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Cultivation as a conservation tool for cacti: review of the botanical evidence and a case study of *Lophophora williamsii*

Anna O. Ermakova[1,2], *Martin K. Terry*[1] *and Keeper Trout*[1,3]

1. Cactus Conservation Institute, 909 East Sul Ross Ave, Alpine, Texas 79830, U.S.A (mkterryaiw@gmail.com) (annapolarfox@gmail.com)
2. Psychedelic Trials Group, Centre for Affective Disorders, Institute of Psychiatry, Psychology and Neuroscience, King's College London, 16 De Crespigny Park, London SE5 8AF, UK. Corresponding author
3. P.O. Box 233, Boonville, CA 95415, U.S.A. (keepertrout@gmail.com)

Photographs: the authors

Summary: In this article we review the literature, with a focus on cacti, about the role of cultivation in conservation. We examine in detail the case study of *Lophophora williamsii*, the peyote cactus, and present arguments that cultivation is not only a necessary conservation strategy for this particular species but is likely the only viable alternative for long-term survival of this cactus in the wild. Concerns about cultivation, as well as recommendations and conservation implications are also discussed.

Zusammenfassung: In diesem Artikel geben wir einen Literaturüberblick zur Rolle der Kultur im Artenschutz, wobei wir uns auf Kakteen konzentrieren. Wir befassen uns eingehend mit dem Fallbeispiel von *Lophophora williamsii*, dem Peyote-Kaktus, und präsentieren Argumente dafür, dass die Kultivierung nicht nur eine notwendige Erhaltungsstrategie für diese spezielle Art ist, sondern wahrscheinlich auch die einzige praktikable Alternative für das langfristige Überleben dieses Kaktus in der freien Natur. Bedenken gegen die Kultivierung sowie Empfehlungen und Auswirkungen auf die Erhaltung werden ebenfalls erörtert.

Keywords: *Lophophora williamsii*, peyote, Cactaceae, cactus conservation, plant cultivation, *ex situ* conservation

Cultivation for conservation – review of the literature

The cacti are a culturally significant group, with diverse uses spanning from ornamental plants to medicine and food. Collection of wild plants for such purposes has led to conservation concerns, and recent global conservation assessment of the whole taxon Cactaceae has concluded that many of these charismatic plants are threatened with extinction. The authors evaluated 1,478 cactus species (out of 1,480 total species – although there are ongoing debates about how the exact number of species should be determined) against the IUCN Red List Categories and Criteria and concluded that 31% of these species are threatened (Goettsch et al., 2015). Amongst the identified drivers of extinction risk, by far the largest is the unscrupulous collection of live plants for the horticultural trade and for private ornamental collections (affecting 47% of threatened cacti) followed by smaller impact from livestock ranching (31%) and agriculture (24%).

Despite the inclusion of the whole family (with only several exceptions) in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), trade in cactus species takes place at both the national and international levels, and it is often illegal (Sajeva et al., 2013). The availability of plants grown from seed in international markets plays a crucial role in whether plants are collected in the wild or not. Although many species are cultivated and techniques of species propagation have been developed (Anderson, 2001), illegal collecting is still a significant threat (Oldfiled, 1997; Robbins & Luna, 2003), with 86% of threatened cacti being collected from the wild (Goettsch et al., 2015).

Population evaluation and demographic studies are the best ways to determine the conservation status of cactus species, which then should be followed by specific conservation plans for preservation of species and their habitats *in situ*. However, in practise, comprehensive demographic

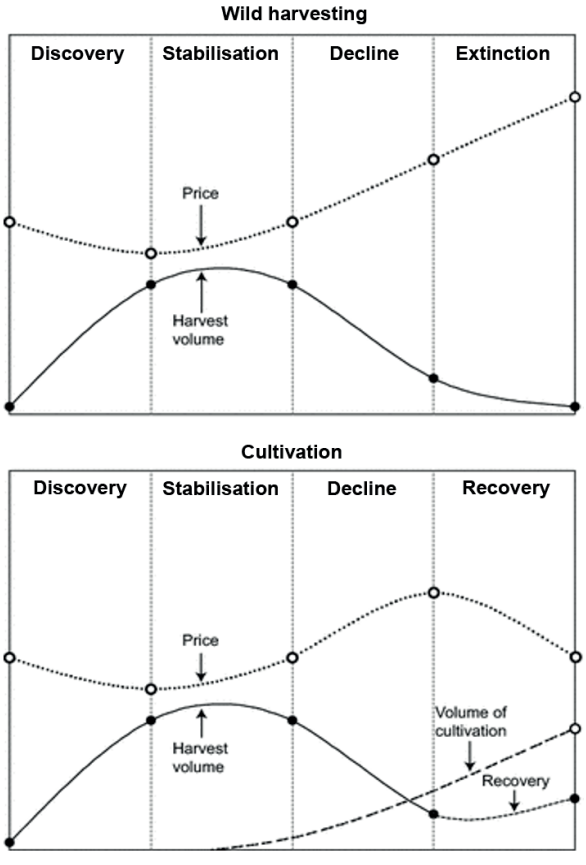

Figure 1. Price and harvest volume variation in the transition from wild-harvesting to cultivation of medicinal plants. As wild resources decline with over-harvesting, the price of raw material increases accordingly. Therefore, cultivation becomes feasible for resource recovery of medicinal plants. Figure from Chen et al., (2016).

assessments and conservation plans are scarce in the regions of cacti biodiversity hotspots, and so is the establishment of comprehensive protected areas (Ortega-Baes & Godínez-Alvarez, 2006). *Ex situ* conservation complements this by protecting and maintaining genetic resources of endemic, endangered and culturally and economically important species outside their natural habitat. Seed banks and botanical gardens are the most common *ex situ* strategies for plant conservation. Additionally, because cacti are particularly popular among plant collectors and horticulturalists, one should not underestimate the protection that existing cactus collections and nurseries can provide from looting wild cacti (Santos-Díaz et al., 2010). The logic behind this is that propagating plants that are a valuable resource (and have considerable demand) reduces the likelihood that these species would be extracted from the wild, as well increasing potential for re-population and restoration of native habitats. Additional benefits include increasing awareness about endangered species. It could possibly even provide a source of funding to supplement endangered plant conservation (Shirey et al., 2013). When commercial and private cacti nurseries are not able to satisfy the demand (or when there are other restrictions on sales), then consumers would purchase cacti plundered from their natural environment, often via unregulated black markets. A relevant report by TRAFFIC about the trade in the cacti from Chihuahuan desert recommends monitoring the cactus trade better, strengthening protection for species under the most pressure, and developing community-based programmes to harvest common species and commercially cultivate slow-growing species (Robbins & Luna, 2003). When it comes to trade in cultivated plants, regulation is the key – after all, one needs to ensure that the plants do indeed come from nurseries and are not plundered from the wild. Slow-growing plants like cacti are vulnerable to wild collection as it is easy to get an old, larger plant, and black-market dynamics fuel this.

Ex situ conservation works in practice, not just in theory. For example, Pulido et al. (2013) analysed the effect of nurseries on cactus conservation and evaluated whether nurseries have been able to decrease illicit removal of cacti in the Barranca de Metztitlán Biosphere Reserve in Mexico. The authors conclude that the nurseries have helped decrease illegal traffic in cacti and have enabled *ex situ* conservation of twenty-two cacti species, changing cactus management by the local communities from extraction to cultivation (Pulido & Cuevas-Cardona, 2013).

Cultivation is particularly important for protection of plants that have medicinal, cultural or economic value. The assertion that cultivation relieves harvesting pressure on rare and threatened medicinal plants is well supported by the conservation evidence (Figure 1). If a plant is freely available in culture, there is less demand for wild plants. Multiple recommendations and guidelines on protecting threatened wild species of medicinal value emphasise the need for the species in question to be brought under cultivation (Lambert et al., 1997; Schippmann et al., 2002). Such production through cultivation can reduce the pressure on wild plant populations, while ensuring continuous supply for those who require a given plant. Moreover, cultivation allows for the seeds to be conserved and stored in seed banks for

future replanting or exchange of genetic material with other growers (Hamilton, 2004; Havens et al., 2006).

Hoodia gordonii (Masson) Sweet ex Decne., a South African succulent, provides an example of a culturally significant plant and the issues involved with its protection, regulation, and ensuring respect of the indigenous rights (in this case the San people) (Wynberg & Chennells, 2009). Another example, in North America, is the case of American ginseng (*Panax quinquefolius* L.), which has been overharvested in the wild, yet successful cultivation programs and other human interventions allowed recovery of the wild populations (McGraw et al., 2013).

One caveat here is that conservation in the 'real world' (outside the confines of strict nature reserves or academic ivory towers) is a multi-disciplinary challenge. Evidence-based approaches to conservation have been recommended (Sutherland et al., 2004), but they are often difficult to apply in practise, a phenomenon termed 'research-implementation gap' (Toomey et al., 2017). Although lack of access to the information is often cited as the reason for the 'gap', there are plenty of other reasons for its existence. Much diplomacy is needed to navigate conflicting values, belief systems and trust issues between different stakeholders. Yet, Nobel-prize winning economist Elinor Ostrom's work demonstrates that multilevel, distributed decision authority is often more effective than top-down approaches at managing resources in complex social-ecological systems (Ostrom, 2015). In other words, to be effective, conservation interventions must emerge from the dialogues with all the major stakeholders, most importantly native peoples and local communities. More inclusive, decentralised decision-making processes, including community-based conservation and co-management, are more desirable and effective in the long-term in socio-ecosystems (Decker et al., 2016). Unless proposed solutions are culturally and socially acceptable, no amount of conservation evidence is going to lead to their implementation.

Scholars have convincingly shown that empirical evidence is only one factor (and often a minor one) influencing decision-making and change (Pielke, 2007; Owens, 2012). Research in psychology, policy making, and effective communication demonstrates that 'facts' are not perceived in the same way by different publics, but rather are altered through existing beliefs, mental models, experiences, and concerns (Nisbet & Scheufele, 2009; Newell et al., 2014). Pre-existing belief systems may even be able to

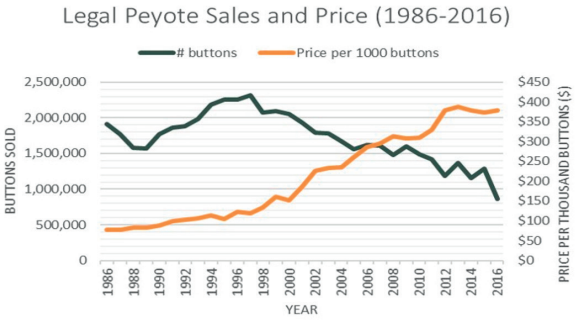

Figure 2. Legal peyote trade data, from Texas Department of Public Safety. One can easily see similarity with the graph depicting wild harvesting in figure 1. The current situation with peyote is that supply is going down (there are less and less plants available to harvest, and the size of individual plants is smaller). The prices are going up, and demand increases, due to increase in the number of members of the NAC.

preclude the evaluation of facts and observations that are in conflict with those beliefs. The progress in conservation science, with its 'wicked problems' of biodiversity loss and climate change, are often halted by the debates and disagreements fuelled by conflicting values and world-views on social justice, economics, and natural resource use. Often, far from resolving discord, scientific information polarises debates around these issues even further (Pielke, 2007; Nisbet & Scheufele, 2009). Yet, as scientists we believe it is important to have a balanced conversation, and our role in it is to provide critical evidence synthesis and evaluation, ensuring that accurate information can be available to help others make their own informed decisions.

Recently there has been a controversy over the cultivation of *Lophophora williamsii* (Lem. ex Salm Dyck) J.M.Coult., or peyote, accompanied by some misleading assertions as to how cultivation potentially affects rare and endangered plants. Cultivation has been successfully used as a conservation tool for the plants that are traditionally harvested from the wild. Seedlings can be grown up to a certain age, and are later re-planted back into their natural habitat, ensured better survival than directly using seeds for re-population efforts, as was successfully implemented with endangered star cactus, *Astrophytum asterias* (Zucc.) Lem, (Birnbaum et al., 2011). Additionally, cultivation can prevent environmental degradation and loss of genetic diversity in the wild. Increased cultivation contributes to decreases in the harvest volume of wild medicinal plants and benefits the recovery of their wild resources (Hamilton, 2004; Schippmann et al., 2005; Larsen & Olsen, 2007).

Figure 3. *Lophophora williamsii*. A – Peyote with flower, B – Peyote plancha, C – Peyote in cultivation in Czech Republic, D – Heavily tufted variety of peyote with fruit.

Below we examine the case study of *Lophophora williamsii* and present arguments that cultivation is not only necessary conservation strategy for this particular species but is likely the only viable alternative for long-term survival of this cactus in the wild. While we aren not telling anyone what to do or not do regarding their own cultivation or their religious practices, we offer our view of the peyote's present state and its future.

Introducing *Lophophora williamsii*

Lophophora williamsii is a small, spineless cactus native to Chihuahuan Desert and Tamaulipan thornscrub ecosystems. It is endemic to Mexico and small parts of south and west Texas. This cactus is blue-green (or reddish-green when stressed), globose in shape and is 2–6cm high and 4–12cm in diameter. Areoles are rounded and are 0.9–1.5cm apart. These cacti have 5–13 ribs which are easily countable (Figure 2). The number of ribs increases with age. From the cusp areoles arises a tuft of soft, whitish woolly hairs. Spines are absent. The growth rate is very slow, and it takes about ten years in the wild for the plant to mature from seed. The flowers of *L. williamsii* are pink and are found on top of the crown. Peyote flowers March–September (Rojas-Aréchiga & Flores, 2016). The fruit is an edible red or pink berry that contains many oval, black-brown, medium-sized seeds (Šnicher et al., 2009). It is a resilient plant species occurring within a wide range of soil types and environmental extremes.

It is hardy to a surprising degree of heat and drought or cold and wet and naturally tends to form populations that can be impressively dense. Individual plants can live to an immense age, and they can form mounded clusters, referred to as planchas, that can span a metre with dozens of crowns. It has become relatively rare to encounter such individuals or populations. Reproduction can be both sexual and asexual. No studies have examined pollination and seed dispersal in the wild populations. Vegetative reproduction is triggered in response to damage to the crown, such as herbivory or harvesting the crown. Therefore, when harvesting it is important to only cut the green part of the plant and leave stem and root in the ground to re-grow more plants (Terry & Mauseth, 2006).

Peyote can rightly be considered a 'cultural keystone species', i.e. a species of exceptional significance, that can influence social systems and culture and are a key feature of a community's identity (Garibaldi & Turner, 2004). It is a medicine and sacrament for several indigenous groups in Mexico and a growing number of the members of the Native American Church in the USA and Canada. The Diné roadman Steven Benally recently estimated that there are presently 400,000 NAC members (Pollan, 2021). Besides its cultural significance, *Lophophora williamsii* are perennial, slow-growing and long-lived, making them particularly sensitive to anthropogenic activities.

According to the IUCN Red List of Threatened Species it is vulnerable (although it should be added that the data on its distribution and occurrence across the entire species range is deficient), with the major threats being habitat loss and over-harvesting (IUCN, 2017). Studies on peyote's ecology, species distribution, population densities and occurrence across the entire species range are rare (Rojas-Aréchiga & Flores, 2016; Ermakova et al., 2021). The potential effects of climate change on peyote have never been evaluated. In Mexico, peyote is considered a species under special protection (NORMA SEMANART, 2010, an acronym for Secretaría del Medio Ambiente y Recursos Naturales – Natural Resources and Environmental Ministry), and in Texas it is considered imperilled (threatened) (NatureServe, 2020). Therefore, approaches for cultivation, sustainable harvesting, and mitigation measures resulting from habitat loss should be developed for the conservation of this species.

Threats to peyote in the USA and Mexico

The biggest threat to peyote in Texas, by far, has been the change in the use of the land. Tamaulipan thornscrub, the native brushland where it grows, is still being rapidly cleared to make way for urban development, agriculture, 'improved' pastures, and oil, gas and wind energy infrastructures. The second largest pressure on wild populations is over-harvesting for the use of the Native American Church. In Texas, approximately 1,000,000 peyote crowns are sold annually by the licensed distributors to the NAC (see Figure 3) (IPCI, 2021),

The reality of the peyote populations left in Texas is dire. Many populations have been overharvested for many years, and shortages of peyote have been noted since the 1980s (Stewart, 1987). Some populations have even been eradicated in this process. The conversion of land continues to this day accompanied by bulldozers removing entire populations of peyote in South Texas along with the brush (Anderson, 1996; Trout & Terry, 2016; Ermakova et al., 2021) and a visual representation by Santore (2019, 2020). Any observer with on-the-ground familiarity is aware that peyote populations in Texas are insufficient to sustain harvesting pressures for very many more years. To offset this, Mexican peyote has long been viewed as the answer (Maroukis, 2012) but to accomplish this legally would be impossible due to CITES, NOM-SEMARNAT-2010 and North American Free-Trade Agreement which prohibits exportation/importation of illegal items (Muneta ,2020). Yet, it is increasingly likely that the Mexican peyote is filling the shortfall that wild harvested Texas peyote can no longer fulfill, although for obvious reasons there is no research on this topic, and there are only anecdotal reports to support this belief (Donovan 2009; Najera Quezada, 2013). Mexico holds vastly larger peyote populations than Texas, but Mexico also has its own peyote using groups (for example Wixárika, Rarámuri, Cora) who rely on Mexican peyote. Moreover, the arid areas of Mexico are undergoing many of the same anthropogenic pressures, including land use and climate change, with additional impacts that peyote there is found on common land, and it is a lot easier to harvest it there compared with Texas, where the more are on private land.

While systematic data about peyote populations, harvesting pressure and rates of poaching is unavailable for most of Mexico (Mandujano et al. ,2020), the state of San Luis Potosi is somewhat better researched than others. This place is not only one of the hotspots for diversity and density of distribution of threatened cacti (Ortega-Baes & Godínez-Alvarez, 2006; Santos-Díaz et al., 2010) but is also a sacred land of immense cultural significance to the Wixárika (Huichol) people, one of the indigenous groups whose culture

is inextricably linked to peyote cactus. Nájera Quezada monitored seventy transect sites within the Chihuahuan desert in a four-year study. Fifty out of seventy sites showed more than 40% reduction in the number of peyote cacti over the course of the study (Quezada, 2018). Several threats to peyote and the desert ecosystem in the sacred land of the Wixárika have been documented. Although the biggest mining threat has been halted after extensive campaigns and court case(s) (Boni et al., 2015; Hollander, 2017), it was replaced by an aggressive expansion of agrobusinesses with associated use and disposal of pesticides, fertilisers and waste (Negrín, 2021). Another is continuing extraction, although what proportion goes for the use in folk medicine, smuggling abroad to the USA and elsewhere, or for the local 'psychedelic tourism' is unknown. Peyote in Mexico is not infrequently used in folk medicine and is a well-known additive to the topical analgesic ointments, so-called *pomadas de peyote*. They are commonly sold in the local markets, although how much peyote, if any, they contain remains an open question (LeBlanc et al., 2021). In addition, peyote tourism continues to be a serious issue in Mexico (in contrast with Texas) for several reasons, including cultural associations (e.g. Mexico's strong association with psychoactive medicine traditions), lack of enforcement, relative ease of getting peyote and its availability, a variety of contexts in which one can obtain peyote – from all-inclusive weekend retreats with 'shamans' of various degrees of authenticity, to pick-it-yourself desert safaris and buying it in the local markets.

Peyote cultivation

One solution that may become more acceptable in the future is cultivation. Cultivation has long been a cornerstone of successful conservation and repopulation efforts. In the case of peyote, Omer Stewart suggested cultivation as a viable path to ensure peyote's future survival as long ago as 1987. It was also presented as a prominent element in Muneta's evaluation of the peyote crisis (Muneta, 2020).

Three aspects of cultivation can be identified, although the distinction between them is not always clear cut. First, cultivation is an important *ex situ* conservation tool, which can protect genetic diversity and aid re-population efforts. Second, cultivation by and for consumption by the NAC should – at least in theory – offer some degree of peyote self-sufficiency in terms of the number and average size of peyote crowns actually purchased from the DEA-licensed peyote distributors. Home-grown peyote would logically also be expected to afford Native American peyoteros some degree of protection from the ongoing general peyote shortage, thus enabling some continuation of the supply of this sacrament/medicine for future generations. Third, small nurseries and individuals can make an important contribution for the conservation by propagating cacti while maintaining genetic diversity and keeping track of locality data, sharing knowledge, and establishing protocols for better propagation and germination. Cactus collectors and those who are interested in this plant for its psychoactive properties, whether for recreational or healing purposes, could also be considered a harm-reduction measure, protecting wild-grown cacti from people who would otherwise collect it in the wild.

Peyote in horticulture

We have previously provided an in-depth critical analysis of peyote regulation in the USA (Terry & Trout, 2017b). In brief, the peyote plant (and not just its psychoactive alkaloid, mescaline) is considered a Schedule I drug (Congress, 1970). However, in many countries around the world, peyote is not illegal as an ornamental cactus, and it is freely available to grow (as long as it is not for consumption).

We do not actually know when peyote entered Western horticulture, but it has been known as an ornamental plant cultivated and offered in commerce in Europe for almost 180 years (Cels, 1842, 1845). We only know that the first peyote specimen to be formally described in 1845 (Lemaire, 1845) was a specimen acquired from a cactus grower in England, and that peyote soon became a popular cactus in many European nations. Commercial growers in Europe were offering European-produced peyote by the 1930s. (Haage, 1927; Jahandiez & Jahandiez, 1934). It can be found offered as an ornamental plant in the USA for around 130 years.

It is an easy plant to grow as it propagates readily via divisions, and it is an easy cactus to produce from seed (Trout, 2014). Seeds collected from the plant can be stored for years under appropriate conditions (Mandujano et al., 2020). Published germination and growth protocols for *L. williamsii* are available (Cortés-Olmos et al., 2018), as well as informal advice on growing can be found on the Internet (Valente, 2008). Due to this, large numbers of peyote presently exist in both European and Asian horticulture. It is openly grown where it is legal to possess, and it is kept out of sight where it is not, but it has always been a very popular cactus among ornamental cactus growers. In fact, a curious phenomenon can be

observed in peyote horticulture: peyote can grow to be older than its growers. A friend in Germany purchased a peyote specimen from an elderly grower who had been growing it for forty-five years. After a person has been growing a plant for decades, the idea of harming it or eating it is in most cases abhorrent.

In Asia, cactus-lovers grow peyote plants with unusual physical characteristics; monstrous, variegated, heavily tufted or otherwise different cultivars. In contrast with the collection of novel forms, one interesting aspect of European collectors is an obsession with locality data. Looking through a variety of seeds commercially available, one can trace more than a hundred different seeds originating from plants across the native range of peyote. In the Koehres' Kakteen listings alone, eighty-seven localities are presently represented (Köhres, 2021). Koehres' approach appears to be typical. He acquires a limited number of seeds and amplifies their growth rate and proliferation of crowns through grafting and division. Those then become his future seed-producing stock. Regrettably, many of the plants now commercially available as artificially propagated cacti in plant nurseries are descendants of seeds or even live plants that were exported from Mexico or Texas by private collectors. However, this means that a potential library of genomes already exists for locality specific re-population, and the collections of these seeds could become potentially invaluable if the populations that they originally came from become depleted or extirpated.

The question arises whether peyote's presence in horticulture where it is legal stimulates wild harvesting on any meaningful scale. As far as we are aware, no scientific study has examined this for peyote, and it would be fascinating to estimate where does peyote offered in the licit and illicit markets come from. However, it seems unlikely that given the choice of legally purchasing a plant or seeds from nursery or cactus collectors someone would go out of their way to obtain cacti on black market or smuggle them across international borders.

There is also no evidence that peyote being legally available in horticulture results in increase in its consumption among growers. Despite peyote being legal to grow in many European countries, it does not feature in the European Drug reports or National Statistics in the UK (EMCDDA, 2021). A study examining the epidemiology of mescaline use (based on 452 English-speaking respondents to a survey) indicates a higher prevalence of peyote use in North America compared with Europe and the rest of the world (Uthaug et al., 2021). Not presented in this study, but very informative would be to compare rates of peyote use (outside NAC) in Canada (where peyote is legal in horticulture) and USA (where it is Schedule I drug).

A present point pertinent to make, is to distinguish cultivation by hobbyists and cactus-lovers from *ex situ* conservation interventions involving cultivation. On one hand it is possible to find people who believe that having a peyote on a windowsill is somehow part of a conservation program. This holds a grain of truth but only when propagation standards developed for *ex situ* conservation are followed, an example of which would be to keep track of geographic locality records of plant origin. Conversely, the gene pool of species could be adversely impacted through founder effect (cultivation of large number of individuals with limited genetic variability) or hybridisation (Shirey et al., 2013), however any propagation is better than none. To preserve wild species means protecting not individuals but rather entire populations of individuals. To accomplish this, preserving their habitat is a crucial element.

Controversies and objections to cultivation

Cultivation can be a complex subject depending on the vantage point. There is opposition to both cultivation by the NAC and general ease of existing restriction in the USA. In no area is this so pronounced as with conservation efforts involving plants that experience human use for religious purposes or evoking adverse moral judgements due to association with 'drug use'.

Current scheduling of peyote in the USA is a direct example of such moral judgement and direct attempts of the federal and state government to restrict peyote use. It took Native Americans decades of legal struggle and court cases to defend their rights to this medicine and sacrament (Maroukis, 2012). In the USA, the federal standard for the sacramental use of peyote (and likewise for growing it as a cactus) is membership in a federally recognised tribe. Many Church leaders worry that widening these restrictions, such as by allowing people who are not members of federally recognised tribes or proposed decriminalisation measures would endanger their already dwindling supply of peyote (NCNAC and IPCI statement 2020).

There are also concerns about cultural appropriation and commercialisation, involving non-NA using peyote and NAC ceremonies for personal gain and profit. In fact, many NA view the current legislation as protection for wild peyote (Sahagún, 2020).

It is understandable that people who value threatened plants as sacred sacraments might feel that the Peyote way could be threatened by changing current situation, whether it be widening the restriction on cultivation or listing peyote under Endangered Species Act. Likewise, it is understandable how people would want sovereignty over what is perceived as their cultural heritage. After all, given the legacy of exploitation of indigenous peoples, broken treaties and persecution of peyote users specifically, there is mistrust and apprehension when it comes to changing policies, collaborating with scientists or working with governments (Pacheco et al., 2013). However, over the last century the field of conservation biology has evolved to be cognisant, respectful and welcoming to a variety of belief and knowledge systems and welcomes constructive dialogue and diversity of opinions held by a variety of stakeholders (Sodhi & Ehrlich, 2010). In the end, what we could all agree on, is that conservation of sacred medicine plants does involve their long-term survival in the wild as its primary goal. But to succeed at achieving that goal, ensuring perpetual supplies to traditional users, and being good stewards of the land for local communities and ranchers is a requisite part of the program. This makes conservation a practice that is of direct and lasting benefit for everyone.

Obviously, no one has the wisdom or the right to tell other people how to practise their religion. Unrealistic or self-defeating views will find their own resolution with the passing of time.

There are still many people who believe the peyote will take care of its own future, particularly now that conservation efforts have begun. We will remain hopeful this can prove to be the case. Especially as there are efforts by the IPCI underway aimed both at conservation through conscious harvesting practices and cultivation intended for replanting (IPCI, 2021) and some tribes have begun working on legal pathways to construct greenhouses on Indian reservations to cultivate peyote for its NAC members (Muneta, 2020). These activities by IPCI and by the increasing number of NAC groups they are empowering are both exciting and promising.

At the same time there are two elements that are still at work alongside those welcomed developments. One is the fact the largest portion of peyote users are not yet a part of this effort. There is a variety of opinions about cultivation by the NA among different tribes and/or chapters of NAC. Some tribes are decidedly pro cultivation. Some would not be opposed to cultivated peyote but lack resources or capacity to cultivate. Yet some NAC members reject the very idea of greenhouse cultivation and would only consider wild-grown peyote as suitable for their purposes. Many of these people believe wild peyote will remain available in perpetuity (Prue, 2016; Muneta, 2020; Pollan, 2021). We want to agree but all available evidence suggests it is going to require both considerable conservation efforts and enough time for that to become true. The current reality of the situation is that peyote is declining across its range, both in Texas and Mexico, and cultivation to ensure supply for the NAC is not only logical, but inevitable. Other plants that are used in NAC ceremonies are already cultivated (tobacco, corn, gourds), but a shift in mindset is required for cultivation for and by the NAC to be more widely acceptable solution to peyote crisis.

Anecdotal accounts among NAC members claim that cultivated plants are commonly lower potency than wild ones. This is due to being well treated when in cultivation. Wild plants experience lengthy drought and heat stress every year. Experiencing high summer heat and going most of any given year without rain is typical for South Texas while farther West summer heat and the duration of annual drought are even more extreme. Some populations in West Texas can receive less than an inch of rain per year. Siniscalco reported that six months of drought stress dramatically increased the mescaline content of peyote being grown in Italy so there may be a basis for this belief. However, it appears to be due to growth conditions not simply the fact the peyote was cultivated (Siniscalco, 1983)

Cultivation caveats

The first and foremost caveat with cultivation is that it has to be culturally appropriate and acceptable to the main stakeholders.

The second caveat is that the current legislation makes cultivation, at least in the USA, problematic. But those are not the only obstacles and issues when it comes to cultivation. An obvious one, if we are talking about cultivation to satisfy the supply for the Native American Church, is the sheer scale of greenhouses necessary, and enormous logistical hurdles needed to overcome to grow at least 1,000,000 peyote plants a year of a slow-growing cactus that can take up to ten years to mature (Trout, 2021). Then, going back to the first point about culturally acceptable cultivation, how would these greenhouses operate in practice? Would it be acceptable to use grafting, artificial lighting, selections to increase alkaloid profile, or to employ the use of fertilisers, soil amendments, pesticides, or fungicides? Of course, it is unrealistic

to expect such centralised production of peyote. A more viable solution is for each NAC chapter to cultivate their own peyote locally and chart their own course on how to answer these questions. It is important also to consider funding necessary to set up and operate a cactus greenhouse, with all the associated infrastructure.

What about genetic diversity? If some of the plants from the greenhouses are to be used for repopulation efforts, care should be taken that plants that are replanted back are of the similar genetic lineage, i.e. from the same geographic locality as they are being replanted. When reintroducing plants, using appropriate genetics is very important for success. Plants of the same species which were adapted to another locality may have different levels of tolerance for cold or for wet or for drought. With peyote there is another consideration in that plants from plants of Mexico are different genetically and have been shown to be self-sterile and requiring cross pollination (Terry, 2008). The plants in Texas are known to be self-fertile and can pollinate themselves if necessary. If stock from parts of Mexico is among what is replanted in Texas, this could lead to reduced fertility (or even worse if there is not an appropriate pollinator in South Texas). An additional concern is that re-locating plants and transplanting them to the wild could potentially introduce pests or pathogens and this risk should be taken into account when moving plants (Garbelotto & Pautasso, 2012). There are very clear guidelines for plant reintroductions (IUCN, 2013; Maschinski & Albrecht, 2017) that are important to follow for these efforts to be successful.

Conclusion, recommendations, and conservation implications

Various sets of recommendations have been compiled regarding peyote conservation, including the establishment of systems for species inventorying and status monitoring, and the need for coordinated conservation practices based on both *in situ* and *ex situ* strategies (Ermakova & Terry, 2021), both of which are hampered by current federal and Texas state legislation (Terry & Trout, 2017a). Cultivation is particularly important for protection of those overexploited and endangered plants with slow growth and low abundance, which is exactly the case with peyote.

Although wild-harvested medicinal plants are considered by some people to be more efficacious than those that are cultivated (and there are some very strong cultural beliefs about this too), cultivation is a widely used and generally accepted practice (Gepts, 2006) that, in our belief, could make a difference between not only survival of peyote in the wild, but also ensure continuing flourishing of traditional practices dependent on it for generations to come. A lot of time, research, resources and experience are needed to set up cultivation projects, but we believe, in the end, that it will prove to be the only viable option to ensure survival of peyote in the wild.

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