Synthesis of wild orchid trade and demography provides new insight on conservation strategies

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Abstract
Illegal wildlife trade represents a global conservation priority, but the booming illegal trade in wild plants remains understudied. We use the Mexican orchid trade to illustrate an interdisciplinary approach to provide novel insight on conservation strategies and policies. We synthesize studies of orchid markets, national orchid confiscation records, CITES registers, and global population dynamics studies to document trade patterns and potential ecological impacts. We found 333 wild-harvested orchid taxa illegally traded in domestic markets. Clear patterns emerged: 90% were epiphytic and <4% traded in high volumes, all of which had pseudobulbs and bloomed during cultural festivals. Most sales were pseudobulbs, not whole plants. Review of demographic studies indicates whole-plant harvest is unviable but simulations show potential for sustainable harvest of pseudobulbs. The combination of social and ecological findings suggests a novel multipronged approach to improve conservation, including selective monitoring, enforcement focused on whole-plant harvest, and community-based wild harvest of pseudobulbs.

KEYWORDS
conservation policy, illegal wildlife trade, matrix models, Mexico, orchids, social–ecological systems

1 | INTRODUCTION

Illegal wildlife trade represents an urgent, global priority for conservation (Cooney et al., 2017). Although illegal trade in large charismatic animals dominates the headlines, there is a parallel, massive illegal trade in wild plants that goes largely unnoticed (Margulies et al., 2019). This includes thousands of species, especially those valued for their ornamental or medicinal value (e.g., Jenkins, Timoshyna, & Cornthwaite, 2018).

International wildlife trade is regulated through the Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES). Implementation of CITES has shifted the international plant trade toward artificially propagated sources (Hinsley, Nuno, Ridout, St. John, & Roberts, 2017), but compliance can be low and CITES has far from eliminated illegal trade in wild-harvested plants (e.g., Phelps & Webb, 2015).

Illegal domestic trade of wildlife can be larger than cross-border trade but has received less attention (Phelps & Webb, 2015). Many countries have legislation restricting use of at-risk species, and government agencies focused on monitoring and enforcement. However, the latter tend to be ineffective in countries with few financial resources and/or weak
governance, and problematic when it involves removing livelihood options for marginalized communities (Hinsley et al., 2017; Phelps, Carrasco, & Webb, 2013).

There is growing recognition, therefore that addressing wildlife trade requires multiple strategies in addition to enforcement (Challender & MacMillen, 2014; Cooney et al., 2017). Identifying which sets of strategies may be appropriate requires a holistic understanding of trade, including of trade patterns and their ecological implications. This kind of approach is lacking for plant species and is a conservation priority for highly traded species such as orchids (Hinsley et al., 2018). We focus on orchid trade in Mexico to provide an example of a holistic approach to understanding wildlife trade and how it can provide insight for conservation policies.

Orchids are among the plant families most threatened by illegal trade. Valued as edible, medicinal, ritual, and ornamental plants for millennia, orchids are sold in local and regional markets across the globe, often in massive quantities (Hinsley et al., 2018). Orchids make up approximately 70% of the species listed under CITES, with most of the family listed under Appendix II. Although domestic legislation for orchids is variable and complex, many national governments ban the wild harvest of all or of a subset of orchids (Hinsley et al., 2018), yet rules are often poorly enforced (Phelps & Webb, 2015; Williams, Gale, Hinsley, Gao, & St. John, 2018).

Wild harvest of orchids is assumed to be unsustainable, both because of reported local declines in heavily harvested species (Hinsley et al., 2018), and because life history characteristics make many orchids vulnerable to disturbance, including narrow ranges, specialist pollinators, low fruit set, and obligate mycorrhizal relationships for seedlings (Koopwitz, 2001). Nonetheless, there is remarkably little information on the population dynamics of orchids in trade (Hinsley et al., 2018). There is less information still on the ecological impacts of different types of trade. For example, although international trade in orchids typically involves whole plants, domestic trade may involve inflorescences or pseudobulbs, with differing ecological implications.

Mexico has over 1,300 orchid species (Hågsater et al., 2015) and a large domestic trade of wild orchids valued especially for religious and cultural celebrations. Orchids are considered nontimber forest products under Mexican law. Local communities have the right to harvest for cultural purposes, but all sales require a government-issued permit, or, if the species is protected, a detailed scientific management plan (SEMARNAT 2013). Yet very few vendors have permits, enforcement is poor and there are growing conservation concerns. We synthesize a diverse set of existing datasets, including studies from local orchid markets, national confiscation records, CITES registers, and global orchid population dynamics studies to address:

1. What are domestic patterns of trade in wild orchids: which species are sold, where, in what volumes and which parts?
2. Given the patterns in trade, what does orchid demography tell us about their potential resilience, or lack thereof, to harvest?

We then discuss approaches that may best achieve orchid conservation.

2 | METHODS

To identify the species and volumes involved in Mexico’s domestic orchid trade, we compiled data from: studies of 21 markets across six states and Mexico City that sold wild orchids (Table S1); confiscation records of raids at local markets by the Mexican government agency responsible for controlling illegal wildlife trade, the Procuraduría Federal de Protección al Ambiente (PROFEPA) from 1997 to 2017; and export volumes from CITES (http://www.unep-wcmc.org/citestrade; Supporting Information Methods).

To identify the potential effects of wild harvest on orchid populations, we compiled available orchid population dynamics studies. Because approximately 90% of orchids recorded in trade were epiphytic, including all highly traded species, we focused on epiphytes. We found studies for 19 species and 43 populations (Table S2). We extracted the projection matrices and observed population structures for each study period and population (Table S3), and projected stochastic long-term growth rates ($\lambda$; Caswell, 2001) and indices of short-term (transient) dynamics (Stott, Townley, & Hodgson, 2011; Supporting Information Methods). Simple matrix models cannot forecast the future but accurately capture population growth rates under current conditions and are effective at assessing net consequences of management alternatives (Crone et al., 2013). To identify potential effects of harvest, we used three approaches (Supporting Information Methods): (a) elasticity analyses to identify which life-history stages, if decreased, would have the largest negative effects on long- and short-term population growth; (b) life table response experiments to identify which life history transitions made the largest contributions to observed differences in population growth between harvested and unharvested populations; and (c) harvest simulations, for traded species whose unharvested populations showed positive long-term growth. We assessed the effects of four harvest strategies on changes in long-term population growth and short-term population density: harvest of (a) whole flowering plants, (b) pseudobulbs with inflorescences, (c) inflorescences only, and (d) pseudobulbs with replanting, based on replanting experiments.
3 | RESULTS

3.1 | Patterns of trade

The market studies and confiscation records revealed 333 wild harvested taxa in domestic trade, including at least 300 different species and 90 genera (Table S4). Most species were sold locally. Two-thirds of the species were found in only one market (Figure 1a). Only three species were found in five or more markets: *Prosthechea squalida*, *Laelia autumnalis*, and *Laelia speciosa*. Similarly, 57% of confiscated species were found in one state, and three quarters were found in two or less states (Figure 1b). Market and confiscation data were complementary (Figure 1c), including in states where both were available. Of the 55,686 orchid plants or plant parts confiscated, 54% were not identified and the confiscation record showed large gaps in space and time (Figures S1 and S2).

Few species accounted for most of the volume traded. High volume species (Supporting Information Methods) represent one-fifth to one-third of species in each market, but over 90% of volume (Figure 1d). The exception was the Xalapa market, with 11% of species representing 52% of volume traded. Of the 187 species for which we have information on sales volumes, only seven species represented 94% of the volume (Figure 2a). Similarly, in the confiscation database, most species were recorded with low frequency, with one species, *L. speciosa*, representing 60% of confiscations (Figure 2b).

All markets sold mostly pseudobulbs (single or groups) with inflorescences, although some species were sold as inflorescences only, or as whole plants or as all of the above (Table S1; Figure 2). The exception was again the Xalapa market, which sold many species of whole plants.

Overall, 89% of species were epiphytic, 62% of species had pseudobulbs, and 28% were endemic to Mexico. About 20% (61 species) are currently protected under Mexican law (NOM-059-2010), including three and seven of the 15 highest-volume species in the market and confiscation datasets, respectively (Figure 2; Table S4).

Exports volumes recorded in CITES from 1981 to 2016 were very small compared to those recorded from local markets (Table S5), representing 23% of trade volume observed at the markets over a single year. Overall 72% of sales were reported to be from artificially propagated sources, and 2% wild harvested.

3.2 | Demographic patterns

Twelve of the 15 Mexican species in the demographic dataset were in our trade dataset. Only three were among
the top selling species: *L. speciosa*, *Euchile karwinskii*, and *Artorima erubescens*. Data from harvested and comparable unharvested populations were available only for the prior two. For these, $\lambda_s > 1$ for unharvested populations, projecting long-term population growth, but $<1$ for harvested populations, projecting decline, with the exception of one *L. speciosa* population (Figure 3).

Of the 17 species for which only unharvested populations were studied, long-term decline was projected for 10. Transient indices indicate that, depending on the species, population densities may be higher or lower compared to that projected by $\lambda$ (Supporting Information Methods). However, for the highly traded species, density is expected to be much lower than that projected by $\lambda$ only for *A. erubescens* (Figure S3). Across all species, stasis of adults (reproductive individuals) or juveniles had the highest elasticity to both long-term and transient growth rates (Figure 4; Figure S4). Fecundity had low elasticity. Where available, elasticity patterns were similar across harvested and unharvested populations.

Lifetable response experiments (Figure 5) showed that for *L. speciosa*, lower adult survival and reproduction were most responsible for lower $\lambda$ observed in harvested populations versus unharvested populations. For *E. karwinskii*, shrinkage of adults and lower juvenile growth were also contributors to the lower $\lambda$ of harvested populations.

Harvest simulations for the three heavily traded species suggest that they cannot withstand harvest of whole plants, but can potentially sustain some flower or pseudobulb harvest (Figure 6a). For *L. speciosa* and *E. karwinskii*, pseudobulb harvest combined with replanting 25% of the pseudobulbs harvested increases $\lambda_s$ as well as short-term population density (Figure 6b). For *A. erubescens*, unharvested populations are projected to decrease over the short term (~8 years) before increasing. Pseudobulbs harvest results in rapid vegetative reproduction of the distal pseudobulb; therefore, while
FIGURE 3  Trends in stochastic population growth rates ($\lambda$) for 19 species of epiphytic orchids. Error bars represent 95% confidence intervals of the stochastic simulations and are very small, therefore represented horizontally. Values above 1 indicate projected long-term population growth. For Artorima erubescens and Aspasia principissa values are derived from single and mean matrices, respectively, therefore deterministic ($\lambda$) values are presented. C: populations located in shade coffee plantations. The two values for Laelia speciosa correspond to studies measuring different populations and using different matrix parameterization.

FIGURE 4  Elasticity values for 19 species of epiphytic orchids. Values are derived from mean matrices generated from multiple populations and years, within a species, except for Artorima erubescens, where only one matrix was available.
Figure 5  Life table response experiment (LTRE) comparing harvested and unharvested populations of two heavily traded orchid species. Positive values represent the contribution of each vital rate to the observed higher population growth rates in unharvested populations. Error bars represent standard deviation based on values from multiple years. In the study populations, *Laelia speciosa* is harvested for whole plants and *Euchile karwinskii* harvested for pseudobulbs.

harvest decreases long-term growth, it increases density over the short term.

4 | DISCUSSION

A massive illegal trade in wild plants persists globally (Jenkins et al., 2018). The Mexican orchid trade is a prime example: we documented hundreds of wild-harvested species sold illegally, including close to one quarter of Mexico’s approximately 1,300 orchid species and one-third of its epiphytic orchids. This is an underestimate. Our dataset represents few markets relative to the large number that exist. Because most orchids are found in only one market, those markets not documented undoubtedly represent more species. Although confiscation records revealed many species from states where we had no market information, these records are also highly spotty, with 60% unidentified and confiscations often occurring every few years. Because sales are seasonal (Cruz-García, Lagunez-Rivera, Chavez-Angeles, & Solano-Gomez, 2015; Dutra-Elliott, 2014), the raids would have missed some species. Those species in high trade and most easily recognizable are likely overrepresented in both datasets.

Illegal harvest is prevalent because, as elsewhere, there are strong disincentives for legal harvest. Harvest permits are inaccessible due to the bureaucracy, scientific studies required, and costs involved (Martínez-Hernández, 2017). Monitoring and enforcement activities are too infrequent to deter illegal sales. Enhanced enforcement would also likely garner little public support: most harvesters and vendors are rural and indigenous women from marginalized communities (Cruz-García, Lagunez-Rivera, Chavez-Angeles, & Solano-Gomez, 2015; Dutra-Elliott, 2014). They engage in seasonal harvest of orchids from community-managed forests as one of multiple strategies to make ends meet. In addition, the majority of sales are for use during cultural and religious holidays in communities and cities alike (Supporting Information Methods), engaging a wide sector of society.

By integrating across social and ecological datasets, our results point to approaches that could inform an improved, multipronged approach to orchid conservation.

First our results identify which types of species are at risk of heavy harvest: close to 90% of traded orchids were epiphytes compared to 60% of the Mexican flora, and 62% had pseudobulbs, compared to 36% of the total flora. A small number of species are sold in high quantities, centering on few genera that produce showy inflorescences during religious and
FIGURE 6 Simulated effects of different harvest strategies on (a) long-term population growth rates and (b) short-term changes in population size, for three heavily traded orchid species. For *Euchile karwinskii* and *Laelia speciosa*, population growth is measured by stochastic lambda values ($\lambda_s$), calculated from simulations of three annual matrices. For *Artorima erubescens*, deterministic lambda values ($\lambda$) are presented because only one matrix is available. Short-term densities are calculated from observed population structures, with population size standardized to 1. For *A. erubescens*, unharvested populations are expected to increase over the long term, but decrease initially over the short term; pseudobulb harvest increases short-term density through increased vegetative reproduction. Whole plant harvest is not simulated for this species due to its climbing growth form.

Orchid identification is difficult. Our findings suggest that an enforcement strategy that need not rely on species identification could target sales of whole plants, as opposed to pseudobulbs and inflorescences, especially during the holidays. Inspection should include propagation facilities. CITES exports involve whole plants, and although CITES data indicate that most exports are cultivated, in reality few species are propagated artificially in Mexico (Eduardo Pérez-García; Jorge Arturo Soria Malváes, personal communication).

Third, the combination of our trade and demographic data suggests that the wild harvest of a portion of pseudobulbs or inflorescences could potentially be a viable option for some species with growing populations, including the three highly traded species in our demographic dataset. The most traded species have pseudobulbs, and the majority of orchid sales are of single or groups of pseudobulbs, with numerous species sold as inflorescences. (The latter are less desirable as they are shorter lived.) While population growth rates, responses to harvest, and appropriate harvest limits vary across species, environmental conditions and time cultural holidays. This focus on few genera is similar elsewhere (e.g. Hinsley et al., 2018; Phelps & Webb, 2015). These genera could serve as indicators to monitor over time.

Second, although orchids are sometimes sold as whole plants, demographic analyses suggest that even low levels of whole plant harvest are not viable for many species. If study environmental conditions persist, over half of the species in our dataset are expected to decline without harvest over the short and long term. One major cause is habitat degradation: populations of all six species in shade coffee plantations, a major land use in Southern Mexico, were declining due to tree pruning and felling. The three species growing on coffee host trees and expanding are at high risk from the common practice of epiphyte removal (Raventós, García-González, Riverón-Giró, & Damon, 2018). Although epiphytic orchids may function as metapopulations, with $\lambda$ values higher when parameterized as such (Winkler, Hülber, & Hietz, 2009), elasticity analyses and simulations suggest that small levels of adult harvest can have large negative effects.
(Ticktin, 2004), short- and long-term elasticity analyses, and simulations suggest some room for sustainable harvest of pseudobulbs and/or inflorescences. Removal of one or two of the largest flowering pseudobulbs leaves the individual alive, with the ability to regrow pseudobulbs of reproductive size. In some species, the potential for sustainability can be increased if harvest is combined with replanting a portion of pseudobulbs. Because many orchids, including those most traded, are used in large quantities by communities for decorative purposes (e.g., for churches during the holidays), the return of a portion of these pseudobulbs to nearby community forests has been considered a potential alternative, with various studies showing high survival and flowering of outplants (e.g., Hernández-Apolinar, 1992; Lemus-Herrera, 2013; Viedma-Vázquez, 2017).

Community-based approaches to wildlife trade can provide a critical complement to monitoring and enforcement (Cooney et al., 2017). For orchids, community-based cultivation is often proposed as an alternative to wild harvest but the conditions for successful farming (Phelps et al., 2013) can be difficult to meet (Liu, Luo, Heinen, Bhat, & Liu, 2014). In Mexico, these include large financial and technical barriers to cultivation for local communities, a lack of distinguishability of farmed versus wild-harvested orchids in markets, the continued abundance of many species in the wild, and communal tenure of forested lands, making uncontrolled access by outsiders easy.

Instead, our results suggest that a community-based approach focused on legal harvest of pseudobulbs or inflorescences from communal lands may be more realistic for some species, including supplementation for those species in decline. Although the sale of pseudobulbs can result from whole plant harvest and subdivision, pseudobulb harvest is the traditional method of extraction, with much associated local ecological knowledge (Cruz-García, 2013; Dutra-Elliott, 2014). Pseudobulb harvest could help foster conditions needed to curb illegal trade (Cooney et al., 2017) by providing more secure benefits to harvesters through reducing risk of confiscation and uncertainty about future harvesting. In some places, a shift to higher harvest levels and from pseudobulb to whole plant harvest appears to have occurred as confiscations led to uncertainty about future harvesting (Dutra-Elliott, personal observation). It could provide more benefits in terms of higher yields, generated from more sustainable practices. Depending on the rate of population increase, this could be observable over time frames as short as 5 years. It could also provide an economic alternative to more destructive but currently legal uses of forests like intensive agriculture or silviculture. Mexico has a successful history of community-based timber harvesting (Bray et al., 2003; Ramírez-Santiago, 2010) providing direct lessons to build from.

Our results provide some insight on the potential for sustainable harvest of epiphytic orchids globally. Despite a limited sample size, our demographic studies span a range of life histories, and our finding that these populations are unlikely to withstand even low levels of whole-plant harvest is consistent with broader demographic literature (Franco & Silvertown, 2004; Ticktin, 2015). This suggests that for most epiphytic orchids, whole-plant harvest for horticultural trade is not likely to be sustainable. However, the harvest of many species elsewhere for decorations as well as cut flowers and medicine (e.g., Coutiño-Cortés et al., 2018; Fonge et al., 2019; Liu et al., 2014; Subedi et al., 2013) can involve removal of only inflorescences and/or pseudobulbs. In these cases, sustainability of wild harvest combined with replanting or supplementation should be explored. Longer term research on more species including experimental harvests and supplementation is needed. Climate change adds another stress (Fay, 2018) and harvest must be evaluated in this context. Testing of additional strategies to enhance sustainability, including those that could help counter the potential impacts of reduced fecundity, as demonstrated by our Life table response experiments, could include (a) hand pollination to increase seed production (Tremblay, Ackerman, Zimmerman, & Calvo, 2005), though under what conditions this translates into higher reproduction needs testing; (b) fostering source populations by leaving individual trees unharvested, because epiphytic orchids may function as metapopulations (Winkler et al., 2009); (c) leaving plants above a certain height in the canopy unharvested (Wolf & Konings, 2001), and/or (d) harvesting fallen orchids (Mondragón & Ticktin, 2011). Together, these suggested policies and research priorities hold potential to maintain orchid populations while supporting traditions that connect people so intimately to them.

**DATA**

All compiled data are in Supporting Information; raw data is archived at University of Hawaii data repository, Scholar Space.

**REFERENCES**

Bray, D. B., Merino-Pérez, L., Negreros-Castillo, P., Segura-Warnholtz, G., Torres-Rojo, J. M., & Vester, H. F. M. (2003). Mexico’s community-managed forests as a global model for sustainable landscapes. *Conservation Biology, 17*, 672–677. https://doi.org/10.1046/j.1523-1739.2003.01639.x

Caswell, H. (2001). *Matrix population models—Construction, analysis, and interpretation* (2nd ed.). Sunderland, MA: Sinauer Associates.

Challender, D. W., & MacMillan, D. C. (2014). Poaching is more than an enforcement problem. *Conservation Letters, 7*, 484–494.
Cooney, R., Roe, D., Dublin, H., Phelps, J., Wilkie, D., Keane, A., ... Biggs, D. (2017). From poachers to protectors: Engaging local communities in solutions to illegal wildlife trade. *Conservation Letters*, 10, 367–374.

Coutinho-Cortés, A. G., Bertolini, V., Morales, F. A., Valle-Mora, J., Iracheta-Donjuan, L., García-Bautista, M., & Ruiz-Montoya, L. (2018). El uso ornamental de *Guaniarthea skinneri* (Orchidaceae), en Chiapas y Guatemala, determina parcialmente su diversidad y estructura genética. *Acta Botánica Mexicana*, 124. https://doi.org/10.21829/abm124.2018.1303

Crone, E. E., Ellis, M. M., Morris, W. F., Stanley, A., Bell, T., Bierzychudek, P., ... Menges, E. S. (2013). Ability of matrix models to explain the past and predict the future of plant populations. *Conservation Biology*, 27, 968–978. https://doi.org/10.1111/cobi.12049

Cruz-García, G., Laguna-Rivera, L., Chavez-Angeles, M. G., & Solano-Gomez, R. (2015). El cultivo de pseudobulbos de la orquídea en riesgo *Laelia speciosa* (HBK) Schltr. (Orchidaceae), como medida para su conservación ex situ (Thesis). Universidad Michoacana de San Nicolás de Hidalgo, Morelia, México.

Liu, H., Luo, Y. B., Heinen, J., Bhat, M., & Liu, Z. J. (2014). Eat your orchid and have it too: A potentially new conservation formula for Chinese epiphytic medicinal orchids. *Biodiversity and Conservation*, 23, 1215–1228. https://doi.org/10.1007/s10531-014-0661-2

Margulies, J. D., Bullough, L. A., Hinsley, A., Ingram, D. J., Cowell, C., Goettsh, B., ... Phelps, J. (2019). Illegal wildlife trade and the persistence of “plant blindness”. *Plants, People, Planet*, 1, 173–182.

Martínez-Hernández, J. J. (2017). La legislación ambiental y el aprovechamiento sustentable de orquídeas de México (Thesis). CIIDIR-Oaxaca-Instituto Politécnico Nacional, Oaxaca, Mexico.

Mondragón, D., & Ticktin, T. (2011). Demographic effects of harvesting epiphytic bromeliads and an alternative approach to collection. *Conservation Biology*, 25, 797–807. https://doi.org/10.1111/j.1523-1739.2011.01691.x

Phelps, J., & Webb, E. L. (2015). ‘Invisible’ wildlife trades: Southeast Asia’s undocumented illegal trade in wild ornamental plants. *Biological Conservation*, 186, 296–305. https://doi.org/10.1016/j.biocon.2015.03.030

Phelps, J., Carrasco, L. R., & Webb, E. L. (2013). Framework for assessing supply-side wildlife conservation. *Conservation Biology*, 28, 244–257. https://doi.org/10.1111/cobi.12160

Ramírez-Santiago, R. (2010). Manejo y conservación del patrimonio natural de Ixtlán de Juárez. In J. Carabías, J. Sarukhán, J. De la Maza, & C. Galindo-Leal (Eds.), *Cien casos de éxito* (pp. 106–107). Mexico City, Mexico: CONABIO.

Raventós, J., García-González, A., Riverón-Giró, F. B., & Damon, A. (2018). Comparison of transient and asymptotic perturbation analyses of three epiphytic orchid species growing in coffee plantations in Mexico: Effect on conservation decisions. *Plant Ecology & Diversity*, 11, 133–145.

SEMNARNAT (Secretary of Environment and Natural Resources). (2013). *Ley General de Vida Silvestre*. México City, Mexico: Diario Oficial de la Federación.

Stott, I., Townley, S., & Hodgson, D. J. (2011). A framework for studying transient dynamics of population projection matrix models. *Ecology Letters*, 14, 959–970.

Subedi, A., Kunwar, B., Choi, Y., Dai, Y., van Andel, T., Chaudhary, R. P., ... Gravendeel, B. (2013). Collection and trade of wild-harvested orchids in Nepal. *Journal of Ethnobiology and Ethnomedicine*, 9, 64.

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, 41, 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T. (2015). The ecological sustainability of harvesting non-timber forest products: Principles and methods. In C. Shackleton, A. Pandey, & T. Ticktin (Eds.), *Ecological sustainability of non-timber forest product harvesting: Case-studies and dynamics* (pp. 31–52). London, UK: Earthscan.

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, 41, 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T. (2015). The ecological sustainability of harvesting non-timber forest products: Principles and methods. In C. Shackleton, A. Pandey, & T. Ticktin (Eds.), *Ecological sustainability of non-timber forest product harvesting: Case-studies and dynamics* (pp. 31–52). London, UK: Earthscan.

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, 41, 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T. (2015). The ecological sustainability of harvesting non-timber forest products: Principles and methods. In C. Shackleton, A. Pandey, & T. Ticktin (Eds.), *Ecological sustainability of non-timber forest product harvesting: Case-studies and dynamics* (pp. 31–52). London, UK: Earthscan.

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, 41, 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T. (2015). The ecological sustainability of harvesting non-timber forest products: Principles and methods. In C. Shackleton, A. Pandey, & T. Ticktin (Eds.), *Ecological sustainability of non-timber forest product harvesting: Case-studies and dynamics* (pp. 31–52). London, UK: Earthscan.

Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, 41, 11–21. https://doi.org/10.1111/j.1365-2664.2004.00859.x

Ticktin, T. (2015). The ecological sustainability of harvesting non-timber forest products: Principles and methods. In C. Shackleton, A. Pandey, & T. Ticktin (Eds.), *Ecological sustainability of non-timber forest product harvesting: Case-studies and dynamics* (pp. 31–52). London, UK: Earthscan.
sur de México (Thesis). FESZ-Universidad Nacional Autónoma de México, Mexico City, Mexico.

Williams, S. J., Gale, S. W., Hinsley, A., Gao, J., & St. John, F. A. V. (2018). Using consumer preferences to characterize the trade of wild-collected ornamental orchids in China. Conservation Letters, 11, e12569. https://doi.org/10.1111/conl.12569

Winkler, M., Hülber, K., & Hietz, P. (2009). Population dynamics of epiphytic orchids in a metapopulation context. Annals of Botany, 104, 995–1004. https://doi.org/10.1093/aob/mcp188

Wolf, J. H. D., & Konings, C. J. F. (2001). Toward the sustainable harvesting of epiphytic bromeliads: A pilot study from the highlands of Chiapas, Mexico. Biological Conservation, 101, 23–31. https://doi.org/10.1016/S0006-3207(01)00053-2

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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