

Stewardship underpins sustainable foraging

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Foraging wild plants and mushrooms can be both beneficial and detrimental to biodiversity. We examine the role of stewardship practices, which are grounded in care, knowledge, and agency, in fostering sustainable use of wild species. These practices are pervasive among foragers across social-ecological systems yet neglected in research and policymaking.

The social and ecological importance of foraging

Foraging wild plants and mushrooms is a complex social-ecological and cultural phenomenon that encompasses searching for, gathering or harvesting, processing, sharing, and using useful species. Foraging underpins place and species attachment, thus the relationship and connectedness between humans and nonhuman nature. In addition to their functional roles in ecosystems, foraged wild plants and mushrooms contribute to all the material, immaterial, and several regulating Nature's Contributions to People, that is, contributions of living nature to people's quality of life [1]. Foraging occurs extensively

worldwide, with increasing demand for wild species that have decreasing abundance [2,3], and it applies to multiple socio-economic contexts, from wild plants and mushrooms being crucial for the food, medical, and economic security of vulnerable human populations [2,4] to recreational foraging [5].

Wild plants and mushrooms can survive independently of human intervention, yet they are often cared for in multiple ways by people who forage them [6]. Indeed, foraging often entails a diversity of practices for tending species and their habitats, supported by continued monitoring and early notice of environmental changes [7]. However, wild plant and mushroom populations can also be negatively affected by foraging, with overharvesting leading to a declining abundance of useful wild species, disrupting the ecosystem balance, degrading habitats, and reducing biodiversity [1,3]. Therefore, foraging *per se* can both sustain and threaten biodiversity at genetic, species, and ecosystem levels (by modifying ecosystem structure, community composition, species populations, and genetic composition), and this controversy leads to a dilemma between promotion and restriction of foraging. These divergent outcomes can also co-occur and are often based on different value systems for nature [2]. State-supported policies, market demands, marginalization of minorities, and climate change are factors contributing to overharvesting, yet the determinants of sustainable foraging are less known [2,8]. To overcome the dilemma and increase sustainable use of wild species, we need to better understand and promote the stewardship practices that are pervasive among many foragers across socioeconomic contexts but often overlooked by academia and policymakers. For example, stewardship practices in foraging are not included in important biodiversity assessments (e.g., the sustainable use assessment of the Intergovernmental

Science-Policy Platform on Biodiversity and Ecosystem Services [2]).

By synthesizing evidence from the literature and providing place-based examples of the contributions of stewardship practices to nonhuman nature, we argue that the promotion of foragers' stewardship holds potential to limit the decline in abundance of useful wild species while supporting manifold material and immaterial contributions to people.

Stewardship in foraging

Stewardship is grounded in care, knowledge, and agency of foragers toward elements of nature (Table 1) [9] and radically differs from technocratic and monodisciplinary natural resource management, as stewards see themselves as part of ecosystems while ecosystem managers position themselves outside [10]. Foragers as stewards are 'vital participants, engaged in a sustained relationship of care and responsible use, whose activities nurture ecosystems while improving human well-being' [10]. Across social-ecological systems, relations of reciprocity are established between many foragers, foraged plants, and foraging places through stewardship practices [5,6,11,12].

Stewardship practices are 'actions taken by individuals, groups or networks of actors, with various motivations and levels of capacity, to protect, care for or responsibly use the environment in pursuit of environmental and social outcomes' (Figure 1) [13]. These practices lead to a range of immediate and long-lasting ecological effects on the harvested species and the ecosystems where they grow [14]. They support ecosystems by maintaining (and potentially enhancing) biological diversity and often coproduce aspects of nature, as they may influence species distribution and abundance or ecosystem structure and composition [14]. Examples for such practices include adequately

Table 1. Examples of foraging stewardship practices

| Foraged species and their social–ecological system | Stewardship practices | Observed social–ecological impacts of stewardship |
|--|---|--|
| French professional harvesters sell mountain arnica (<i>Arnica montana</i> L.; medicinal) to the pharmacological industry. Mountain pastures, hay meadows, moors. | Keeping open habitats by burning, mowing, or grazing. Whistle-blowing about changes altering species and spaces (since foragers are particularly attentive to the presence and abundance of the harvested species and associated biodiversity). | <i>A. montana</i> is an ‘umbrella’ species; its care contributes to conserving nonfertilized open habitats and associated biodiversity. Foragers’ stewardship benefits rangers, landowners, and local authorities. |
| Norwegian commercial foragers sell sea rocket (<i>Cakile maritima</i> Scop.; edible) to the high gastronomy market, and recreational foragers harvest it for home use. ~100 km around urban centers; coastal habitats. | Removing invasive and other competing species, monitoring area of distribution, harvesting only a proportion of available individuals, switching to other populations and species when necessary. | Maintenance of <i>C. maritima</i> populations (in areas where competing species are not removed, populations struggle). |
| Local communities of Trigrad (Bulgaria) sell Greek mountain tea (<i>Sideritis scardica</i> Griseb.; medicinal) for international trade. Mountain areas. | Seeds from wild populations harvested and sown around villages in similar habitats (cultivation). Monitoring availability and harvesting pressure. | Distribution and abundance of species modified to increase <i>S. scardica</i> accessibility. |
| Local communities of Northern Pakistan harvest true morels (<i>Morchella</i> spp.; edible mushroom) for national and international trade. Moist, temperate, alpine, and subalpine forests. Kashmir, Hazara, and Malakand regions. | Selected healthy and mature mushrooms are left for spore dispersal. | Sustainable income generation by supporting the natural regrowth of <i>Morchella</i> spp., preventing its overexploitation. |
| Locals in rural Slovenia harvest various plants, such as meadowsweet [<i>Filipendula ulmaria</i> (L.) Maxim.] and nettles (<i>Urtica dioica</i> L.). Agricultural areas. | Selective mowing of unwanted species, others left for harvesting in permaculture gardening. | Favorable conditions for the growth of foraged plants created within agricultural areas. |
| Huancavilca Indigenous communities harvest various parts of the culturally important ivory palm (<i>Phytelephas aequatorialis</i> Spruce; edible, medicine, construction materials, symbolic value) for commercial and household use. Tropical and subtropical forests, common in agricultural areas (West Ecuador). | Seedlings transplanted, canopy cleared to enhance growth, limited harvesting of seeds. | Heterogeneity created within forest ecosystems with small and dense populations of <i>P. aequatorialis</i> , feeding grounds for herbivores. Enhanced governance and self-management. The species sustains people–nature relational values, attachment to place, identity, and social cohesion. |
| Bassari communities harvest yams (<i>Dioscorea</i> spp.; edible, medicinal, symbolic value). Subtropical grasslands, savannas, and shrublands of Southeast Senegal. | Maintenance of tuber heads in soil and reburial after harvesting. Several prohibitions dictate who should (not) harvest. Many of the sacred forest areas, where harvesting is strictly prohibited according to traditional rules, overlap with particularly vulnerable ecosystems. | Maintenance of <i>Dioscorea</i> spp. populations and their habitats. |
| Commercial common juniper (<i>Juniperus communis</i> L.; edible for alcoholic beverages) berry pickers. Lower slopes of the Pyrenees (Catalonia, Spain). | Harvesting done with a traditional system designed to only pick last year’s berries without damaging the current year’s immature cones; boxwood sticks are used to hit the branches and collect on nets only the mature cones that fall easily (many modern pickers use gloves that rip all the berries, the ripe and the green). Switching harvested populations when necessary. | Traditional harvest methods avoid negative impacts on yields and protect species reproduction. |

limiting the levels of extraction (in terms of quantity, timing, area, frequency, etc.) by picking only a proportion of what is available, picking only what is needed, cleaning, pruning, weeding, verifying the maturity and quality of the product, picking specific plant parts with adapted harvesting

methods and tools, selecting locations, fallowing, maintaining habitat, planting, spreading seeds, transplanting, removing invasive species, and removing rubbish (Table 1) [7,11,12]. Some of these practices are not specific to foraging but common with broader conservation practices.

Care

Stewardship practices are practices of care grounded in personal and collective values, aesthetic and moral ideals, ecological knowledge, and identity [9]. They underpin and are underpinned by feelings of attachment and responsibility. These



Figure 1. Foraging stewardship establishes reciprocal relations between people and nature in social-ecological systems across biodiversity and social levels. Stewardship practices are often invisible despite shaping landscapes and involving considerable care, knowledge, and agency. Illustration by Clara Teixidor-Toneu.

feelings often lead to care behaviors, which can be inscribed in cultural world-views but also developed through sustained experience outdoors throughout a person's life [15]. Care is deepened by spending time outdoors, which foraging facilitates, and moves experienced

foragers to teach each other as well as the younger generation about nature-related values [5–7, 11].

Knowledge

At local scales, foraging can contribute to biodiversity conservation through the

stewardship practices of experienced foragers. Often, the practices of more experienced foragers and foraging communities that have accumulated ecological knowledge are more attuned to the conservation of biodiversity. This has been observed in contexts of Indigenous knowledge-based foraging but also in commercial settings among migrant workers [5] and professional harvesters [11]. Knowledge (including, but not restricted to, taxonomic, phenological, and ecological knowledge) is cumulative at the individual level and based on place and plant experience but also on cultural experiences and world-views of the foragers' communities. There is a diversity of social, economic, ecological, and climatic indicators that help foragers decide whether and where (not) to forage, including (changes in) landscape use, habitat availability, number of foragers, harvest signs, and population's area of distribution, among others [16]. Many of those indicators are used to avoid negative ecological impacts.

Agency

Foraging can be performed by an individual, group, or community. It may lead to common-pool management and governance, although these expressions of agency are deeply affected by local, national, and international legislation and political scenarios [9]. Individual stewardship, social norms, multiscale regulations, and land tenure govern forager–plant relations and practices. In some cases, this mindfulness has resulted in concerted efforts to organize collective action to control the impact of harvesting on the resource or to regulate the economic context of the activity. In any case, foragers are also aware that the activity itself occurs in territory with very specific access regulations; it is open access (open to all and used on a first come, first serve basis), private (which requires one-on-one agreements with the owners), commons (which implies the authorization of a group of individuals or their representative), or public (belonging to the

state). Each one of the property regimes mentioned (open access, private, public, or commons) implies a specific and different assemblage of social actors with asymmetrical political power; legal, institutional, and relational frameworks; productive and cultural priorities; history; and spatial scales that will condition the rights to include or exclude users and set up the field of possibilities for every actor's agency. Some of the configurations of these assemblages will provide incentives for the emergence of collective action, and some will make concerted efforts difficult.

Future action to promote stewardship practices

Foraging fosters diverse values of nature and stewardship that help halting or reversing the decline in wild species important for material and immaterial contributions to people and protect the habitats where they live [1]. Promoting foraging and stewardship education (transmission of knowledge within and across knowledge systems, sharing the values of care, respect, and responsibility within and across generations) can contribute to overcoming overharvesting threats where present [17] and help achieve the potential of wild plants and mushrooms to curve climate change [4]. Local communities and foraging associations promote stewardship education through customary institutions, voluntary codes of conduct, events, publications, social media, and videos [5,11]. Policies should build on such initiatives to establish legal conditions that foster foraging stewardship, rather than jeopardize related activities by establishing restrictive harvesting guidelines, and thereby support connectedness between humans and nonhuman nature [6].

The under-representation of stewardship practices in the scientific literature may be due to the fact that foraging has been studied separately by the social and natural sciences. Typically, the social sciences have revealed foragers' knowledge, practices, and governance, while the natural sciences

have focused on the ecological impacts of foraging. Thus, a complete vision of foraging in social–ecological systems is lacking. Transdisciplinary research combining both approaches and cocreating knowledge with foragers is needed to foster a holistic view of the stewardship practices applied and the related ecological impacts.

Future research should identify which individual, collective, and contextual factors foster stewardship practices in foraging. What social, ecological, cultural, and economic drivers along with individual motivations and values foster the persistence and adaptation of ecological knowledge and stewardship practices? Foraging practices are also quickly changing, abandoned along with changing lifestyles, restricted by new legislation, impeded by changing land use and climate, or taken up by neophyte foragers. What do these changes entail for foraging stewardship?

Acknowledgments

We would like to thank the workshop participants who, despite not contributing to the final article, participated in the first discussions on the topic of this article in a workshop at the 18th Congress of the International Society of Ethnobiology (Marrakech, 15–19 May 2024). I.T.-T. has received financial support from the French government under the France 2030 investment plan, as part of the Initiative d'Excellence d'Aix (Marseille Université) A*MIDEX (AMX-22-CPJ-05) and the IRD ANR-CPJ contract number 402299/00. Open access funding provided by University of Natural Resources and Life Sciences Vienna (BOKU).

Declaration of interests

The authors declare no competing interests.

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<https://doi.org/10.1016/j.tree.2025.01.004>

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