objective selection of the species most frequently (highest UV) used future work will be emphasized upon evaluating the biological activities of these plants in order to validate this traditional knowledge	Hudaib et al. (2009)
Lebanon	'. . . the purpose of this work on the use of plants as a foundation for a national survey, so as to preserve the knowledge of these medicinal plants which is rapidly going to be lost' (sic) (p. 315)	Number of communities where a use was recorded, number and frequency of people mentioning the indication in a single plant	–	Rheumatism, neuralgia	It can be said that herbal remedies for rheumatic and neuralgic diseases are still used in Lebanon and thus it was of prime importance to document the evidence that still exists	El Beyrouthy et al. (2008)
Pakistan	Document the ethnoveterinary medicinal (EVM) practices for the treatment of different parasitic diseases of livestock in Cholistan desert	Number of use reports	Animal-based products used also included	Ethnoveterinary	The treatments and practices . . . need to be validated in order to identify those which can be of practical advantage in agricultural development	Farooq et al. (2008)
Pakistan	Documentation of botanical anthelmintics used in the traditional veterinary practices in Sahiwal district of Punjab	Frequency of usage	Dosage and mode of application	Ethnoveterinary	Species as promising candidates for their future use as anthelmintics	Hussain et al. (2008)
Turkey	'The aim of this study is to *collect i*nformation about the traditional medicine of this region before it is completely lost.'	Number of communities this information was recorded in	Quantitative assessment of frequency of use in therapeutic categories	Broad	Comparison with other regions (shared taxa). Documentation as such is essential due to loss of knowledge	Kültür (2007)
Europe						
Greece	The present study aims to identify the "mints" traded in the market of Thessaloniki and find the correspondence between scientific and commercial names and of plant smells. Furthermore, the essential oil content of the "mints" is estimated and the medicinal uses recommended for them are given in comparison to those reported from other Mediterranean countries	None for recorded reports. Number of medicinal uses recorded from the Mediterranean area for the various "mint" taxa	The study links ethnobotanical data with a phytochemical study of the essential oil content of the groups of species identified on the basis of smell	Illnesses treated with mints	Identification of quality control needs	Karousou et al. (2007)
Italy	Documentation of knowledge The aim of this paper is to highlight the eventual occurrence of an ethnobotanical *koin'e* extending from inland Campania to the coastal areas. Comparison of traditional plant knowledge with that reported for other the municipalities	Comparison of use with neighbouring communities		Broad	Comparison with neighbouring regions, rescuing information	de Natale and Pollio (2007)
Serbia	'. . . this study was undertaken in order to compose detailed *documentation* on wild medicinal flora, its ecological status and usage based on ethnobotanical knowledge in a locality with the most diverse flora and vegetation—Kopaonik Mountain.'	% estimates		Broad, but limited to 'wild medicinal herbs'	Significance of medicinal herbs in the lives of the peasants of this region	Jarić et al. (2007)

Spain	(i) Identification of rare medicinal plants and uses, so that they might be the basis of pharmacological studies; (ii) collection and preservation of the valuable popular knowledge concerning plant use; and (iii) establishing comparisons with other territories sharing similar characteristics	Frequency of recorded use		Broad	'Ethnobotanical studies constitute a valuable first step in the bioprospection process, which may lead to the development of new plant-based medicines.'	Rigat et al. (2007)
UK	Documentation of knowledge (frequency of use, culinary use, preference for traditional vegetables) and assessment of the perception of taste and potential medicinal value by migrant women	Frequency ranked into three categories	Link between food an health	Food with potential health benefits	Comparison with other studies, indicators of cultural relevance of such products: 'If traditional cuisines are an integral part of complex cultural heritage systems, and if they are used by migrant communities as a means of representing cultural identities, it is clear that public health researchers and policy-makers need to have a much better understanding of migrants' concepts and views regarding the health-promoting properties of traditional foods so that these can be utilized in future primary health care programmes.'	Pieroni et al. (2007)
UK	(1) A comparison of fieldwork data on plant species and treatments used by Colombians in London and Colombian ethnobotanical literature in order to analyse the potential continuity of traditional health care practices. (2) An evaluation of treatments reported in Colombian literature (for all species actively used by Colombians in London) that were not supported by fieldwork data in order to study potential loss of knowledge and/or practices. (3) An assessment of species and treatments used by Colombians in London that are not described in Colombian ethnobotanical literature in order to find potential newly acquired elements in the folk pharmacopoeia of the Colombians in London	Estimation of frequency of usage of a species; quantification of 'active use-categories'	Comparison with data from ethnobotanical studies in Colombia and detailed comparison with these data	Broad	Cross-cultural adaptation related to health care practices is a multifaceted process	Ceuterick et al. (2009)

ICF: informant consensus factor (F_{ic}, see text); RI value: elative importance value.

* Emphasis by authors of this review.

- What is the cultural logic behind the use of this biodiversity and is there a targeted selection of specific taxa?
- How are food and medicinal plants interrelated?
- What has changed over time and what has caused this change? What impact has this had on the society?
- How does the use of medicinal plants compare, for example, to their use in a neighbouring community?

In each case these research questions are linked to one or more testable hypotheses.

In the future it will be essential to ascertain that ethnopharmacological field studies are based on the testing of such hypotheses. To illustrate this with an abstract example: ethnic group A in one region of a country is well known for its extensive use of plants and these data have already been published However, no studies have so far focused on a neighbouring group B. Consequently, it will be of interest to test the hypothesis that these two neighbouring groups share an important part of their local and traditional knowledge about medicinal plants. A recent example of such a study, comparing the ethnobotany of two neighbouring Amazonian peoples, shows how deeply varying cultural forces can shape significant differences in the use of essentially the same environment (Shepard, 2004). Another example is the work by Inta et al. (2008, cf. Table 1) who compare the local knowledge of medicinal plants used by Akha people in Thailand and China, an ethnic group separated 100–120 years ago, although unfortunately the number of informants the authors worked with in this study is too small to expect any reproducible results. Researchers may then want to compare quantitatively the taxa the two groups share, and they may also decide to evaluate whether there have been extensive trade or other links between the two groups which facilitated such exchange of information. Alternatively, they may wish to focus on what is unique to culture B and assess what makes this part of the culture's knowledge system so special (e.g. are the plants preferentially used for specific purposes).

One could also test the plants (or a subset of them) documented for a third culture C in an *in vitro* assay, which is relevant for the local and traditional uses and then assess whether the use corresponds to these *in vitro* data (or not). On the other hand, one could assess the pharmacological biomedical knowledge already available in the scientific literature and assess whether the local and traditional use can be explained in biomedical terms (Ortiz de Montellano, 1975). This may both be on the basis of emic (i.e. culture-specific) or etic (i.e. one *not* based on indigenous concepts) criteria.

In order to illustrate the need for a hypothesis-driven approach a third example has to suffice: ethnic group D lives in an environment which over the last generation has been degraded very dramatically due to external factors (e.g. extensive logging). The starting hypothesis could then be that knowledge about plants from primary forests is restricted to older members of the community who have a first hand knowledge of the primary vegetation. One can then test this, for example, by assessing whether younger members of the community are more likely to use plants commonly found in secondary (disturbed) vegetation or, alternately, whether they are more likely to use chemically defined medicines. Importantly, in both cases a quantitative and comparative element needs to be included in such an analysis.

In very simple terms, this requires a detailed assessment of previous studies conducted in a country and the critical assessments of the gaps in our scientific knowledge. As an aside, it is important to recognize that simple differences in the amount of knowledge held by older people is not evidence of the "loss of knowledge." Loss or change in knowledge can only be clearly demonstrated by comparative studies done over time.

All the above cases highlight ways we as researchers can strengthen our analysis. If none of the above is possible, quantitative and statistical analysis of the survey needs to indicate which subset of species (botanical drugs) is used so heavily that there really is a good traditional basis for use. Or one may want to link such botanico-medical knowledge to other domains within a culture. Prime examples are the numerous studies on the use of hallucinogenic species in the context of traditional and local medicine (e.g. Wilbert's detailed monograph on tobacco, 1987). In this case the information gathered is put into a broader context by rigorously studying related elements of the culture. Minimally, any field study should examine how plant knowledge is distributed in a society, and include some sort of consensus analysis to highlight the difference between common and specialist knowledge (Moerman, 2007; Weller, 2007).

It is also important to recognize that the logic of non-western cultures is often more expansive than is our more science-driven system of thought. Thus, in many traditional societies, there are at least as many plants used "magically" – to protect infants from witches or evil spirits, to enhance an athlete's performance or to help one run faster, to find animals more effectively, or to make one's arrow fly straighter – as there are for the mundane concerns of treating diarrhoea or sore eyes. Frequently, the same plant has both types of uses; often one cannot understand the logic of the use of a plant in the second category without understanding it in the first (see e.g. Moerman, 2007). It is crucial that field studies do not neglect these emic categories, i.e. the indigenous concepts about these topics.

On the other hand, it is necessary to highlight that there is another approach: it has been argued that a repository is needed for such information, similar to those which exist, for example, in databases for microorganisms, cell lines, genes and proteins. In this context the information is essential, and as suggested by Verpoorte (2008), ethnopharmacologists need to think about the best ways that this can be achieved. In recent years some countries have also implemented central facilities to store such knowledge; the best-known case is the Indian National Institute of Science Communication and Information Resources [NISCAIR] of the Council for Scientific and Industrial Research [CSIR] (www.niscair.res.in, New Delhi 110012, India).

As can be seen in Table 1, the majority of the 40 contributions we discuss here are from countries which are currently undergoing rapid and often traumatic change, which implies a rapid loss of this type of knowledge. For example 11 contributions are from Africa (including 3 each on Ugandan and Ethiopian indigenous knowledge systems), 8 from South or Central America (including 4 from Brazil), and 14 from Asia (including 4 from China, and 5 from India). No such studies from Australia-Oceania or North America and five from Europe have been published during this period. However, in our view, this sort of documentation can only be *one* of the functions of ethnopharmacological field studies published in the *Journal of Ethnopharmacology* and such studies should go beyond simply listing local and traditional knowledge.

2.2. Basic requirements

Numerous basic ethical (cf. Rosenthal, 2006) and methodological requirements exist and have to be met. Clearly a project has to be reviewed and approved by the relevant ethical and other review boards and the reviewers need to first familiarise themselves with the legal requirements of a country and the ethical basis of such research [as exemplified, for example in the statement on ethics of the AAA (1986) or the Code of Ethics of the International Society of Ethnobiology http://ise.arts.ubc.ca/global_coalition/ethics.php)]. Despite of this such projects may not succeed for complex reasons (Berlin and Berlin, 2005b). It is beyond the scope of this article to discuss the specific requirements and obstacles in terms of permits and informed consent declarations in detail but every proposal will

have to comply with these requirements (e.g. Cotton, 1997; Martin, 1995; Heinrich, 2001, for principles on access and benefit sharing see: http://www.kew.org/conservation/principles.html). This is not only requested by the countries where such studies are conducted, by funding agencies and academic institutions, but also, for example, by learned journals (in the US for example, the Institutional Review Boards, in Europe Ethics Committees, both groups with varying responsibilities). In a few cases it may also be a requirement that certain information is not passed into the public domain, but is only stored by the investigator or by the local community where the research has been undertaken, for example the Aurukun Ethnobiology Database (Edwards and Heinrich, 2006). This database is now mainly used in the community, for example, to inform students' about the knowledge of the elders. Our general view is that arrangements like this should only be agreed to by investigators as a very last resort (Moerman, 2008).

In conclusion, the *Journal of Ethnopharmacology* is dedicated to publishing ethnopharmacological information and all authors need to ascertain that they can publish the information on local and traditional uses in an international scientific journal and thus make it available for further academic and commercial research.

3. Challenges in conducting a field study

3.1. Minimal methodological standards—biology

This part is generally based on the methodological requirements for any sort of botanical research. Full botanical documentation is achieved by collecting voucher specimens and depositing them both in an international accessible herbarium (like the National Herbarium of a country) – and for local access—also in regional herbaria. The collection requirements for botanical samples are well described and included specialized methods for example for fungi, Bryophyta or succulents, as well as for zoological specimens. Of course, botanical (and all other biological) nomenclature (including authorities) requires checking in an internationally recognized database like the International Plant Name Index (IPNI) (http://www.ipni.org) or W3Tropicos (http://www.mobot.org). In some cases, samples of commercial botanical drugs or of other preparation (including complex mixtures of botanical drugs or drugs which have been processed in a special way) may need to be deposited. It is often argued that the collection of specimens of very common plants and cultivated plants is not necessary, but for the sake of later assessment and the full botanical identification (also on a subspecies level) this may be desirable. The identification requires the collaboration with well-equipped herbaria and often exchange with specialized collections.

A prerequisite for all this work are the relevant permits, for conducting the research, collecting and transporting (and often exporting) the specimens (see Section 1). A plant drier in order to effectively dry the specimens and a standard plant press are essential instruments. It is indispensable that at least some of the researchers are fully trained in all these aspects of field research. Full documentation both of the research strategies used in the project and of the relevant samples is a sine qua non of any ethnopharmacological research report (for details on botanical methods in general and more specifically for the documentation of useful plants see Bridson and Forman, 1992; Cotton, 1997; Bennett and Balick, 2008 and also Martin, 1995).

3.2. Minimal methodological standards—anthropology

An essential element of any ethnopharmacological field study needs to be a sound understanding of the sociocultural basis of the ethnic group the researchers collaborate with and an integration of the ethnopharmacological information with the cultural basis (Etkin, 1988). Plants are not used in a cultural vacuum and any field study will have to be put into the sociocultural context of the particular group. In simplistic terms a short background chapter will have to include information on topics like

- the ecological setting (in terms of the environment a community lives in and how this environment is changed by human use);
- the socioeconomic basis of the culture, including dependencies with neighbouring cultures and the groups' integration into the national cultures (which may be very strong as in case of urban migrants, e.g. Sandhu and Heinrich, 2005; Pieroni et al., 2007), or still relatively independent;
- their linguistic and cultural characteristics (including, if available, information on the size of a group, the degree of monolingualism, as well as important cultural traditions);
- gender-specific questions of knowledge distribution and the use of such resources;
- special aspects of the culture and the reasons why they are of particular scholarly (and/or applied) interest.

In this review we have neither tried to be comprehensive, nor do we want to suggest that these guidelines can be used like a recipe from a cookbook. Instead, after an initial decision on what researchers want to study and where they want to do it, a systematic and validated methodology needs to be developed that is then put to the test using established methods. Numerous social science oriented methods manuals are available (Bernard, 1988 and other editions, 2000a and b, Fowler, 1988; Bowling, 2002; and specifically in the field of ethnobotany Alexiades, 1997, c.f. Stepp, 2005). Similarly, investigators have to decide which specific methods will be best suited to the specific situation. Examples include structured and unstructured interviews, focus group discussions, ethnobotanical walks with informants, work in schools including the use of drawings and many others.

In the following we want to highlight an anthropology-based conceptualization of ethnopharmacology. As pointed out above, studies of indigenous or other local resources may be linked with a variety of other disciplines, including sociology, political sciences, or economics. However, most rely on anthropological concepts and from the huge diversity of approaches we have selected some which we consider to be particularly pertinent (Heinrich et al., 2006).

Anthropologists have argued for a long time that we have to overcome a paternalistic and simplistic representation of minority cultures. It is beyond the scope of this article to expand on this, but clearly every ethnopharmacologist who has engaged with a culture will appreciate the diversity and richness which cultures display. In general terms, such descriptive aspects and scholarly approaches to study local and traditional knowledge systems have been criticized from a multitude of perspectives, but ethnopharmacologists should certainly be keen to provide what Geertz (1973, 1983) termed 'thick description': a rich and detailed account of a culture. It is worth expanding on this in more detail in order to highlight the importance of a detailed ethnographic understanding of a culture.

In 1973 the term "thick description" (borrowed from the British philosopher G. Ryle) was introduced into anthropology; the concept highlights the proposition that (local) knowledge is a system of symbols (Geertz, 1973, 1983). Geertz was interested in how knowledge is structured within a culture. It is essential to understand these systems of symbols and to properly describe them in detail. Thus a "thick description" is one based on the experience of a researcher who often comes from a foreign culture, which simultaneously shows meaning systems which have not been visible to the indigenous groups. "Local knowledge" is an all encompassing concept. As Geertz has put it focusing on legal questions:

> "Like sailing, gardening, politics, and poetry, law and ethnography are crafts of place: they work by the light of local knowledge" (Geertz, 1983, p. 167).

Thus all aspects of culture rely on a complex system of thought which in its totality forms local knowledge. Therefore, local knowledge about food and medicinal plants or any other aspect of local knowledge is just one part of this complex system, which has an important meaning to the members of the culture. The challenge is to see "... the broad principles in parochial facts" (Geertz, 1983, p. 167).

These concepts provide a strong theoretical foundation for working on the complex meaning systems of indigenous and "'traditional" societies. That some of this is widely accepted, as can be seen in the use of a common acronym "TEK" – traditional ecological knowledge – this acceptance often masks a casual attitude toward the complexity of these ideas, when, for example, we see attempts at "rapid assessment of TEK" where it is imagined that one can resolve these matters in a few days. Research using the term often lacks a systematic and detailed discussion of applied aspects of such knowledge systems.

A starting point for such a discussion needs to be the question: "Who on a local level is interested in preserving, disseminating or using this information?" We propose that there are excellent models for the requisite rigor in gathering and understanding these ideas. For example, intricate cultural patterns impacting on the groups' environment and ideally favouring environmental maintenance exist. Atran et al. (1999) studied the behaviours, cognitions, social relationships and awareness of ecological complexity involving animals, plants, and people and practices in three Guatemalen groups and showed that this has a direct impact on the lowland ecosystems.

TEK, with a strong interest in the application of science, has been defined as "a body of knowledge built up by a group of people through generations of living in close contact with nature" (Johnson, 1992); our view is that this statement is somewhat naïve, since people do not live in "nature," they live in a "culture," but we again want to stress that it is essentially the authors' challenge, task and opportunity to develop a conceptual framework which best fits her/his needs and ideas.

Another definition describes TEK as a "cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes et al., 2000). It includes a system of classification, a set of empirical observations about the local environment, and a system of self-management that covers resource use. The quantity and quality of TEK varies among community members, depending upon gender, age, social status, intellectual capability and profession (hunter, spiritual leader, healer, etc.). TEK often includes knowledge of very different sorts than those appreciated by investigators, including ghosts, spirit ancestors, and other variously malign and benign actors; these elements of the environment are often extremely important in understanding local customs and behaviors (Rappaport, 1984).

According to Johnson (1992, p. 1971) 'with its roots firmly in the past, traditional knowledge is considered to be both cumulative and dynamic, building on the experience of earlier generations and adapting to the new technological and socioeconomic changes of the present.' Compared to Geertz's emphasis, TEK highlights the applied role of such a knowledge system and there is little interest in symbolic or other theoretical aspects. TEK is very popular with activists and applied researchers in all fields (e.g. Johnson, 1992), which involve the local and sustainable development of resources, the critique of outside involvement in such developments and most notably the implications of the Convention on Biological Diversity (CBD or Convention of Rio do Janeiro adopted in 1992, cf. Secretariat of the Convention on Biological Diversity, 2001). Despite its apparent restriction to ecological knowledge it normally also encompasses botanical, zoological, pharmaceutical, geographical, geological, and many other aspects of local knowledge. This concept also provides a clear recognition of the enormous contribution that traditional knowledge systems have made and can make in the future both to the conservation and the sustainable use of biological diversity. Most indigenous and independent local communities live in regions where the vast majority of the world's plant genetic resources are found. Simultaneously these activists and scholars argue for urgent action to safeguard such traditional knowledge and for a broad view of how humans and the environment interact. Importantly, this discussion proceeded with a focus on non-European indigenous groups while far less attention has been paid to the situation within Europe (Heinrich et al., 2006; Nebel et al., 2006).

One of the important outcomes of the discussions on TEK systems has been the broad recognition, *that a new relationship between researchers and "keepers of traditional knowledge" is needed*. Since it was agreed upon in 1992, the Convention on Biological Diversity has been at the centre of the discussions about equitable benefit sharing between the "South" and the "North." Some activist groups argue for a complete ban on bioprospecting or other research activities which have the potential of resulting in new economically exploitable products, while others argue for a novel relationship between keepers of traditional knowledge and (mostly "Western") researchers (see below). These two related, but diverse streams of thought have been integrated in recent years as summarized very clearly by Maffi (2001) in a volume that addresses the link between linguistic and biological diversity and the need to counteract the linguistic and cultural erosion, which is taking place worldwide on an unprecedented scale:

> "... landscapes are anthropogenic not only in the sense that they are physically modified by human intervention, but also because they are symbolically brought into the sphere of human communication by language: by the words, expressions, stories, legends, songs and verbal interactions that encode and convey human relationship with the environment and inscribe the history of those relationships onto the land." (Maffi, 2001, p. 12)

As mentioned above, this discussion cannot be comprehensive but instead offers one, currently very widely shared, line of thought in terms of conceptualizinglocal and traditional use and more specifically using an anthropological framework. Clearly, very little of this scientific framework has been used in the studies we have reviewed here (the most notable exception is Pieroni et al., 2007). Ultimately, it will be crucial to ascertain that a scientifically accepted terminology is used in any project and that all aspects of the project are described with precision and throughout (McClatchey, 2005). To cite just one example, the term 'traditional' is often used without considering that all cultures constantly develop and adapt to changing environments and often it may be better to talk about the specific medicine one is writing about (e.g. Nahua, Yoruba or Singhalese medicine).

3.3. Minimal methodological standards—ethnomedical questions

Ideally in any project like the ones discussed here, a medically qualified research collaborator would conduct a clinical assessment of patients and help with translating indigenous and local diagnosis into biomedical terms. However, especially based on our own experiences with individual PhD-studentship-funded project (e.g. conducted by ML, SE, and MH), very few projects have the funds to achieve this. Alternatively, researchers need to document not only the local terms for medicinal plants, but also the indigenous terms

of illnesses and how people describe the signs (or symptoms) of these illnesses (e.g. Anderson, 2002; Berlin et al., 1993; Heinrich, 1994). Freelisting may help to identify the culturally most important diseases. While this may not be reported in the same article as the ethnobotanical material, it should be part of the project as a whole.

Diseases for which, in a strict sense, no traditional treatments exist, pose particular challenges. Hypertension, diabetes, most cancers, and more recently, AIDS, are illnesses that were traditionally unknown. In the case of diabetes, some of the symptoms might have been recognized, but not the disease as described biomedically today. Therefore, treatment had to be developed (or, if one wants, invented) locally or adopted from neighbouring cultures. In this case it will be essential to understand how the disease state had been diagnosed, what (if any) concomitant medication is taken, who diagnosed it (e.g. a medical doctor or nurse), and how this has led to the selection of a specific local treatment. In addition, it will be of interest to know what the indigenous names of diabetes are, or whether the terms were borrowed from other languages.

Authors must recognize the extreme difficulty (Bourbonnais-Spear et al., 2007) – indeed the frequent impossibility – in translating symptoms from one disease to another across cultural lines. So far few if any studies in the *Journal of Ethnopharmacology* have included such specific diagnostic ethnomedical questions and, while this is highly desirable, currently it would be very problematic to include such requirements. Therefore, this is one of the discipline's future tasks.

3.4. Minimal methodological standards—quantifying the information

In the past decade *understanding* the plant use and rationales for selecting specific natural resources in traditional, local and alternative medicine has become a key concern of ethnobotany, ethnobiology and ethnopharmacology. In ethnobotanical research it is no longer sufficient to simply and uncritically provide lists of species and plant families used, but additionally to contribute to an understanding of the cultural basis and to draw conclusions from such reports on local medical use. As highlighted by Einstein one could say: "Information is not knowledge." One of the early examples of such a quantitative approach was used in the assessment of the use of chewing sticks in Africa (Adu-Tutu et al., 1979) and was later developed somewhat differently for comparative purposes (Heinrich et al., 1998; Teklehaymanot et al., 2007).

One approach, which helps to make clear statements, is to analyse the data with an appropriate selection of statistical methods and by the formulation of a clear hypothesis. One branch of statistics, descriptive statistics, is in one way or another present in most, if not all, ethnobotanical studies. Descriptive statistics comprises the collection, classification, summarizing and the presentation of the data obtained. It is the branch of statistics that includes data summaries and presentations like tabular listings, graphical descriptions (e.g. by means of diagrams) and numerical characterizations of the data through the calculation of parameters including measures of central tendency (arithmetic mean, median, mode) and measures of variation (variance, standard deviation, range).

Before beginning with collecting and counting, that is, with a statistic census, something somewhere has to be defined and identified. What is reflected by many of the papers reviewed here is that many different things can be counted. However, counting anything and everything is not a relevant approach in field-based ethnopharmacology. Early in a project a researcher will have to decide which aspects can meaningfully be assessed by using quantitative methods. For gathering ethnic myths and legends a qualitative approach is generally more adequate. Very often the most important plant families of a certain ethnopharmacopoeia are reported, based on a count of medicinal species. This does *not* help in order to achieve a critical understanding of local plant use unless the number of species used are compared to the total flora available in the region (cf. Moerman, 1998, 2007). In addition, preparation modes, plant parts used, routes of application and the life forms of medicinal plants may in some cases be quantified but only if it is put into relation with the use-categories. If herbs and little shrubs are the most frequently used life form, leaves will inevitably result as the most frequently used plant part. Pieroni et al. (2007) provide their species list with a frequency of consumption but not by frequency of citations, which would have added the final information to an otherwise interesting work. Therefore, *the strategic question here has to be to critically ask oneself what contribution the quantification of a certain set of parameters makes to resolving and understanding a scientific problem.*

The *Journal of Ethnopharmacology* some years ago introduced five rules for potential authors. Rule number 4 specifies that it is important that one is able to make choices for further studies and to have information on how frequently plants are cited in surveys. Therefore, uncritically listing species resulting from ethnopharmacological and ethnobotanical surveys without information about the cultural importance of these species, e.g. by giving the frequency of citation of use by informants, is grounds for an immediate rejection of the manuscript.

Information on the frequency of citations confers transparency to such studies since it offers one way to assess the relative cultural importance of a species or a group of species and this provides the opportunity to compare such studies. In statistics this is called the "Law of large numbers" indicating that the more sampling (extraction of single-point data) is made, the more accurate and significant extrapolations can be drawn with regard to the main unit (i.e. the measuring/sampling error of bigger data sets will be reduced).

Consequently, in ethnobotany the cultural importance of species is reflected more accurately the more informants and use reports have been obtained (and cited) in an ethnobotanical survey. Ideally, ethnobotanical and ethnobiological fieldwork covers the vegetation cycles and flowering period of all plant species and all the morphological states of animal species, that is, at least 1 year. While it is not possible to define minimum number of informants or a minimum number of use reports, every attempt needs to be made to obtain a representative sample of the group one collaborates with. The exact size of the sample depends on numerous factors, including the population size, its spread over a region and the goals of the project and, therefore, project leaders need to assess this at the start of a project.

The ethnobotanical survey and interviewing can either be directed at a group of specialists (Heinrich et al., 1992; Leonti et al., 2001) or at a representative percentage of the total population. In the first case it is important to identify and individually contact the knowledgeable persons. Generally, working with the specialists, semi-structured interviews and freelisting are used, while during the survey of a representative part of the total population validated questionnaires and freelisting are implemented more frequently.

Culturally important species with more than average number of citations may be:

- More effective,
- used for a more common disease or event,
- easily available, or
- have a special cultural significance.

On the other hand, species with few (below average) citations may:

- Be artefacts (i.e. the result of a mix-up during the interview),
- have fallen into disuse because of cultural adaptation,

- be ineffective for the condition(s) reported,
- have become rare species, or
- might belong to cultural fringe knowledge.

One must be careful since it may also be specialist knowledge of unusually high value. However, most importantly the presentation of a species list with frequency of citations allows readers to appreciate the overall situation (for example in a community or with a group of healers) and to draw their own conclusions. By taking into consideration the number of consulted informants it furthermore permits anyone to establish ratios of cultural importance and compare this with other data sets.

Notwithstanding the introduction of the rules of 5, the papers reviewed here rarely provide such quantitative information, which not only casts a doubt on the authors but even more sadly, on the reviewers.

One widely used method for analysing quantitative data is based on the works of Trotter and Logan, 1986 who introduced the informant agreement ratio (IAR), also called informant consensus factor and calculated as follows:

$$F_{IC} = \frac{n \cdot UR - n \cdot taxa}{nUR - 1},$$

where n is the number and UR is the use reports.

This factor is commonly applied in studies based on freelisting interviews and open interviews within specific cultural domains (e.g. medicinal plants, food plants) and use-categories.

The IAR or F_{IC} gives information about the consensus or consistency of the informants for the treatment of a certain use-category, e.g. emic illness or symptom groups. However, the IAR (F_{IC}) approximates its relevance with larger numbers. Hence, it tells us something about the cultural coherence of the selection of a set of medical agents used in the treatment of a certain illness category and nothing about the importance of the single plant species used.

To assess the importance of a single species it is a reasonable to propose that the greater the independent citation of a particular species for the treatment of a certain illness category, the greater is its cultural importance; Berlin and Berlin (2005a). This is one of the simplest and most widely employed indices and could be termed "frequency of citation" or "frequency of quotation" (Tardio and Pardo-de-Santayana, 2008).

Various strategies for analysing quantified ethnobotanical data were recently reviewed and assessed by Tardio and Pardo-de-Santayana (2008). In their conclusion they propose the 'cultural importance index' (CI), which they perceive to be most objective because it is based on the informant consensus (number of citations) and additionally considers the diversity of uses, that is, the number of use-categories for which the species is cited. This index is, however, dependent on the numbers and classification of the use-categories. Such use-categories should be built based on the emic perception of the informants, while standard categorizations proposed by the WHO, for example, should not be consulted. These emic categories or cultural domains can be identified with the help of freelistings (Quinlan, 2005) and require an approach involving intensive fieldwork. These use-categories inherently vary between cultures and make inter-cultural comparisons based on indexes more difficult. Therefore, such indices are, to a certain extent, always a subjective transformation of data. Moreover the numbers resulting from such calculations are not as readily accessible as use reports and should therefore be presented together with the absolute use-frequencies (i.e. use reports) as done by Alves and Rosa (2007) or as exemplified by Giovannini and Heinrich (2009) who conducted freelisting interviews of the two cultural domains—medicinal plants and locally available pharmaceuticals. An approach to analysing a set of data which is always useful is to compare it with similar sets of data and record of use reports so that the new data set can subsequently be subject to statistical comparison with other quantitative surveys.

For hypothesis testing, inferential statistics need to be applied. Inferential statistics is used when data i.e. information has been gathered or is available only for a fraction of the subject of study. In this respect incomplete knowledge exists. The acquisition of comprehensive data able to furnish total cognition is in most cases too expensive, too tedious or sheer impossible. By means of inferential statistics it is possible to gain cognition about the whole object of study based on the relatively few data gathered. The inference that is made from the sample, however, is tied to a margin of error, which can be quantified by means of probability calculations (Bourier, 2006, p. 3). By means of inferential statistics we can exclude that something happened by chance. In ethnobotany this is of relevance mostly in inter-cultural comparisons where data of one ethnic group, culture or region is compared to that of another. Ideally the comparison is made with data sets which have specific features in common, for example, culture, history, space or ecology. The most detailed example is Moerman (1996) which includes standardized information not only for botanical aspects, but also information on use-categories and ethnic groups for which the uses were recorded; this data set was used in various comparative analyses. However, it makes little sense to compare ethnobotanical records and uses of, hypothetically, the Swiss Alps with that of the Mapuche Indians. In conclusion, the most important prerequisite to allow for comparison is that the data set has been recorded with a comparable scientific approach and methods.

Most importantly, a quantitative approach guarantees more possibilities for inferential hypothesis testing and for multi-directional statistical analyses than do non-quantitative approaches. Statistical comparisons of quantitative ethnographic data may open up new perspectives and harbour conclusions about data sets, which otherwise would have remained in the realm of speculations or would have remained undetected at all. Again, it is not feasible to provide prescriptive methods, but here we highlight how more robust ethnobotanical approaches may be developed.

In conclusion, an essential aspect of field studies needs to be a rigours and clearly documented methodology, a representative sample size and the (semi-)quantification of data preferably by documenting the number of recorded use reports.

3.5. *Using databases for storing and subsequent analysis of information*

Increasingly ethnopharmacology, like biology, has become an information science, with dependency on expert-curated databases to manage the data generated from research findings and published literature (Morgan et al., 2004). A rigorous methodological approach in ethnopharmacology invariably requires the use of a database that ideally serves two main functions: storage of data, and facilitation of analysis, such as quantification and comparisons. As in other cases, prior to starting the research it is essential that the researchers and collaborators clearly define what strategic objectives they want to achieve with a database. A database may, for example, be based on a community study and used mainly in the context of local educational or outreach projects (for example, as teaching material, Edwards and Heinrich, 2006) or it may serve as a repository of previously published information for a whole subcontinent (Moerman, 1998).

One area of potential conflict in ethnopharmacological research is determining who is ultimately going to be in control of the data that are collected and stored in the database, and where the database is going to be held. Will it be in the public domain and made available over the Web, or private with limited password-controlled access? Small, local databases may be effective for managing (and even repatriating) data for say, a particular minority

ethnic group or area (e.g. the Aurukun Ethnobiological Database, see Edwards and Heinrich, 2006), but these may be totally inappropriate in areas where IT capabilities, or even literacy skills, are limited. Locally managed databases, while serving a function for local peoples, on the other hand may not be ideal from a scientific perspective, since they may be developed to different standards, thus inhibiting comparisons of data between groups. There are advocates of large, centralised databases (Skoczen and Bussmann, 2006), which by their nature permit easier comparisons of data across regions (e.g. Moerman's database of Native American Ethnobotany, http://herb.umd.umich.edu). However, large centralised databases may raise a number of issues relating to access and intellectual property rights (IPR). These issues warrant an entire paper of their own, and in fact much has been written about IPR in ethnopharmacology already (Soejarto et al., 2005), and thus outside the scope of this current paper. Suffice to say that these are important initial considerations when developing any ethnopharmacological database.

The most appropriate choice of database management system will often vary, depending on factors such as the current operating system, potential size of database, number of users, cost, etc., but what all databases should have in common is a well-thought out data structure or schema. A large flat two-dimensional table (e.g. an Excel spreadsheet) will cause problems due to the inevitable duplication of data values, which may result in data inconsistency. A relational database addresses this by creating multiple tables of related data, with the relationships between these tables representing the 'real-world' multi-dimensions. A well-structured schema that includes all relevant tables and correct relationships between them, is not only easier to maintain, but also facilitates analysis of data. *Normalisation* is the process, or series of steps, which database developers use to refine the schema so that data and data dependencies are preserved, data dependencies make sense, and that redundant data are eliminated (Kolahi, 2007). These steps reduce the amount of space a database uses, ensure that data are logically stored, and reduce the chance of data inconsistency. While normalized tables are the basis for a database, it is also important to look at the design of the database as a whole, and ensure that correct relationships and referential integrity are in place.

Adherence to data standards will facilitate data consistency, exchange of data and comparative analyses. A number of botanical and taxonomic standards have been developed over the years, some of which could be incorporated into ethnopharmacological databases. These include the Economic Botany Database Standard (Cook, 1995), which has use-categories, including a detailed breakdown of medicinal uses (developed from a biomedical perspective). This is potentially useful in ethnopharmacology, although it does not incorporate an option to include local terminologies. Also, the disease categorization does not always correspond easily to a biomedically defined disease; in which case, broader less-defined medicinal categories have to be used. The World Health Organisation's (WHO's) International Classification of Diseases (ICD), also has 22 chapters or broad categories, further subdivided into separate categories (WHO, 1994), each with a unique identifier code. This is of potential use in an ethnopharmacological database since it is a globally recognized standard used by governments for generating statistics on morbidity, and is available on-line. It is, however, always important to remember that the local understandings of disease and illness which may have the most relevance for local consultants – protecting their infants from ghosts or evil spirits, for example – will probably not appear in such WHO lists.

Ethnopharmacological data usually pertain to biological organisms and derived products, predominantly from flowering plants, but also to a lesser extent gymnosperms, ferns, mosses, algae, lichens, fungi and also some animals and marine organisms. An ethnopharmacological database needs to contain a taxon table, for holding known scientific data associated with the organism. Nomenclature is vitally important, as the name is the 'key' to the data. At a minimum taxon records should contain the accepted scientific name (genus, species, etc.), authority, family, and, where they exist, synonyms. As with other branches of science, taxonomy is constantly evolving, and increasing use of molecular analytical tools, especially DNA analysis, has led to more accurate knowledge of phylogenetic relationships. This has resulted in some taxa being re-categorized, into, for example, another family, with corresponding amendments to accepted nomenclature (cf. Section 3.1).

While scientific names are essential, in addition vernacular names are usually required. Of course, care must be taken when using vernacular names, as they may apply to more than one scientific taxon, which may or may not be closely related. For example, there are a number of plant species known commonly as "Chamomile," including *Anthemis nobilis*, *Matricaria chamomilla*, *M. discoidea*, and *Tanacetum annuum*. Conversely, a scientific taxon may be known by a number of vernacular names and categorized in folk taxonomies that do not correspond exactly to scientific taxa. This relationship between scientific taxa and vernacular names is 'many-to-many'—a sign of 'complex data.' 'Many-to-many' relationships are avoided in a relational database by creating another separate entity that combines the keys to both tables. This entity has a one-to-many relationship with both the scientific taxon table and vernacular names table, thus creating a valid downward link to both tables and facilitating querying on either entity. In addition to taxon and nomenclatural data, voucher specimen data is vital. Misidentification of a species will invalidate other associated data, thus having a permanent record in the form of a voucher lodged at a recognized herbarium will serve as proof—an indemnity in case of misidentification and any taxonomic revisions. An ethnopharmacology database is also likely to store data about other entities and their attributes, including uses, collection data, phytochemistry, toxicology, references, etc.

Other standards that exist in the public domain that may be of use in an ethnopharmacology database are those produced by the Biodiversity Information Standards (TDWG—formerly known as the Taxonomic Database Working Group http://www.tdwg.org). These include standards relating to geographical distribution of plants, plant name authorities, plant occurrence and status, in addition to the Economic Botany Data Collection Standard mentioned above.

A few notable databases that contain ethnopharmacological data are currently available over the Web, including NAPRALERT^{SM}, a comprehensive natural products database, which includes ethnomedical information and pharmacological/biochemical information of extracts of organisms and secondary metabolites (http://www.napralert.org). Dr. Duke's Phytochemical and Ethnobotanical Databases (http://www.ares-grin.gov/duke/), and the Plants for a Future Database (http://www.pfaf.org/links/linksOldBib.php) are other examples. The USDA's Plants database (http://plants.udsda.gov) holds useful information on US-occurring plant species including taxonomy, images, distribution, threatened and endangered status, species of cultural significance and their usage; note that Moerman's http://herb.umd.umich.edu is linked to the USDA Plants database by clicking on the binomial.

It is likely that the emerging semantic web technologies including adoption of ontologies will result in a revolution in how data, information and knowledge are accessed and exchanged. This will undoubtedly have ramifications for many scientific disciplines, including ethnopharmacology. The concept of the 'ontology paradigm' applied to information science has led to the development of defined ontologies for use in bioinformatics (Schulze-Kremer, 2002), which are also likely to be of potential benefit to areas of ethnopharmacological research and drug dis-

covery (Gardner, 2005). While the term 'ontology' has been in use for centuries, a widely cited definition used by computer scientists is: "*A specification of a conceptualization* [of a knowledge domain]" (Gruber, 1993).

Essentially an ontology can be a standardized glossary of keywords that is arranged in a structured order or network. For example, increasing numbers of scientists are collaborating to develop controlled vocabularies relating to their disciplines which will facilitate data exchange and data mining across the Web, irrespective of data source. This is, of course, dependent on implementation of the commonly adopted ontologies within each data source. Groups which have adopted use of ontologies include the Gene Ontology consortium (http://www.geneontology.org/) that aims to provide a controlled vocabulary to describe gene and gene product attributes in any organism, and the Plant Ontology Consortium (POC) (www.plantontology.org) who are developing a controlled vocabulary for plant structure (anatomy) and growth stages. Since ontologies are machine-readable, this allows applications to be standardized, while allowing the domain-specific information to be modified (McGuinness, 2003). Development of an ontology or ontologies specifically for ethnopharmacology will require agreement and collaboration between scientists, although the extent to which ethnopharmacologists will take up this challenge remains to be seen.

Very often this information and the use of databases will not be visible to the readers of a learned journal like the *Journal of Ethnopharmacology*, but such information storage offers a multitude of applications which will be addressed in the following sections. Most importantly, it offers a strategy for developing a data set which can then be analysed in more detail by the researchers.

4. Future uses of such studies

4.1. How can this information be used for example in the context of experimental research

The most immediate direct link between field studies and pharmacological testing is provided by studies where researchers test a plant based on their traditional use. Famous historical examples include the discovery of curare based on the use of arrow poisons, which was the outcome of research efforts by explorers like Alexander von Humboldt and one of the fathers of pharmacology, Claude Bernard. A very recent example is the ongoing development of novel anticancer agents based on traditional European knowledge of *Euphorbia peplus* L. (garden spurge), used popularly in the treatment of skin keratinosis, warts, and other skin disorders (Heinrich, 2009). Another recent example is the study by Michel et al. (2007), linking data on the local and traditional use of medicinal plants in a Q'eqchi community (Guatemala) with data on the safety and *in vitro* effects, "in order to contribute to Guatemala's national effort to improve public health measures in rural areas through the documentation of Mayan medical practices" (Michel et al., 2007, p. 93). They focused on plants used in the context of reproductive medicine and used a biochemical binding assay (oestrogen receptor—ERα and β) in order to arrive at a preliminary assessment of the extracts' effects. This is a classical approach which had been used in many studies and highlights the specific potential of combined ethnobotanical and *in vitro* screening studies. Here it serves as an example for a knowledge driven approach, i.e. of selecting (preferably simple) biological assays based on uses directly relevant for this target.

Defining standards in this context one needs to consider the fast developing field of biological assays available. Clearly, they need to be of direct relevance, but also be able to discriminate between the various extracts tested. Experimental setups which result in the vast majority of extracts being active generally indicate that either the researchers considered dose levels as active which are far too high and are not of physiological relevance, or that the assay has no discriminatory power. A case in point are *in silico* antioxidant assays which often highlight physiologically non-relevant effects as highlighted in the journal's Rules of Five (Verpoorte et al., 2006).

4.2. How can this information be used in the context of applied projects

Several of the authors whose work is summarized in Table 1 address the potential relevance of such information in the context of biodiversity conservation (e.g. Yineger et al., 2007; Jeruto et al., 2008), but Karousou et al. (2007) go furthest in highlighting that 'mint' species (not all belonging to the genus *Mentha*) sold on a Greek market vary in their composition and quality and thus highlight further need to regulate such commercial use.

We hope that these authors can be encouraged to further develop these ideas and to present specific concepts to show this can be achieved. Numerous examples now exist where researchers make such information available locally and in an adequate format. This ranges from the Farmácias vivas in Brazil, to books or booklets on the public dissemination of such knowledge (e.g. Vandebroek et al., 2003; Verde-López and Fajardo-Rodríguez, 2003; Nebel, 2005). Similarly, if guidance in setting up health policies will be an outcome (Kamatenesi-Mugisha and Oryem-Origa, 2007), it will be exciting to see future articles on how this has been approached and implemented. In this context it may also be of particular relevance to highlight the use of rarer species (e.g. Rigat et al., 2007).

Continuity and change is the focus of de Albuquerque et al. (2007) and their detailed and rich introduction may serve as an excellent and concluding example of how such information can be put into a broader context:

> The purpose of the present study was to analyze a list of species sold in one of the oldest and most traditional markets of Recife, Pernambuco State (northeastern Brazil), and compare the data collected at two distinct dates with a 7-year interval between them. This paper also addresses the questions: (1) Was there a change in the taxonomic richness during the 7-year period between the surveys? Here, we are working with the supposition that these markets are open and dynamic systems . . . and, as such, will tend to become richer over time with the addition of new elements to their repertoire; (2) Were there differences over time in the proportions of plants used for either medicinal or magical-religious purposes? We believe that in spite of the strong market for plants that satisfy Afro-Brazilian religious cult demands. . ., medicinal plants are the dominant commercial element as they are sought by a wider spectrum of society. . .; (3) Considering the time interval of 7 years, are there differences in the relative importance of the different species? In the same way that we suspect that there will be a taxonomic enrichment of the species offered over time, the influence of modern communication and informal information exchange between people might result in new uses being ascribed to a given plant (de Albuquerque et al., 2007, p. 77).

5. Conclusion

Setting standards for field based ethnopharmacological research is a challenging undertaking. With this review we do not want to limit the options available to research in this important field, but want to highlight the minimum conceptual and methodological requirements. The concepts and approaches summarized here should serve as an example and we have made no attempt to be comprehensive. The field-based studies used here as an example are the outcome of tremendous research efforts and we hope that this

analysis highlights the achievements and how such projects can be developed further. Some of the points addressed are essential and they all related to the need to have conceptually sound and methodologically robust approaches. Only such knowledge will contribute to improving human health on a local and/or a global level. This review most importantly highlights that conceptual approaches and methods are linked and that researchers need to have a clear vision for what and how they want to achieve such a methodologically sound standard. One limitation of this approach is clearly that it largely focuses on articles published in the *Journal of Ethnopharmacology*, where quite a few articles reporting field studies are published. Journals like *Economic Botany*, the *Journal of Ethnobiology and Ethnomedicine* and *Phytotherapy Research* also contain field-based contributions and to these journals, too, a scientific dialogue may be of interest. Ultimately this may well result in a broader discussion about the reasons for such studies and the best approaches. We cannot offer ready made 'solutions' or protocols for field studies, and in each case local needs, requirements and interests have to inform the development of such a research strategy. At the same time minimal requirements as outlined in the various parts of this article are essential elements of field-based studies.

In the first instance this article will hopefully contribute to a dialogue among the authors and readers of the *Journal of Ethnopharmacology* and comments based on this article will hopefully increase not only our awareness about basic scientific standards (which are important for all sciences) but also about the need for a continuous critical assessment of every scientific contribution highlighting strengths and weaknesses.

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