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Local ecological knowledge indicators for wild plant management: Autonomous local monitoring in Prespa, Albania

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ABSTRACT

Broad consensus affirms the need to better understand the status and trends of biodiversity and the important role that local ecological knowledge (LEK) plays in establishing successful monitoring programs. Although often present, autonomous local monitoring systems are frequently ignored by externally-driven community-based or participatory conservation projects. Here we explore the autonomous LEK-led monitoring carried out by local medicinal plant harvesters to guide the management and harvesting of six locally useful medicinal plant species in Prespa National Park, Albania. Open and semi-structured interviews with harvesters (n = 22), National Park staff (n = 2) and scientific advisors (n = 2) were combined with participatory mapping, joint plot assessments with key informants and a science-led ecological plot survey. Results suggest that harvesters possessed detailed LEK and adopted a variety of socio-economic, management, ecological and environmental indicators to assess wild resources and inform their harvest practices. LEK- and science-led plot assessments generally agreed on most monitoring aspects, suggesting that LEK indicators were relevant and LEK-based perceptions were accurate and could be used to assess the status and trends of useful species. However, while LEK focused on the harvestable resource; i.e. certain individuals and plant parts, the science-based approach assessed plant populations as a whole. Official monitoring based on existing LEK-led monitoring appears to be feasible, but LEK may be more appropriate for monitoring resources for wild harvesting or certification purposes than for 'pure' conservation monitoring of plant populations.

1. Introduction

Broad international consensus affirms the importance of better understanding status and trends of global biodiversity and its benefits to people (Díaz et al., 2015). In particular, the global community needs to obtain more locally-based monitoring information and recognise local ways of knowing to make management decisions that are relevant to the local context (Tengö et al., 2014; Turnhout et al., 2012). Communities have their own more or less formal ways to monitor their environmental resources according to local custom, thus directing local management decisions (e.g. Cinner and Aswani, 2007; Fernández-Giménez and Estaque, 2012; Sheil et al., 2015; Turreira-García et al., 2018). Official scientific monitoring systems should be based as much as possible on already existing autonomous monitoring wherever present to increase stakeholder participation and sense of ownership by local resource users, decrease monitoring costs and increase the likelihood that monitoring continues even after external technical assistance and donor funding cease (Danielsen et al., 2014a; Garcia and Lescuyer, 2008).

Much research has focused on the different forms of community-based monitoring in which local resource users and community members participate to varying degrees in environmental monitoring (Danielsen et al., 2009). The basic idea of local monitoring is that the closeness of users to a resource confers an ability to observe the local environment in detail and to monitor changes therein over time (Berkes, 2012). Local resource users have demonstratively observed changes in plants or animals brought about by biophysical growing conditions, ecological processes or by their own management practices (Staddon et al., 2014). The most locally-based forms of monitoring are those which are carried out without any external input. They have been termed "autonomous local monitoring" (Danielsen et al., 2009) and are often part of 'customary' or 'traditional' systems which draw on locally specific knowledge (Berkes and Folke, 2002). Different terms have been used to indicate this environmental knowledge, such as "traditional ecological knowledge (TEK)" (Berkes, 2012) or "indigenous ecological knowledge (IEK)" (Spoon, 2014). Here we adopt the term 'local ecological knowledge' (LEK) to include knowledge that may be part of a tradition, but does not exclude more recently developed knowledge or

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knowledge held by non-indigenous groups (Huntington, 2000).

Although often present, autonomous local monitoring systems are frequently ignored by externally-driven community-based or participatory conservation projects (Staddon et al., 2014). They have rarely been documented and are generally poorly recognised (Sheil et al., 2015). This is partly because they are so embedded into everyday life that they are mostly invisible, informal and difficult to elicit (Garcia and Lescuyer, 2008), but also because they have often been regarded as imprecise and qualitative and thus of little value for scientific monitoring (Moller et al., 2004). However, the lack of precise categorisations in LEK allows for an adaptable and dynamic body of knowledge and practices which seems more appropriate for facing uncertainty (Mistry and Berardi, 2016). Research focus has been on the integration of LEK into the structure of science-based monitoring (Bohensky and Maru, 2011). This research mainly looked at how locals can contribute through their data collection skills (i.e. as citizen scientists) or their environmental knowledge (LEK) by fitting scientific requirements, rather than at how LEK-based autonomous monitoring works and how scientific monitoring can build on LEK in ways relevant to the local context (Berkes, 2012). Some scholars suggest starting from the LEK present at local levels and looking for relevant scientific information only where necessary to fill in gaps – i.e. not for validation purposes, but for more options for action (Mistry and Berardi, 2016). Others maintain that comparing local methods with broadly accepted techniques in terms of accuracy and precision may help in enhancing and formalising autonomous local monitoring systems (Danielsen et al., 2005).

Due to the complexity of ecosystems, a combination of indicators is often chosen to act as proxies for the condition of the whole environment (Dale and Beyeler, 2001). Ecological indicators are quantitative or qualitative variables of an ecosystem which can be measured and described to monitor changes over time. While science-led monitoring tends to focus on a small number of quantitative indicators, LEK-led approaches often observe a large number of qualitative indicators (i.e. signs and signals) to assess environmental change (Berkes and Berkes, 2009). LEK indicators have been studied, for example, for monitoring environmental sustainability (Reed et al., 2008), land degradation and rangeland health (Roba and Oba, 2008), forest ecosystems (Pei et al., 2009), population trends of animal and plant species (Danielsen et al., 2014b; Sobral et al., 2017), tree diseases (Rist et al., 2010), tree phenology (Campos et al., 2018), weather and rainfall (Raj, 2006) or marine animals (Heaslip, 2008). The use of LEK indicators can offer a local detailed perspective (Fernández-Giménez and Estaque, 2012). Thus, growing evidence suggests that local communities can participate in and contribute to monitoring and indicator development (Fraser et al., 2006; Reed et al., 2006). Considering indicators used in autonomous local monitoring systems may reduce costs, time investment and the need for external expertise (Sheil, 2001). It may also help in developing ‘good’ indicators, i.e. which are simple, reliable, locally relevant and acceptable to all stakeholders (Tengö et al., 2014; Turnhout et al., 2007).

Locally-based species monitoring is especially relevant to discussions about sustainable resource management (Fernández-Llamazares et al., 2016). Unsustainable wild plant collection is considered a major issue in rural areas of the Balkans, in particular in Albania (Bazina, 2012). Albania underwent a major transition from state-controlled to market economy after the collapse of the Communist regime in 1991. Under Communism (1946–1991), Albania isolated itself from the rest of the world and heavily relied on its natural resources. The well-organised centralised market network for medicinal plants employed about 100,000 people and exported mainly wild collected plants to Germany and Austria (Naka and Musabelliu, 2004). In the period of socio-economic uncertainty after the collapse, natural resources were exposed to unregulated harvesting and overgrazing. Wild medicinal plant collection and trade has remained to date an important economic sector contributing to the herbal markets of Europe and the US (Imami et al., 2015; Torres-Londoño et al., 2008). Currently, an estimated 60,000–80,0000 medicinal plant harvesters (Ilbert et al., 2016) rely on medicinal plant harvest for a significant part of their household income (Niedfind, 2003).

In Albania, resource managers generally believe that because resource access remains uncertain, harvesters have low awareness about sustainability issues, needing to learn about issues of resource ecology, proper harvesting techniques or quality (Bojadzi et al., 2012; Naka and Musabelliu, 2004). Given the importance of drawing on LEK and pre-existing informal monitoring systems for successful resource monitoring (Garcia and Lescuyer, 2008), here we explore the autonomous local monitoring carried out by medicinal plant harvesters to guide the management and harvesting of six locally useful medicinal plant species in Prespa National Park, Albania. We focused on LEK-based perceptions of plant population status and trends as well as LEK indicators applied by harvesters to assess them. The following research questions guided the process:

- What are local harvesters’ perceptions of the population status and trends of selected species?
- Which indicators are harvesters’ assessments of plant populations based on?
- Do LEK-based perceptions match the results of a science-led ecological plot survey?

2. Materials and methods

2.1. Study site

The study was carried out along the shores of Greater Prespa Lake situated within Prespa National Park (hereafter PNP), located in the south-east of Albania on the border with Greece and the Republic of North Macedonia (Fig. 1). As a European hotspot for biodiversity, the Prespa region is part of the wider Transboundary Reserve of Prespa and Ohrid Lakes and is home to a variety of species and habitats, many of which are endemic and of conservation significance. The landscape is characterised by oak, juniper and beech forests along the shores of Makro Prespa lake (850 m a.s.l.) and alpine meadows on the mountain massif tops of Mali i Thatë (2,287 m a.s.l.). The climate has Mediterranean and continental traits and is characterised by hot summers and cold winters.

Due to its complex socio-economic history, this mountainous area has widely remained unindustrialised and livelihoods are based on small-scale subsistence agriculture, semi-pastoralist activities, fishing and wild medicinal plant harvest. The latter had been a major activity in Prespa during the Communist period (1946–1991), during which families earned additional cash by selling a large but fixed number of species to a local cooperative at predetermined prices. The PNP was established in 1999 with the aim to limit environmental degradation and promote sustainable use of natural resources (Fremuth et al., 1999). Sustainable medicinal plant collection for trade purposes under a special label of the PNP is part of the long-term vision of ecological development of the area (Fremuth et al., 2014). Harvesting is planned to be allowed only in “sustainable use” zones after obtaining a permit and prohibited in “core protection” zones. To guarantee sustainable wild collection of medicinal plants, the PNP requires scientific monitoring to be in place, but monitoring capacity is currently insufficient and wild collection remains uncontrolled (Fremuth et al., 2014). A comprehensive action plan has recently been elaborated for the transboundary monitoring of Mountain tea (*Sideritis raeseri* Boiss. & Heldr.), the regionally most collected medicinal plant (Bojadzi et al., 2012).

2.2. Data collection

Fieldwork was conducted between May and September 2015. A mixed-method approach was adopted to capture all aspects of the

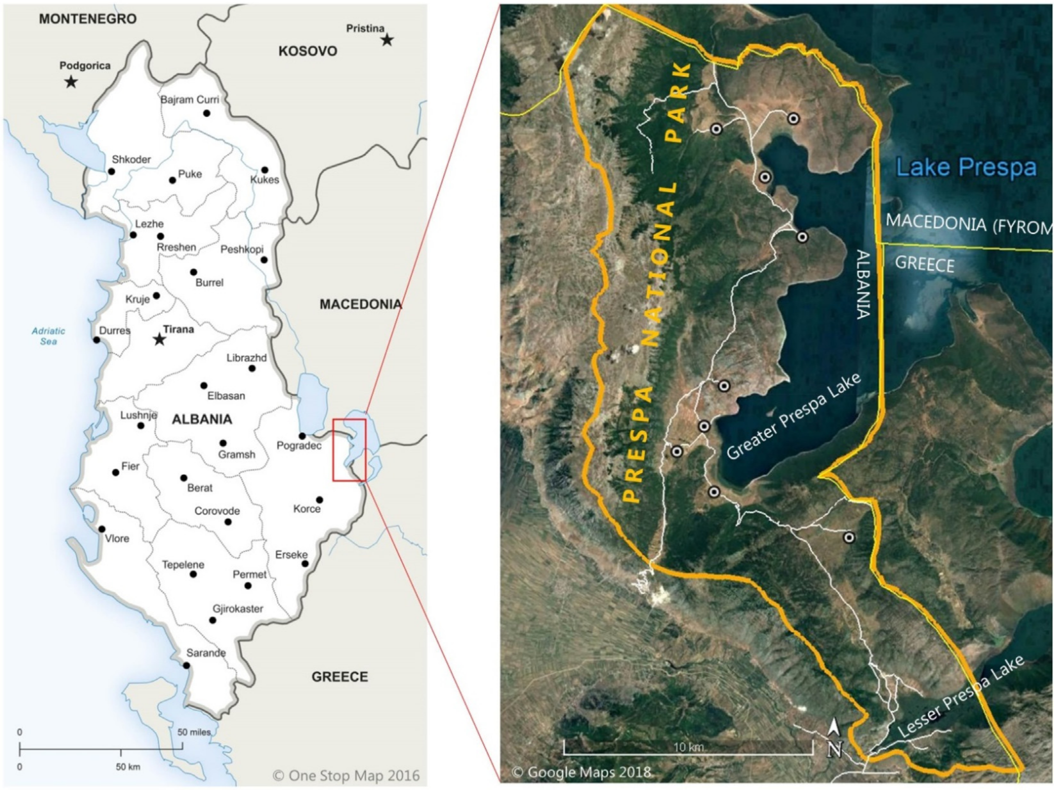

Fig. 1. Field site location. Prespa National Park boundary in orange.

autonomous local monitoring system. We conducted repeated open and semi-structured interviews, participatory resource mapping, and forest walks with medicinal plant harvesters of the Macedonian ethnic minority inhabiting the PNP. Harvesters (n = 22; 60% women) were between 40 and 70 years old (mean = 51.1, sd = 8.7) and came from six of the nine villages of the commune of Pustec along Greater Prespa Lake, as well as all current PNP staff (n = 2) and PNP scientific advisers (n = 2). Harvesters were selected among current and past medicinal plant harvesters based on their expertise and willingness to participate. Open and semi-structured interviews highlighted the key subsistence and cultural species, of which six species were selected to cover a range of characteristics influencing their vulnerability to unsustainable harvesting and their resulting need for monitoring (Cunningham, 2001) (Table 1). Voucher specimens were collected and deposited at the Tirana National Herbarium within the Centre for Flora and Fauna, hosted by the Faculty of Natural Sciences of the University of Tirana. Taxonomic identification was carried out according to the official Flora of Albania and confirmed by Prof. l. Shuka, a local botanist from the University of Tirana, expert of the Prespa region. The botanical nomenclature and family assignments followed The Plant List (2013).

Main interview questions related to general species knowledge (name, use, habitat), species ecology (flowering/fruiting/seeding time, reproduction, growth), aspects of harvest (plant part, locations, timing, quantities, prices) and population status and dynamics (abundance, frequency, population trends, causes of change) (see detailed questions in Appendix 1). During interviews, harvesters were presented with photographs of the selected species. We elicited their perceptions of population status (i.e. abundance levels) and trends of the selected species by asking them to explain how common they thought the selected species were in the PNP territory. For each species, harvesters differentiated between two abundance areas: 'rare' and 'common' areas. These were characterised in detail for each species during participatory resource mapping exercises. The main harvest areas for each species were also recorded. Harvesters were asked why they perceived the plants that way or what "signs and signals" they observed to reach their conclusion.

We identified a group of four to eight key informants (38% women, mean age = 53.8 years, sd = 4.8), representing the currently most active and experienced harvesters for each species, to participate in LEK-led joint plot assessments (Cunningham, 2001; Roba and Oba, 2008). During these, the group of key informants led the scientific team (consisting of the first author and a field assistant) to 'rare' and 'common' areas for each species. For each species, 20 plots were placed along random transects (10 in 'rare' areas, 10 in 'common' areas) and assessed separately by key informants and scientists. Key informants were asked to jointly assess plant abundance within the plots and describe site-related indicators, on the basis of which they reached their conclusion. This gave insights into: a) what narrow-scale plot-specific and wider-scale landscape indicators are used by harvesters to assess plant abundance and trends and adapt their harvest strategy; and b) which characteristics harvesters considered important to measure for each species. The same plots were subsequently assessed by scientists according to ecological plot methods as described below.

In addition to the 20 jointly assessed plots, the scientific team carried out a more comprehensive plot-based vegetation survey for each species. This was done to provide a means of comparing results with the autonomous local monitoring methods and facilitating communication with PNP staff and scientific advisors. Plot sampling was based on the LEK-based distinction of abundance areas. Between 25 and 53 slope-corrected plots per species were placed along random transects, of which about half were positioned in 'rare' areas and the other half in 'common' areas. Together with the 20 jointly assessed plots, this resulted in a total of 45 to 73 plots per species (see number of plots per species in Table 3 and map of plot locations in Fig. 5). In all, the plots covered 2.81 ha out of 6000 ha of meadows and shrub land existing in the PNP (Fremuth et al., 2014), of which about half was accessible to local harvesters. Thus, plots covered approximately 0.09% of the utilised area. An overall survey protocol was designed together with the

Table 1
Profile of selected species.

Scientific name, botanical family, voucher specimen	Life form	Plant part harvested	Conservation status	Threats	Trade level	Distribution	Altitude range in the PNP (m a.s.l.)	Ethnobotanical use
Sideritis raeseri Boiss. & Heldr. (Lamiaceae), PR30	Perennial herb, forming tufts with wooden base	Aerial parts before flowering	Sub-endemic, nationally endangered (EN A1c)[1]	Collection pressure, destructive harvest, grazing animals, habitat loss	Local, regional, international	Even	> 1500, far from villages	Culturally and economically highly important species locally used as tea, for flu symptoms and respiratory disorders.
Orchis spp. *(Orchidaceae) [including Orchis pallens L. PR11; and Anacamptis morio (L.) R.M.Bateman, Pridgeon & M.W.Chase, PR10]*	Perennial herb	Bulbs	CITES Appendix II	Collection pressure	Local, regional	Clustered	> 1500, far from villages	Dried tubers used for making *salep*, a hot beverage used as a constituent during flu season.
Primula veris L. (Primulaceae), PR21	Perennial herb, forming basal rosettes	Flowers, roots	Not listed	Collection pressure	Local	Clustered	> 1500, far from villages	Mainly traded; partly used as tea for respiratory disorders.
Crataegus monogyna Jacq. (Rosaceae), PR08	Shrub	Flowers, buds, leaves, fruits	Least concern (IUCN Red List)	Destructive harvest	Regional, international	Even	900–1100, close to villages	Mainly traded; used as tea for heart disorders; fruits eaten raw as a snack.
Crataegus heldreichii Boiss. (Rosaceae), PR29	Shrub	Flowers, buds, leaves, fruits	Sub-endemic,[1] Least Concern (IUCN Red List)	Destructive harvest	Regional, international	Even	1000–2000, far from villages	Mainly traded.
Juniperus oxycedrus L. (Cupressaceae), PR02	Shrub	Fruits	Endemic, PNP priority habitat, nationally vulnerable (VU A1b)[1]	Destructive harvest	Regional	Even	900–1100, close to villages	Mainly traded in the past; sometimes used to make an alcoholic drink (*raki*).

[1] According to Fremuth et al. (2014).

PNP staff and advisors.

In each plot, we recorded presence/absence, density, age classes, harvest signs, as well as habitat, vegetation community and soil characteristics. The diversity of life forms across the selected species required that the overall protocol be modified for each species. Density, i.e. number of individuals per unit area was measured for all species except *Primula veris*, for which aerial cover was assessed instead, as individuals were difficult to distinguish. Plot sizes varied between 5 × 5 m for *Primula veris* L. and *Orchis* spp. and 10x10m for the remaining species, as these sizes best reflected the area the harvesters visually assessed in their own autonomous monitoring. Species-specific measures and vigour indicators were added based on LEK elicited during joint plot assessments. Examples include plant height; diameter of tufts, trunk or stem; number of stems, number of inflorescences or flowers; fruiting or old individuals (see Table 3).

2.3. Data analysis

To analyse LEK-based perceptions, *emic* time periods and abundance categories were adopted, reflecting the view of informants. Participants clearly distinguished three time periods in which resource abundance and harvest practices differed: the past (under Communism, before 1991), the recent past (under the democratic government, 1990–2010), and the present (under the socialist government, 2011–2015). When talking about species abundance, participants distinguished three categories: i) common (*mnogu ima*), i.e. many plants seen all over the PNP's territory; ii) locally abundant (*ima*), i.e. many plants seen in their specific habitats; or iii) rare (*retko*), i.e. few plants seen in their habitats.

To account for differences in harvest experience and associated knowledge, we assessed the reliability of the information provided by harvesters, by evaluating each statement about abundance and trends against five criteria. These were adapted from the reliability index developed by Ziembicki et al. (2013) and included: a) informant correctly identified species; b) informant was an active harvester at the time of the research; c) informant was an active harvester under Communism; d) informant' statements were confirmed by statements of other informants; e) informant was a recognised knowledge holder by other harvesters. For each affirmative answer per criterion a score of 1 was assigned; for each negative answer a score of 0. Thus, summing all scores, each record could be of 'high reliability' (4–5 points), 'intermediate reliability' (2–3 points), or of 'low reliability' (0–1 points). For example, a harvester may state that "*Sideritis raeseri* populations are decreasing". With regard to this specific species, the harvester may:

- have been able to correctly identify the species (criterion a = 1);
- have been an active harvester at the time of research (criterion b = 1);
- **not** have been an active harvester under Communism (criterion c = 0);
- have stated a similar trend to that mentioned by other harvesters (criterion d = 1);
- **not** have been recognised as a key knowledge holder by other harvesters (criterion e = 1).

In total, the statement would thus have earned a score of 4 out of 5 possible points and would have been categorised as having 'high reliability'.

LEK indicators of plant abundance and trends were grouped into four *etic* indicator classes (i.e. reflecting the authors' interpretation): i) socio-economic indicators relating to number of harvesters, harvesting practices or market price changes; ii) management-related indicators related to PNP interventions such as grazing regulations or plant cultivation; iii) ecological indicators relating to changes at landscape, plant population or individual level; and iv) environmental indicators relating to climate or natural disasters.

Descriptive statistics of vegetation survey data were performed in an

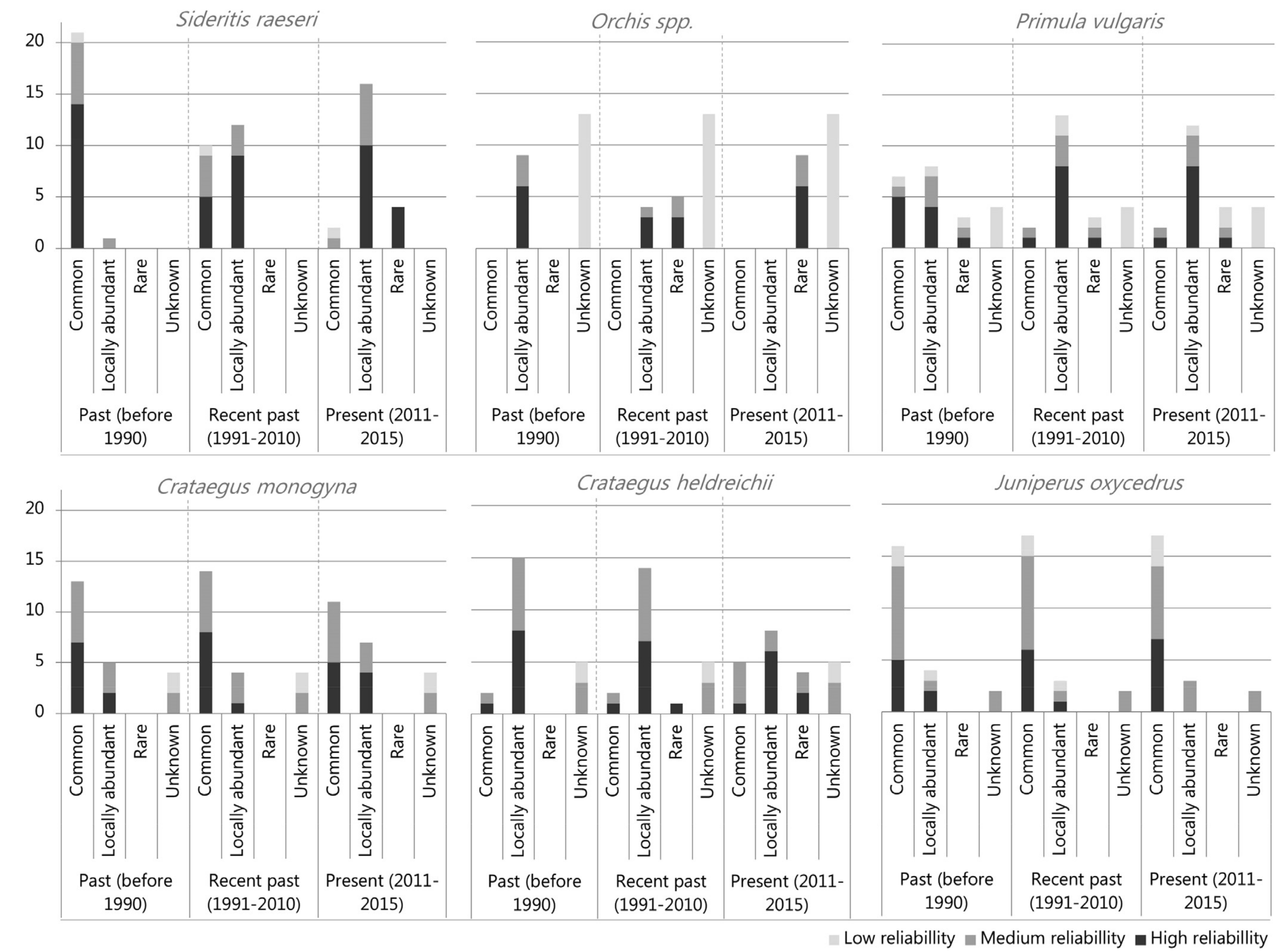

Fig. 2. LEK-based perceptions of population status. Reliability level of each record was determined according to five criteria adapted from Ziembicki et al. (2013).

Excel spreadsheet. Frequency (i.e. number of times a species is present in a given number of plots) was calculated and chi square tests performed to compare the ‘rare’ and ‘common’ areas determined by harvesters at an aggregated level. Average density per plot was chosen as a measure of abundance comparable to LEK-based density estimates recorded during joint plot assessments. LEK estimates of selected abundance and vigour indicators (between three and four per species) were matched with actual numbers from the vegetation survey (cf. Danielsen et al., 2014b).

3. Results

3.1. Perceived population status and trends

Harvesters’ perceptions of population status (Fig. 2) were in line with their perceptions of population trends (Fig. 3). According to harvesters, *Sideritis raeseri* was the most widely known species with the highest number of reliable records and widest consensus on status and trends. Harvesters indicated that the species had started to be more heavily harvested for trade only after the fall of Communism. The currently most common species were *Juniperus oxycedrus* and *Crataegus monogyna*. *Crataegus* spp. and *Juniperus oxycedrus* had low consensus on population trends, which were perceived as mostly stable, with decreased harvest pressure balancing out destructive harvest practices such as tree felling for easier flower harvesting (*Crataegus* spp.) or for competing use as fire wood or wood poles (*Juniperus oxycedrus*). The rarest species were *Orchis* spp. These and *Sideritis raeseri* were said to be significantly decreasing in numbers due to increased harvest pressure and destructive harvesting for trade.

3.2. LEK indicators

Harvesters adopted a variety of socio-economic, management, ecological and environmental indicators to assess status and trends of wild medicinal plant populations and inform their harvest practices (Table 2). They mentioned between six and 25 indicators per species, mentioning more indicators in number and diversity for the most collected species, e.g. *Sideritis raeseri*. The most mentioned indicators were visible damage due to destructive harvest practices and changing number of harvesters.

Interviews led mostly to the identification of indirect, non-ecological indicators such as the number of outside or resident harvesters or price fluctuations. These were the first to be used by all harvesters, including those who harvested specific species less regularly and were thus less knowledgeable about them. During joint plot assessments with experienced key informants, *in situ* ecological indicators at population and individual level were more likely to come up. Examples include proportions of young or dry plants, number of flowers or flower stalks. They needed more regular observation in the field and were thus less known by harvesters who collected less regularly. LEK elicited during joint plot assessments demonstrated a deep understanding of the species’ ecology and optimal harvest conditions. Harvesters indicated

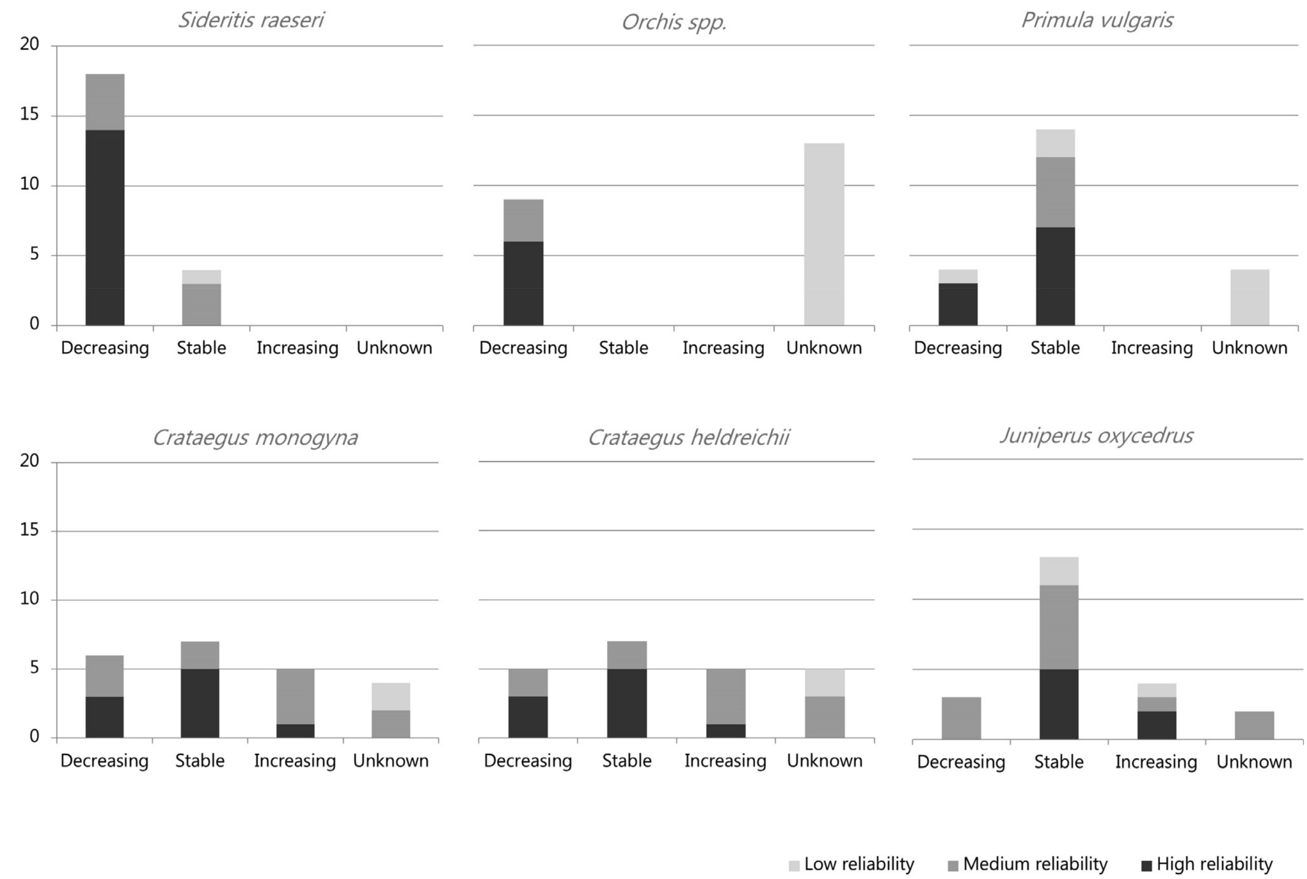

Fig. 3. LEK-based perceptions of population trends. Reliability level of each record was determined according to five criteria adapted from Ziembicki et al., (2013).

quantitative measures and thresholds of harvesting and population health for each species which may be interesting for monitoring of sustainability of harvest practices.

Quantitative measures of harvesting were indicated, for example, for *Sideritis raeseri.* Under Communism it was common to harvest between 20 and 200 flower stalks of per plant individual, while presently only 2–10 flower stalks could be found per individual on average, and only very rarely up to 150 flower stalks per individual. In the case of *Primula veris* it was common, up to the recent past, to harvest individuals with 3–5 flower stalks and 10–15 flowers per flower stalk, while after 2010, this amount decreased to one flower stalk with five flowers per stalk.

Harvesting thresholds were mentioned for example for *Sideritis raeseri*, *Primula veris Orchis* spp. and *Juniperus oxycedrus*. These thresholds should not be crossed if the natural regeneration cycle is to be respected and harvesting is to be sustainable:

- *Sideritis raeseri* can be harvested yearly, up to three times per season if rains are abundant in late summer, but a minimum of 10 days between harvest trips should be complied with;
- roots of *Primula veris* may be harvested every three years;
- *Orchis* spp. bulbs should only be harvested from individuals with flower stalks thicker than 1 cm at the base, as their bulb will be of an appropriate size for harvest; and
- *Juniperus oxycedrus* cones can be harvested every two years.

Quantitative population health indicators were particularly detailed for *Sideritis raeseri*, a healthy population of which would look like this according to harvesters: plant individuals would form large tufts of 50–100 cm in diameter per plant individual, tufts would create a thick carpet over large areas, flower stalks had the time to grow to 50–70 cm height and would be cut in bunches with a sickle, and at least two young seedlings in an area of 100 m2 would ensure regeneration. Harvesters described that this was the situation under Communism, but at present plant individuals rather formed tufts of 15–30 cm in diameter, they were spaced 5–10 m apart, flower stalks reached around 15–20 cm height and were picked one at a time, and young seedlings were rarely seen. In the case of *Primula veris*, qualitative population health indicators included the increasing presence of 'ill' flowers, looking pale and dry, which were unsuitable for collection.

3.3. LEK-based versus science-based survey

Overall, there was agreement between the LEK-led and science-led vegetation survey, but results varied between species (Table 3). Estimates matched more often within 'rare' areas (57% of indicators) than in 'common' areas (46%). 'Common' and 'rare' areas were significantly different in species frequency for all species ($p < 0.05$), except *Orchis* spp. (Table 4), indicating that local perceptions of species' frequency were accurate overall and that dividing the landscape into 'rare' and 'common' areas made sense in the local context.

LEK-led and science-led density estimates mostly matched, except for the less abundant species, *Crataegus heldreichii*, *Orchis* spp. and *Primula vulgaris* in their respective 'common' areas. Agreement of species-specific indicator estimates was highest for *Sideritis raeseri* (80% of indicators matching), and lowest for *Orchis* spp. (38% of indicators matching) and *Crataegus heldreichii* (30% matching), indicating higher correspondence for commonly collected species and lower correspondence for less collected and rare ones. For *Juniperus oxycedrus*, neither 'rare' nor 'common' areas showed agreement on the number of fruiting individuals, as it was currently rarely harvested. However, estimates matched for mean density of shrubs, probably because they remained easily visible growing in proximity to the villages. Harvest signs were systematically underestimated by the science-led approach due to

Table 2
Summary table of LEK indicators and proportions of indicator classes across species.

Indicator class	Level	Specific indicator	Sideritis raeseri	Orchis spp.	Primula veris	Crataegus spp.	Juniperus oxycedrus
Socio-economic	Collectors	Number of outside collectors	√	√	√	√	
		Number of local collectors for trade	√			√	√
	Harvest	Destructive harvest	√			√	√
		Timing of harvest	√	√			
		Interval between harvest trips to same areas	√				
		Number of harvest days	√				
		Harvestable resource		√			√
		Option to select preferable types				√	
	Market	Price	√	√	√	√	√
		Market demand	√				
		Number of traders		√			
		Total socio-economic indicators	**8**	**5**	**2**	**5**	**4**
Management	Landscape	Grazing of wild animals	√				
		Grazing of livestock			√		
	Landscape	Cultivation	√				
		Total management indicators	**2**		**1**		
Ecological	Landscape	Habitat availability	√		√	√	√
		Disappearance from specific areas	√		√		
		Presence of stones			√		
	Population	Number of individuals per unit area	√		√		
		Frequency of seeing individuals along the path				√	
		Regeneration	√				
		Proportion of dry individuals	√			√	
		Proportion of old individuals			√	√	
		Proportion of flowers/fruits after harvest season	√		√	√	
		Harvest signs	√	√			
		Harvest per unit effort	√				
		Abundance compared to Macedonian side	√		√		
	Plant individual	Number of flower stalks	√		√		
		Number of tall flower stalks	√				
		Number of flowers per stalk			√		
		Harvest amount per individual	√				
		Tuft diameter	√				
		Respect of growth cycles			√		
		Number of flowerless or fruitless years			√		√
		Presence of “ill” flowers			√		
		Number of cut or dry stems or branches				√	
		Number of fruits					√
		Total ecological indicators	**13**	**1**	**12**	**6**	**3**
Environmental	Climate	Annual variations due to weather	√		√	√	
	Natural event	Wildfire	√				
		Total environmental indicators	**2**		**1**	**1**	
		TOTAL number of indicators	**25**	**6**	**16**	**12**	**7**

difficulties in easily recognising or clearly distinguishing them from grazing signs. Harvesters based their assessment on their own harvest practices, for example stating that they had themselves harvested the area a week before.

For most indicators, harvesters felt confident providing quantitative estimates, though these were usually stated as a range of values. Where precise numbers or range of numbers did not match with science-led estimates, there was often still agreement regarding patterns between ‘rare’ and ‘common’ areas (64% of indicators matching). For example, for *Sideritis raeseri*, exact number estimates differed for the mean number of flower stalks per tuft in rare areas (five according to the scientific approach versus two according to LEK). However, the two approaches still agreed that the mean number of stalks per tuft was smaller in ‘rare’ areas than in ‘common’ ones.

Participatory resource mapping showed that for more abundant species such as *Sideritis raeseri* or *Juniperus communis*, PNP staff and scientific advisors had a more general overview of species occurrence (Fig. 4) compared to harvesters. The science-based understanding of PNP staff focused on the range of the species, preferring to mark big, connected areas rather than small isolated locations. For example, according to PNP staff, *Sideritis raeseri* occurred “all over the PNP”. Harvesters had more fine-grained knowledge about the presence or absence and abundance levels (rare or common) of useful species in specific locations (Fig. 5). Thus, for *Sidertis raeseri*, they would identify the abundant areas on the mountain tops, while still being aware of very small populations occurring along the lake shores. For the less abundant species, such as *Orchis* spp., *Crataegus heldreichii* and *Primula veris*, PNP staff was not aware of some populations.

Participatory mapping also showed that harvesters and PNP staff had a different perception of what should be included and measured. In the harvesters’ perception the harvestable resource was the focus, i.e. certain individuals and plant parts which can be harvested, to the point where they would say “there is nothing here” regarding an area where the species was present but there was no *harvestable* material. PNP staff and scientific advisors were concerned about the plant population as a whole but did not distinguish between harvestable or non-harvestable individuals and areas.

4. Discussion

4.1. LEK for monitoring species abundance and trends in the face of complexity

Harvesters of Prespa carried out autonomous local monitoring of medicinal plants informally, while going about their daily activities, as has been found elsewhere (LaRochelle and Berkes, 2003; Sheil et al., 2015). The quality and breadth of LEK varied among species. Naturally, records were more reliable and consensus stronger for those species

Table 3
Comparison of science-led and LEK-led vegetation survey. √ = agreement between science-led and LEK-led monitoring. X = disagreement between science-led and LEK-led monitoring.

Species	Attributes	RARE AREAS Science-led	RARE AREAS LEK-led	Agreement	COMMON AREAS Science-led	COMMON AREAS LEK-led	Agreement	Pattern between rare and common areas	Agreement
Sideritis raeseri	Plot size (m2)	100			100				
	Number of plots	35			38				
	Number of plots in which species occurred	9			27				
	Total number of individuals	78			381				
	Frequency (%)	0.26	Rare		0.71	Common			
	Mean density per plot	2.23 ± 5.35	2	√	10.03 ± 10.81	5-10	√	Rare < Common ↑	√
	Mean diameter of tufts (cm)	25.14 ± 15.00	20-30	√	22.17 ± 12.57	15-20	√	Rare > Common ↓	√
	Mean number of flower stalks per tuft	5.55 ± 6.54	2	X	6.90 ± 9.86	5-10	√	Rare < Common ↑	√
	Mean height of stalks (cm)	32.20 ± 13.81	20-40	√	18.77 ± 7.16	15	√	Rare > Common ↓	√
	Individuals with harvest signs (%)	0.56	0.50	√	0.52	0.90	X	No pattern X	X
Orchis spp.	Plot size (m2)	25			25				
	Number of plots	23			22				
	Number of plots in which species occurred	10			15				
	Total number of individuals	46			249				
	Frequency (%)	0.43	Rare		0.68	Common			
	Mean density per plot	2.00 ± 4.50	2-5	√	11.32 ± 29.61	20-100	X	Rare < Common ↑	√
	Mean number of individuals with stalk >1cm	2.57 ± 2.19	2	√	4.33 ± 4.43	10	X	Rare < Common ↑	√
	Mean height of stalks (cm)	32.19 ± 9.92	25	X	18.67 ± 4.44	20	√	Rare > Common ↓	√
	Individuals with harvest signs (%)	0.02	0.20	X	0.00	0.50	X	No pattern X	X
Primula veris	Plot size (m2)	25			25				
	Number of plots	27			27				
	Number of plots in which species occurred	3			23				
	Frequency (%)	0.11	Rare		0.85	Common			
	Mean percentage cover	0.32 ± 0.28	0.10-0.50	√	0.22 ± 0.18	0.70-0.90	X	No pattern X	X
	Mean number of stalks per rosette	1.25 ± 1.60	1	√	1.48 ± 2.64	1	√	Rare = Common ↔	√
	Mean number of flowers per stalk	5.83 ± 1.07	5	√	4.65 ± 2.51	5	√	Rare = Common ↔	√
	Individuals with harvest signs (%)	0.01	0.20	X	0.01	0.50	X	No pattern X	X
Crataegus monogyna	Plot size (m2)	100			100				
	Number of plots	31			30				
	Number of plots in which species occurred	7			14				
	Total number of individuals	43			147				
	Frequency (%)	0.23	Rare		0.47	Common			
	Mean density per plot	1.39 ± 2.91	1-3	√	4.90 ± 7.22	5-10	√	Rare < Common ↑	√
	Mean height (cm)	155.81 ± 84.12	150	√	97.43 ± 58.94	100	√	Rare > Common ↓	√
	Old individuals (diameter >5cm) (%)	0.21	0.50	X	0.11	0.10	√	Rare > Common ↓	√
	Flowering individuals after harvesting (%)	0.51	0.30	X	0.01	0.10	X	Rare > Common ↓	√
	Individuals with harvest signs (%)	0.56	0.70	X	0.52	0.90	X	No pattern X	X
Crataegus heldreichii	Plot size (m2)	100			100				
	Number of plots	30			31				
	Number of plots in which species occurred	6			21				
	Total number of individuals	33			88				
	Frequency (%)	0.20	Rare		0.68	Common			
	Mean density per plot	1.10 ± 2.96	1	√	2.84 ± 3.05	5	X	Rare < Common ↑	√
	Mean height (cm)	112.82 ± 44.80	200	X	149.33 ± 123.39	150	√	No pattern X	X
	Old individuals (diameter >5cm) (%)	0.09	0.50	X	0.28	0.10	X	No pattern X	X
	Flowering individuals after harvesting (%)	0.39	0.30	√	0.25	0.10	X	Rare > Common ↓	√
	Individuals with harvest signs (%)	0.30	0.70	X	0.34	0.90	X	No pattern X	X
Juniperus oxycedrus	Plot size (m2)	100			100				
	Number of plots	31			30				
	Number of plots in which species occurred	11			28				
	Total number of individuals	42			221				
	Frequency (%)	0.35	Rare		0.93	Common			
	Mean density per plot	1.35 ± 2.51	1-2	√	7.37 ± 5.08	5-10	√	Rare < Common ↑	√
	Mean diameter at 30cm (cm)	5.72 ± 4.24	5	√	7.16 ± 5.73	5	X	No pattern X	X
	Mean height (cm)	152.81 ± 96.28	100-150	√	137.90 ± 66.29	50-100	X	Rare > Common ↓	√
	Fruiting individuals (%)	0.29	0.50	X	0.36	0.80	X	Rare < Common ↑	√
	Individuals with harvest signs (%)	0.10	0	X	0.02	0	√	No pattern X	X

* Means are followed by ± standard deviation

Table 4
Difference in frequency of plants between 'rare' and 'common' areas.

Species	Chi Square (*p* values)
Sideritis raeseri	0.00011
Orchis spp.	0.09550
Primula veris	0.00000
Crataegus monogyna	0.04777
Crataegus heldreichii	0.00017
Juniperus oxycedrus	0.00000

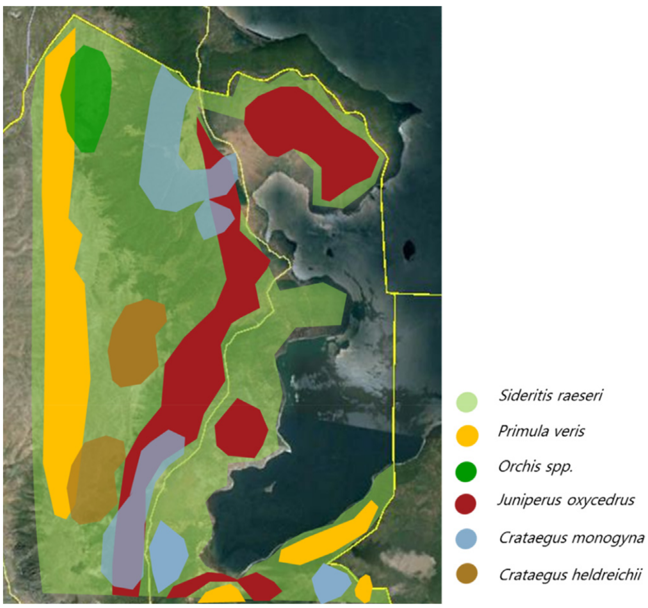

Fig. 4. Participatory distribution map according to National Park staff and advisors.

which harvesters were most regularly in contact with through harvest-related activities (Biró et al., 2014; Gilchrist et al., 2005; Hellier et al., 1999). Studies have shown that a species' usefulness has implications for the use of LEK in monitoring species of conservation interest (Hellier et al., 1999; Zhao et al., 2016). In Prespa, LEK about *Sideritis raeseri* populations was considerable, and could potentially provide useful insights for monitoring within the transboundary action plan elaborated for this species (Bojadzi et al., 2012).

Despite growing in remote areas on the mountain tops, *Sideritis raeseri* was well-monitored among harvesters, indicating that cultural and economic importance were more significant determinants of monitoring efforts than proximity. Scholars have argued that monitoring efforts are highly dependent on (continued) harvest and use (LaRochelle and Berkes, 2003). Harvesters and other community members had no knowledge of or use for a rare endemic indicator species for habitat integrity in the PNP, *Crocus cvijicii* Kosanin, for which some scientific monitoring had been initiated (Shuka, 2012). This resonates with findings from a study in East-Central Europe, in which local community members had limited to no local knowledge about population trends of threatened and rare plant species (Biró et al., 2014). However, harvesters continued to monitor species such as *Juniperus oxycedrus* despite its decreased economic importance because it was growing in close proximity to the villages. This is potentially relevant for the PNP management as this species has been declared a priority habitat in the PNP (Fremuth et al., 2014).

As participatory mapping exercises showed, harvesters had detailed knowledge about the location of plant populations, even when small and categorised as 'rare', which guided their decision-making on where to go for a cost-efficient harvest trip. PNP staff and scientific advisors, being more interested in the range of species distribution for conservation purposes, often ignored specific locations, especially for rare species. This may be explained by the difference in perception of what should be measured: the harvestable resource or the population as a whole? This questions whether LEK is relevant for 'pure' conservation assessments and monitoring, as it seems to be more appropriate for monitoring resources for wild harvest management or certification purposes. Development and auditing of certification schemes for sustainable wild plant collection such as the FairWild Standard (FairWild Foundation, 2010) may benefit from LEK input.

For most species of this study, no literature was available to compare LEK of species' status and trends with scientific abundance records. According to an informal survey of the medicinal flora of the PNP in 1999, *Sideritis raeseri* was present in some locations at that time with large and dense individuals with 20 flower stalks or more and a tuft diameter of 50 cm (Fremuth et al., 1999), confirming LEK of past abundance. According to the Action Plan for *Sideritis raeseri*, it was included in the *List of Protected Species of Flora in Albania* as an endangered species (status EN A1c) due to a rapid population decrease by 50% over 20 years (Bojadzi et al., 2012), which confirms LEK-based perceptions for populations in Prespa. Just across the border in the Republic of North Macedonia, the Galičica National Park carried out transect-based monitoring of *Sideritis raeseri* between 2010 and 2012. Preliminary results showed a population density between 36.8 and 105.9 tufts/ha (Bojadzi et al., 2013, 2012). For comparison, vegetation survey results in Prespa suggest a much higher density: between 222 and 1002 tufts/ha. This finding is inconsistent with the perception of harvesters, who repeatedly maintained that *Sideritis raeseri* grew in denser stands in the Republic of North Macedonia because there were fewer collectors. However, harvesters' perceptions about population density across the border were likely unreliable as they only rarely visited Macedonian harvest sites.

That estimates matched more often within 'rare' than in 'common' areas may be due to the 'rare' areas being usually closer and more frequently observed either for harvesting (hence the 'rarity' of the species) or while taking animals on the grazing range. LEK-based perceptions and science-led survey results regarding the harvestable resource were sometimes inconsistent, e.g. on the number of flower stalks per *Sideritis raeseri* tufts, the number of thick-stalk individuals of *Orchis* spp., or the presence of flowering *Crataegus* shrubs after harvest. Overestimations by harvesters may be explained by some harvesting having occurred prior to the time of measurement or by the harvest season of 2015 being shorter than usual due to adverse weather conditions. Low indicator matches and lack of significant difference between 'rare' and 'common' areas for *Orchis* spp. may also be caused by unsuitable ecological sampling design, as rare and clustered species would benefit from adaptive cluster sampling for more accurate population measurements (Acharya et al., 2000). Mismatches may also be due to harvesters integrating their knowledge about the wider area into their plot-based assessment, despite directions to focus on the plots. It felt unnatural to them to limit their observations to a plot especially when it did not seem representative to them of the wider landscape in which it was located.

Vegetation survey results showed a high standard deviation and an increase in the sampled area may have reduced the high variation. However, the primary aim was to understand the autonomous local monitoring and the present sampling intensity is likely to reflect the PNP capacity for monitoring. The high variation is also in line with the tendency of harvesters to indicate ranges of values rather than precise numbers. Working with value ranges allowed harvesters to account for 'normal' seasonal variability in resource abundance within complex ecosystems and distinguish it from changes out of the norm. They thus considered population trend a more useful measure than current status because it overlooked smaller fluctuations. This was also reflected in their choice to talk about 'present' population status over a period of five years (2011–2015). This may be explained by their understanding

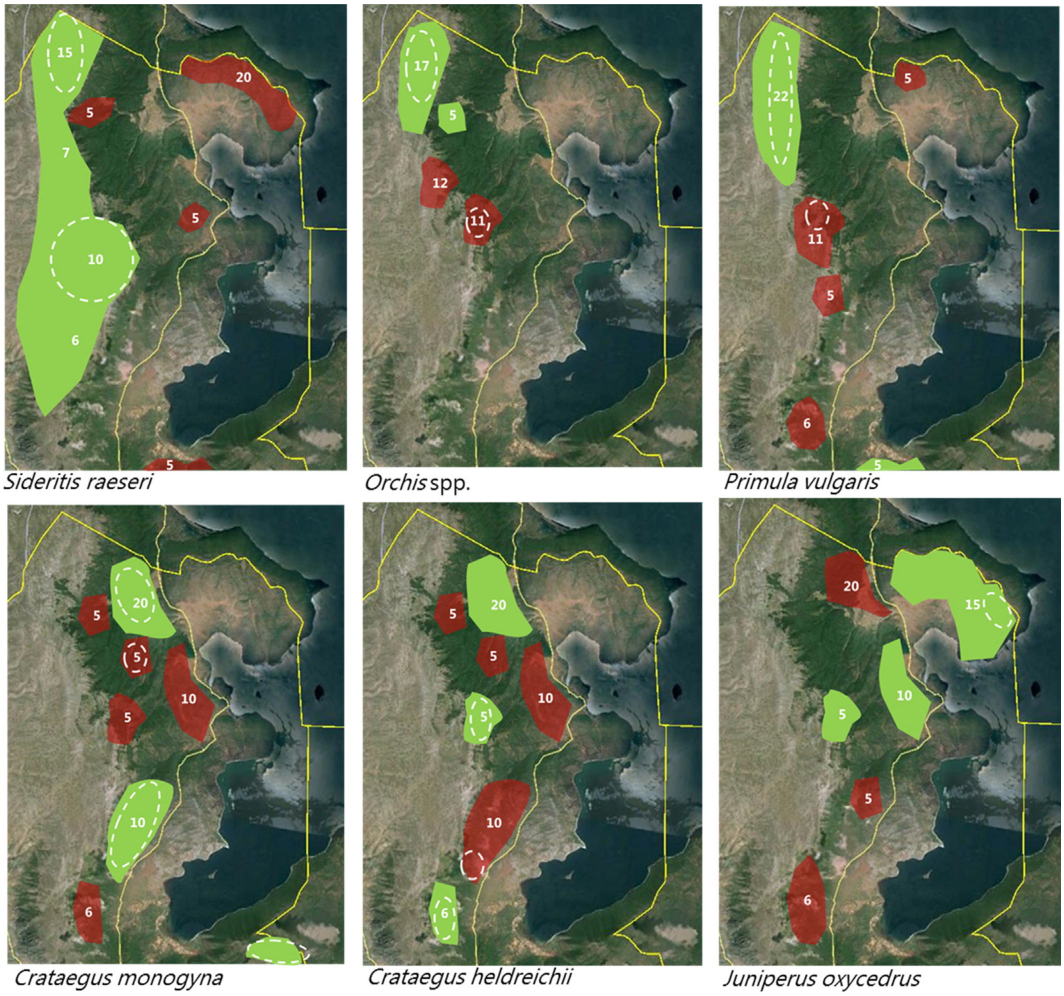

Fig. 5. Participatory distribution maps indicating rare (red), common (green) and main harvest (dotted circle) areas for each species according to harvesters. Numbers indicate the number of survey plots placed within each area.

of their environment as a complex system, in which only flexible ranges of values can deal with fluctuations and changes (Berkes, 2012). The importance of trajectories, thresholds and flexible LEK in the face of uncertainty has been extensively discussed in the literature on complex adaptive socio-ecological systems (Folke, 2009; Harris, 2007).

The practice of comparing LEK-based and science-based approaches has often been criticised (Brook and McLachlan, 2005). One of the risks is to categorise the dynamic and adaptable nature of LEK in order to fit scientific framings, thus compromising those characteristics that represent LEK's major strengths. In the present study, the scientific monitoring approach was not taken as the standard (Agrawal, 2002). On the contrary, LEK determined which species-specific measures should be considered in the science-based survey to produce monitoring relevant to the local management context. The comparison of LEK-led and science-led monitoring may thus give voice to local resource users in negotiating with PNP officials over their role in the management and monitoring approach for the sustainability of medicinal plant harvest. Although this may not be enough to reduce the power asymmetry between local stakeholders (Garcia and Lescuyer, 2008), it represents a first step towards encouraging communication between them.

4.2. LEK indicators for wild plant monitoring: 'counting what counts'

Harvesters adopted a large number and variety of indicators to assess species abundance similar to other studies (Sobral et al., 2017). This is in line with previous findings about autonomous local monitoring, i.e. that a broad suite of simple, less-specific, "fuzzy" variables, instead of a few detailed and costly ones, allows local communities to obtain a holistic picture of the environment and to better capture and adapt to complexity (Berkes and Berkes, 2009). Many of the indicators found reflect LEK indicators elsewhere and point towards similarities in the perception of natural resources between local resource users (Moller et al., 2004; Sheil et al., 2015). Examples include harvesting per unit of time or effort, ratio of young versus reproductive individuals, population density or noticing unusual patterns, e.g. the presence of 'ill' flowers in *Primula veris*. The use of socio-economic indicators (e.g. number of harvesters) appears to be characteristic of LEK systems, in which human activities are considered just as important as ecological variables in the assessment of wild plant species (Roba, 2008; Sobral et al., 2017). Although the relationship between socio-economic indicators and the state of the resource is uncertain (Global Environment Division, 1998), monitoring based on ecological indicators alone might miss subtle changes which would be crucial for harvest decisions (Roba, 2008).

Harvesters in Prespa felt confident with giving quantitative estimates for most indicators and species. This was surprising as LEK is usually known to produce and use mainly qualitative measures (Berkes, 2012; Heaslip, 2008) and only in a few cases have quantitative LEK estimates been reported, for example the timing of bird migrations and bird species distributions (Gilchrist et al., 2005). The use of quantitative measures in Prespa may be a result of using joint plot assessments instead of solely interviews far from the resource in question (e.g. Sobral et al., 2017). It may also reflect a local distinctive trait, i.e. an aspect of the legacy of Communism, during which harvest quantities and practices were frequently recorded and discussed. LEK is usually not used in decision-making due to its inability to provide quantitative estimates, but official monitoring schemes in Prespa could relatively easily incorporate or be entirely based on LEK.

The richness of species-specific LEK indicators currently adopted by harvesters may be a source of inspiration for official monitoring programs, ensuring that only what really matters is measured to assess species populations (Danielsen et al., 2014b). Examples include counting presence or absence of tall flower stalks (> 50–70 cm) of *Sideritis raeseri*, recording the timing at which its harvest season begins each year to indirectly monitor harvest pressure, counting the number of fruitless years to assess population health of *Juniperus oxycedrus* or evaluating thickness of flower stalk in *Orchis* spp. to indirectly assess below-ground tuber condition. As the PNP administration plans to implement sustainable harvesting, many of the indicators may also serve as a basis to establish best-practice harvest rules, such as minimum size class, allowed harvest periods or minimum time intervals between harvest trips.

It has been argued that in order to be useful to scales beyond the local, participatory data has to meet the needs of the decision-makers (Lawrence, 2010). Danielsen et al. (2014b) have shown that autonomous local monitoring could potentially monitor 23% of international biodiversity monitoring indicators, if there was a link between self-established local monitoring and international environmental agreements. LEK may help track indicators mentioned by the Convention on Biological Diversity (CBD), the Circumpolar Biodiversity Monitoring Program (CBMP), the Organisation for Economic Cooperation and Development (OECD) or the Streamlining European 2010 Biodiversity Indicators (SEBI). The present study showed that harvesters' LEK in Prespa could potentially provide information on such indicators, e.g. ecosystems contributing to livelihoods (CBD), trends in abundance of key species or of biodiversity for traditional food and medicine (CBMP), abundance and distribution of selected species (SEBI) or intensity of use of forest resources (OECD). Indicators applied to assess the threat status of species such as those used in Red List assessments carried out by the International Union for Conservation of Nature (IUCN) also show similarities to LEK indicators found in Prespa: e.g. changes in local extent of occurrence; area of occupancy; number of locations; number of mature individuals. At the least, LEK can provide early warnings of changing aspects of an ecosystem (Mallory et al., 2003; Olsson et al., 2004).

4.3. The future of autonomous local monitoring in Prespa

Contrary to the general belief that harvesters in Prespa need training on sustainable harvest techniques, informants were well aware of proper collection techniques. However, economic pressures led them to collect early and fast to avoid competition from outside collectors. Resource status assessment was no longer the basis for choosing to harvest or protect a resource, as happens in functioning customary management systems (Sheil et al., 2015). This is where harvesters expressed the need for help from the PNP in regulating resource access. Guaranteeing that Prespa residents have priority resource access and regulating outsiders' access may be more efficient at reducing unsustainable harvesting than training harvesters in good harvesting practices.

Anecdotal evidence suggests that originally harvest taboos were in place in Prespa to protect certain species in the landscape. Such resource taboos have been shown to effectively contribute to species conservation (Colding and Folke, 2001; Gadgil et al., 1993). Among LEK indicators informants mentioned no-take zones and seasons for proper species management so that it is likely that customary rules were part of the resource management system in Prespa before Communism. One key informant spoke about a traditional rule of thumb that no fruit tree (such as *Crataegus* spp.) should be felled or someone in the family would die. Like many other traditional beliefs and religious practices, this simple prescription was probably overridden by the natural resource management rules established under Communism.

Current monitoring was found to happen on an individual basis with harvesters not usually sharing observations among themselves (c.f. Biró et al., 2014). Assessing resources during joint plot assessments was new to them and although they agreed on many aspects, they remained sceptical about imagining a more formally organised LEK-based resource management due to a persisting negative perception of cooperative work. Building a monitoring program on LEK may be a way to valorise the knowledge of the poorer community members who rely on medicinal plant harvesting and encourage a continued observation of the environment, even when harvesters are too old to collect plants or when economic development leads to the abandonment of this lifestyle. External conservation interests in Prespa could contribute to existing efforts of individual harvesters by supporting instead of replacing them (Sheil et al., 2015).

5. Conclusions

The results of this study suggest that harvesters possessed detailed LEK about the species they collect and that they adopted a variety of socio-economic, management, ecological and environmental indicators to autonomously assess wild medicinal plant resources and inform their harvest practices. LEK indicators seem to be relevant for official resource monitoring and LEK appears to be accurate for most monitoring aspects and could thus be used to assess the status and trends of useful species.

One of the challenges for combining LEK and its indicators with official scientific monitoring for conservation purposes remains that the two systems refer to different monitoring units: while resource users focus on the harvestable resource, conservation monitoring considers the plant population as a whole. This limits the inclusion of LEK in 'pure' conservation monitoring. However, LEK may still play a role in providing early warning signals for changes in species populations. In Prespa, the detailed knowledge of harvesters regarding medicinal plant occurrence and abundance may serve as the basis for developing official monitoring approaches and for adapting the recently top-down designed "core protection" and "sustainable use" zones of the PNP. For the moment, these exist only on paper but may considerably limit harvesters' access to an important part of the landscape and their resources, thus endangering the related LEK.

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Declaration of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2019.01.076. These data include Google maps of the most important areas described in this article.

References

Acharya, B., Bhattarai, G., De Gier, A., Stein, A., 2000. Systematic adaptive cluster sampling for the assessment of rare tree species in Nepal. For. Ecol. Manage. 137, 65–73.
Agrawal, A., 2002. Indigenous knowledge and the politics of classification. Int. Soc. Sci. J. 54, 287–297.
Bazina, E., 2012. Enabling sustainable management of Non Wood Forest Products in South East Europe – Albania' s experience. J. Life Sci. 6, 1391–1395.
Berkes, F., 2012. Sacred ecology, third. ed. Taylor & Francis, New York, US.
Berkes, F., Berkes, M.K., 2009. Ecological complexity, fuzzy logic, and holism in indigenous knowledge. Futures 41, 6–12.
Berkes, F., Folke, C., 2002. Back to the future: ecosystem dynamics and local knowledge. In: Gunderson, L., Holling, C.S. (Eds.), Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington DC, USA, pp. 513.
Biró, É., Babai, D., Bódis, J., Molnár, Z., 2014. Lack of knowledge or loss of knowledge? traditional ecological knowledge of population dynamics of threatened plant species in East-Central Europe. J. Nat. Conserv. 22, 318–325.
Bohensky, E.L., Maru, Y., 2011. Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on "integration"? Ecol. Soc. 16, 6.
Bojadzi, A., Brajanoska, R., Stefkov, G., Fotiadis, G., Shumka, S., Avukatov, V., 2012. Conservation action plan for Mountain tea in the Prespa Lakes watershed. UNDP/GEF project report.
Bojadzi, A., Menković, N., Avramoski, O., 2013. Preliminary results of the monitoring of Sideritis raeseri Boiss. & Heldr, in: 35th Meeting of Eastern Alpine and Dinaric Society for Vegetation Ecology, 3-6 July 2013. Ohrid, Republic of Macedonia.
Brook, R.K., McLachlan, S.M., 2005. On using expert-based science to "test" local ecological knowledge. Ecol. Soc. 10, r3.
Campos, L.Z., Nascimento, A.L.B., Albuquerque, U.P., Araújo, E.L., 2018. Use of local ecological knowledge as phenology indicator in native food species in the semiarid region of Northeast Brazil. Ecol. Indic. 95, 75–84.
Cinner, J.E., Aswani, S., 2007. Integrating customary management into marine conservation. Biol. Conserv. 140, 201–216.
Colding, J., Folke, C., 2001. Social taboos: "Invisible" systems of local resource management and biological conservation. Ecol. Appl. 11, 584–600.
Cunningham, A., 2001. Applied Ethnobotany: People, Wild Plant use and Conservation. Earthscan, London, UK.
Dale, V.H., Beyeler, S.C., 2001. Challenges in the development and use of ecological indicators. Ecol. Indic. 1, 3–10.
Danielsen, F., Burgess, N.D., Balmford, A., 2005. Monitoring matters: examining the potential of locally-based approaches. Biodivers. Conserv. 14, 2507–2542.
Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Ngaga, Y., Poulsen, M.K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E., Yonten, D., 2009. Local participation in natural resource monitoring: a characterization of approaches. Conserv. Biol. 23, 31–42.
Danielsen, F., Pirhofer-Walzl, K., Adrian, T.P., Kapijimpanga, D.R., Burgess, N.D., Jensen, P.M., Bonney, R., Funder, M., Landa, A., Levermann, N., Madsen, J., 2014a. Linking public participation in scientific research to the indicators and needs of international environmental agreements. Conserv. Lett. 7, 12–24.
Danielsen, F., Topp-Jørgensen, E., Levermann, N., Løvstrøm, P., Schiøtz, M., Enghoff, M., Jakobsen, P., 2014b. Counting what counts: using local knowledge to improve Arctic resource management. Polar Geogr. 37, 69–91.
Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, T.S., Asfaw, Z., Bartus, G., Brooks, A.L., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y., Zlatanova, D., 2015. The IPBES Conceptual Framework – connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16.
FairWild Foundation, 2010. FairWild Standard Version 2.0. Weinfelden, Switzerland.
Fernández-Giménez, M.E., Estaque, F.F., 2012. Pyrenean pastoralists' ecological knowledge: documentation and application to natural resource management and adaptation. Hum. Ecol. 40, 287–300.
Fernández-Llamazares, Á., Díaz-Reviriego, I., Guèze, M., Cabeza, M., Pyhälä, A., Reyes-García, V., Fernandez-Llamazares, A., Diaz-Reviriego, I., Gueze, M., Cabeza, M., Pyhala, A., Reyes-Garcia, V., 2016. Local perceptions as a guide for the sustainable management of natural resources : empirical evidence from a small-scale society in Bolivian Amazonia. Ecol. Soc. 21, 2.
Folke, C., 2009. Traditional knowledge in social-ecological systems. Ecol. Soc. 9, 7.
Fraser, D.J., Coon, T., Prince, M.R., Dion, R., Bernatchez, L., 2006. Integrating traditional and evolutionary knowledge in biodiversity conservation: a population level case study. Ecol. Soc. 11, 4.
Fremuth, W., Schopp-Guth, A., Hoda, P., Mersinllari, M., Dinga, L., 1999. Assessment of the sustainable use of medicinal plants from the Ohrid and Prespa region. Tirana, Albania.
Fremuth, W., Shumka, S., Lako, T., 2014. Management plan of the Prespa National Park in Albania 2014-2024. Gorica e vogel, Albania.
Gadgil, M., Berkes, F., Folke, C., 1993. Indigenous knowledge for biodiversity conservation. Ambio 22, 151–156.
Garcia, C.A., Lescuyer, G., 2008. Monitoring, indicators and community based forest management in the tropics: pretexts or red herrings? Biodivers. Conserv. 17, 1303–1317.
Gilchrist, G., Mallory, M., Merkel, F., 2005. Can local ecological knowledge contribute to wildlife management? case studies of migratory birds. Ecol. Soc. 10, 20.
Global Environment Division, 1998. Guidelines for monitoring and evaluation for biodiversity projects. World Bank.
Harris, G., 2007. Complexity and complex systems. In: Seeking Sustainability in an Age of Complexity. Cambridge University Press, Cambridge, pp. 19–27.
Heaslip, R., 2008. Monitoring salmon aquaculture waste: the contribution of First Nations' rights, knowledge, and practices in British Columbia, Canada. Mar. Policy 32, 988–996.
Hellier, A., Newton, A.C., Gaona, S.O., 1999. Use of indigenous knowledge for rapidly assessing trends in biodiversity: a case study from Chiapas. Mexico. Biodivers. Conserv. 8, 869–889.
Huntington, H.P., 2000. Using traditional ecological knowledge in science: methods and applications. Ecol. Appl. 10, 1270–1274.
Ilbert, H., Ioxha, V.I., Sahi, L., Courivaud, A., Chailan, C. (Eds.), 2016. Le marché des plantes aromatiques et médicinales: analyse des tendances du marché mondial et des stratégies économiques en Albanie et en Algérie, Option méd. ed. CIHEAM/FranceAgriMer, Montpellier, France.
Imami, D., Ibraliu, A., Fasllia, N., Gruda, N., Skreli, E., 2015. Analysis of the medicinal and aromatic plants value chain in Albania. Gesunde Pflanz 67, 155–164.
LaRochelle, S., Berkes, F., 2003. Traditional ecological knowledge and practice for edible wild plants: biodiversity use by the Rarámuri, in the Sirerra Tarahumara, Mexico. Int. J. Sustain. Dev. World Ecol. 10, 361–375.
Lawrence, A., 2010. Introduction: learning from experiences of participatory biodiversity assessment. In: Lawrence, A. (Ed.), Taking Stock of Nature: Participatory Biodiversity Assessment for Policy, Planning and Practice. Cambridge University Press, Cambridge, pp. 1–29.
Mallory, M.L., Gilchrist, H.G., Fontaine, A.J., Akearok, J.A., 2003. Local ecological knowledge of Ivory Gull declines in Arctic Canada. Arctic 56, 293–299.
Mistry, J., Berardi, A., 2016. Bridging indigenous and scientific knowledge. Science 352, 1274–1275.
Moller, H., Berkes, F., Lyver, P.O.B., Kislalioglu, M., 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecol. Soc. 9, 2.
Naka, K., Musabelliu, B., 2004. Albanian national forest inventory (ANFI) special study: social and economic relevance of NTFPs in Albania. Agrotec Consortium, ANFI project report.
Niedfind, B., 2003. Albanien: Wildsammlung immer noch von großer Bedeutung (Albania: Wildcrafting still very important). J. Med. Spice Plants 8, 6.
Olsson, P., Folke, C., Berkes, F., 2004. Adaptive comanagement for building resilience in social-ecological systems. Environ. Manage. 34, 75–90.
Pei, S., Zhang, G., Huai, H., 2009. Application of traditional knowledge in forest management: Ethnobotanical indicators of sustainable forest use. For. Ecol. Manage. 257, 2017–2021.
Raj, R., 2006. Harmonizing traditional and scientific knowledge systems in rainfall prediction and utilization. In: Reid, W.V., Berkes, F., Wilbanks, T.J., Capistrano, D. (Eds.), Bridging Scales and Knowledge Systems: Concepts and Applications in Ecosystem Assessment. Island Press, Washington DC, USA, pp. 225–240.
Reed, M.S., Dougill, A.J., Baker, T.R., 2008. Participatory indicator development: what can ecologists and local communities learn from each other? Ecol. Appl. 18, 1253–1269.
Reed, M.S., Fraser, E.D.G., Dougill, A.J., 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. Ecol. Econ. 59, 406–418. https://doi.org/10.1016/j.ecolecon.2005.11.008.
Rist, L., Shaanker, R.U., Ghazoul, J., 2010. The use of traditional ecological knowledge in forest management: an example from India. Ecol. Soc. 15, 3.
Roba, H.G., 2008. Global goals, local actions: A framework for integrating indigenous knowledge and ecological methods for rangeland assessment and monitoring in Northern Kenya. Norwegian University of Life Sciences, Ås, Norway.
Roba, H.G., Oba, G., 2008. Integration of herder knowledge and ecological methods for land degradation assessment around sedentary settlements in a sub-humid zone in northern Kenya. Int. J. Sustain. Dev. World Ecol. 15, 251–1164.
Sheil, D., 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. Conserv. Biol. 15, 1179–1182.
Sheil, D., Boissière, M., Beaudoin, G., 2015. Unseen sentinels: local monitoring and control in conservation's blind spots. Ecol. Soc. 20, 39.
Shuka, L., 2012. Survey on vegetation of alpine meadows and pastures of the Prespa National Park in Albania – Draft report. Tirana, Albania.
Sobral, A., La Torre-Cuadros, M., de los, Á., Alves, R.R.N., Albuquerque, U.P., 2017. Conservation efforts based on local ecological knowledge: the role of social variables

in identifying environmental indicators. Ecol. Indic. 81, 171–181.
Spoon, J., 2014. Quantitative, qualitative, and collaborative methods: approaching indigenous ecological knowledge heterogeneity. Ecol. Soc. 19, 33.
Staddon, S.C., Nightingale, A., Shrestha, S.K., 2014. The social nature of participatory ecological monitoring. Soc. Nat. Resour. 27, 899–914.
Tengö, M., Brondizio, E.S., Elmqvist, T., Malmer, P., Spierenburg, M., 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: the multiple evidence base approach. Ambio 43, 579–591.
The Plant List, 2013. Version 1.1 [WWW Document]. URL http://www.theplantlist.org (accessed 12.12.17).
Torres-Londoño, P., Doka, D., Becker, H., 2008. Collection of medicinal and aromatic plants in Albania – an analysis given by examples of the surroundings of Peshkopi (Dibër Region). Z. Arzn. Gew. 13, 153–160.
Turnhout, E., Bloomfield, B., Hulme, M., Vogel, J., Wynne, B., 2012. Listen to the voices of experience. Nature 488, 454–455.
Turnhout, E., Hisschemöller, M., Eijsackers, H., 2007. Ecological indicators: between the two fires of science and policy. Ecol. Indic. 7, 215–228.
Turreira-García, N., Meilby, H., Brofeldt, S., Argyriou, D., Theilade, I., 2018. Who wants to save the forest? characterizing community-led monitoring in Prey Lang, Cambodia. Environ. Manage. 61, 1019–1030.
Zhao, M., Brofeldt, S., Li, Q., Xu, J., Danielsen, F., Læssøe, S.B.L., Poulsen, M.K., Gottlieb, A., Maxwell, J.F., Theilade, I., 2016. Can community members identify tropical tree species for REDD+ carbon and biodiversity measurements? PLoS One 11, e0152061.
Ziembicki, M.R., Woinarski, J.C.Z., Mackey, B., 2013. Evaluating the status of species using Indigenous knowledge: novel evidence for major native mammal declines in northern Australia. Biol. Conserv. 157, 78–92.