

# Conservation status of the genus *Hampea* (Malvaceae: Gossypieae) in Mexico

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## Abstract

**Background.** The genus *Hampea* (Malvaceae: Gossypieae) has 21 reported species and occurs in Mexico, Central America and Colombia. Mexico has eleven species, of which seven are endemic. *Hampea* is of special conservation interest because its members are wild relatives of cultivated cotton and several species are apparently threatened by anthropogenic activities.

**Questions.** What is the conservation status of species of *Hampea* in Mexico?

**Study site and years of study.** Observations were made in the field during 1991-1995, 2012 and 2016 in southern Mexico. Specimen data was obtained from the CONABIO data base and from national and international herbaria from 2014-2016.

**Methods.** The conservation status of species of *Hampea* in Mexico was evaluated using criteria given in the Methods of the Evaluation of Risk of Extinction of Plants (MER-Plantas) (NOM-059-SEMARNAT-2010). The potential distribution was calculated using Maximum Entropy Algorithm and biological data for species were obtained from literature and field observations.

**Results.** Seven species of the genus *Hampea* were considered to be in a category of risk under the MER-Plantas criteria. *Hampea montebellensis*, *H. breedlovei*, and *H. longipes* were categorized as “at Risk of Extinction,” (En Peligro de Extinción); *H. latifolia* was categorized as “Threatened” (Amenazada) and *H. stipitata*, *H. mexicana*, and *H. tomentosa* categorized as “Subject to Special Protection” (*Sujeto a Protección Especial*).

**Conclusions.** The species *H. breedlovei*, *H. montebellensis*, *H. longipes*, *H. latifolia*, *H. mexicana*, *H. stipitata* and *H. tomentosa* need to be included in *ex situ* and *in situ* conservation programs.

**Key words:** Conservation, cotton tribe, wild crop relatives.

## Resumen

**Antecedentes.** El género *Hampea* (Malvaceae: Gossypieae) está compuesto por 21 especies y se encuentra en México, América Central y Colombia. México tiene once especies de las cuales, siete son endémicas. *Hampea* es de interés especial para la conservación porque son plantas silvestres parientes del algodón cultivado y algunas especies son amenazadas por actividades antropogénicas.

**Preguntas.** ¿Cuál es el estatus de conservación de las especies de *Hampea* en México?

**Sitio y años de estudio.** Se realizaron observaciones en el campo en el sur de México durante 1991-1995, 2012 y 2016. Se obtuvieron datos de especímenes de los base de datos de CONABIO y datos de herbarios nacionales e internacionales de 2014-2016.

**Métodos.** El estatus de conservación del género *Hampea* en México fue evaluado usando los criterios de Método de Evaluación del Riesgo de Extinción de Plantas (MER-Plantas) de NOM-059-SEMARNAT-2010. La distribución potencial y de las especies fueron evaluadas con el algoritmo Maximum Entropy y datos biológicos fueron obtenidos de una revisión de la literatura y de observaciones en el campo.

**Resultados.** Siete especies del género *Hampea* fueron consideradas entre un criterio de riesgo de MER-Plantas. *Hampea montebellensis*, *H. breedlovei* y *H. longipes* fueron categorizadas como “En Peligro de Extinción”; *H. latifolia* como “Amenazada” y *H. stipitata*, *H. mexicana* y *H. tomentosa* fueron consideradas como “Sujeto a Protección Especial.”

**Conclusiones.** Las especies *H. breedlovei*, *H. montebellensis*, *H. longipes*, *H. latifolia*, *H. mexicana*, *H. stipitata*, y *H. tomentosa* requieren ser incorporadas en programas de conservación *ex situ* e *in situ*.

**Palabras Clave:** conservación, parientes plantas cultivadas, tribu de algodón.

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### Authors Contributions:

R. W. Jones, writing, analysis of MER criteria, field work and specimen examination; F. Cruz-Torres, modeling of potential distribution; C. López-González, Mer criteria and editing; M. Duarte-Fernández, compilation of data base.

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**T**he cotton tribe (Malvaceae: Gossypieae) is composed primarily of genera with either widespread pantropical distributions (*Gossypium* L., *Thespesia* Sol. ex Corrêa, *Cienfuegosia* Cav.) or of genera with highly endemic distributions restricted primarily to oceanic islands (*Kokia* Lewton, *Lebronnecia* Fosberg & Sachet, *Gossypioides* Skovsted, *Cephalohipiscus* Ulbr.) (Fryxell 1979, Areces-Berazain & Ackerman 2016). The exception to this pattern is the genus *Hampea* Schltdl., which although tropical, is restricted to the American Continent with a relatively widespread distribution of species extending from central Mexico into northern Colombia (Fryxell 1979). The genus is also unique in being the only members of the tribe to be primarily dioecious (Figure 1) and to have an arillate fruit (Figure 2). The genus is composed of 21 species of small to medium-sized trees with relatively restricted distributions (Fryxell 1979, 1980). Mexico has the greatest richness of *Hampea* with 11 of the 21 species, followed by Guatemala with seven species (Fryxell 1968, 1969, 1979, 1980, 1988). Species of *Hampea* occur in wet to seasonally dry tropical forests and tropical montane cloud forests, from sea level to elevations below the frost line (Fryxell 1979) and range in abundance from very common to very rare (Fryxell 1968).

One species in Mexico is listed in the IUCN Red List, *H. montebellensis* Fryxell, as “Endangered” (González-Espinosa 1998, IUCN 2012) and is also listed in the Mexican list of species at risk (NOM-059-SEMARNAT-2010) as “Threatened.” Several species outside of Mexico are also listed in the IUCN Red list and include: *H. micrantha* A. Robyns in Panama, *H. sphaerocarpha* Fryxell from the Caribbean coast of Guatemala and Honduras, *H. reynae* Fryxell found in El Salvador, and *H. thespesioides* Triana & Planch., from central Colombia (IUCN 2012). Within Mexico, various species are also apparently threatened by deforestation and agricultural expansion (Jones & Baro-Peruyero 2002, Jones 2001, González-Espinosa 1998), although these have not been systematically evaluated.

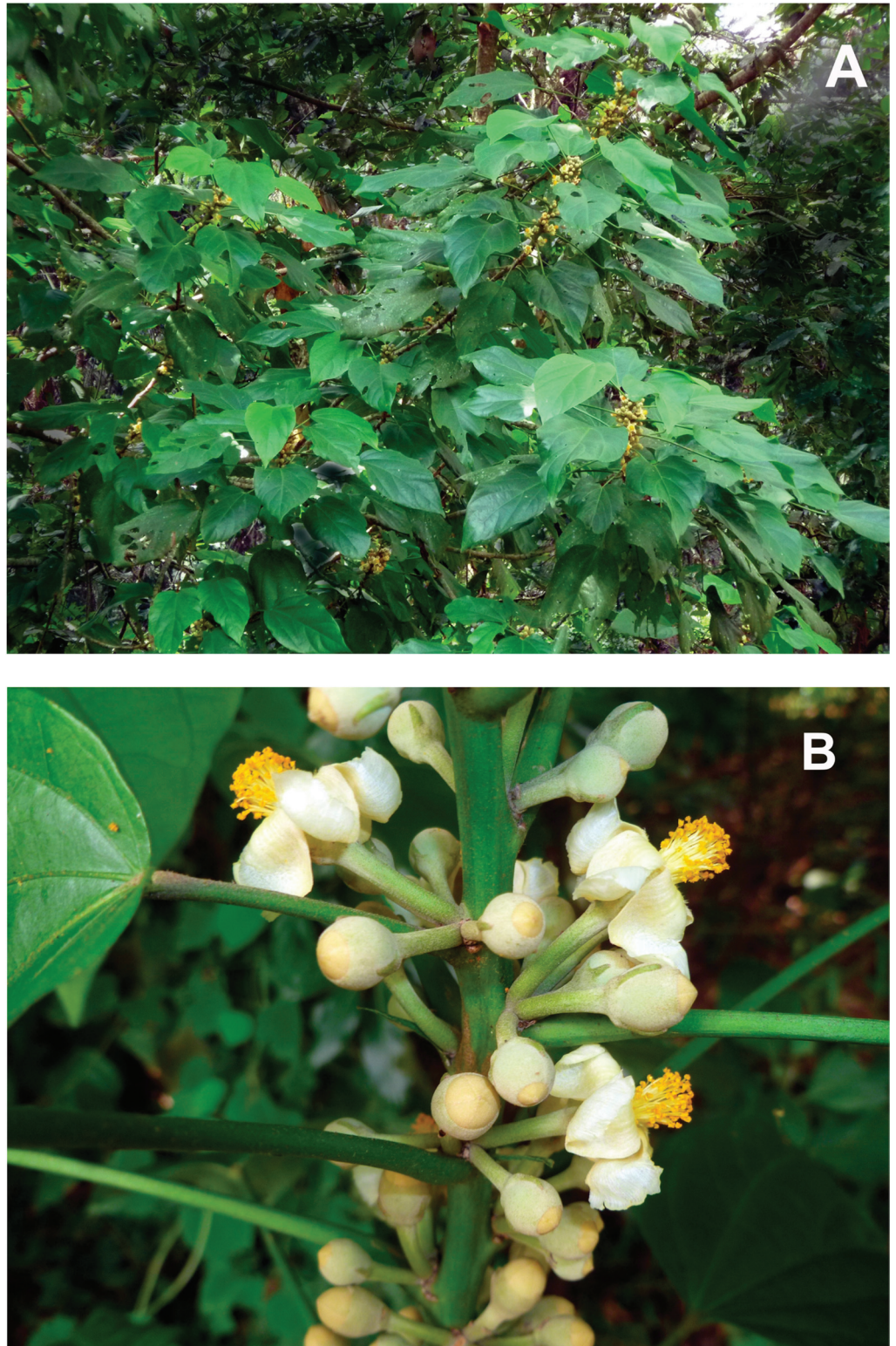
Species of *Hampea* are of particular interest for conservation because, as members of the cotton tribe Gossypieae, they represent wild relatives of cultivated cotton (*Gossypium*). The conservation of wild crop relatives has long been recognized as a priority for development of sustainable options for world agriculture (Frankel 1970, Meulleur & Hodgkin 2004, Maxted *et al.* 2012). In the case of *Hampea*, several species share similar insect herbivore guilds with those found on cultivated cotton, including several important pest species such as the boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae) and the pink bollworm (*Pectinophora gossypiella* Saunders) (Burke *et al.* 1986). In addition, more species of parasitoids associated with the boll weevil have been reported from species of *Hampea* than from all species of wild or cultivated cotton (Cate *et al.* 1990, Jones 2001). Of the evaluated parasitoids, *Catolaccus grandis* Burks, has displayed promise as an effective control agent of the boll weevil in commercial cotton (Summy *et al.* 1992, Morales-Ramos *et al.* 1998). Also, the association of *Hampea* with the boll weevil and other pests may have apparently resulted in the evolution of effective characters that impart resistance against insect damage (Cate *et al.* 1990, Jones 1994, Jones & Baro-Peruyero 2002).

The objective of the present work is to evaluate the conservation status of the genus *Hampea* in Mexico using the Methods of the Evaluation of Risk of Extinction of Plants (MER-Plantas) developed by the Mexican Ministry of Environment and Natural Resources (NOM-059-SEMARNAT-2010, SEMARNAT 2010). The evaluation was conducted given the apparent conservation risk to several species of *Hampea* in Mexico, and also because of the added importance given that species of this genus are wild relatives of cultivated cotton and share related insect pests and their natural enemies. In addition, the present work will address questions of the general conservation status of species of *Hampea*, given that it is a poorly studied plant genus with greatest diversity in Mexico and Central America and with seven species endemic to Mexico.

## Materials and Methods

*Data records.* Specimen data of *Hampea* were obtained from the following herbaria: Paul Fryxell herbarium (pf) now part of the New York Botanical Garden herbarium (NY); Herbario Nacional de México, México D.F. (MEXU); Instituto de Ecología, Xalapa, Veracruz, México (XAL); El Colegio de la Frontera Sur, San Cristóbal, Chiapas, México (CH); and el Herbario de la Universidad Autónoma de Querétaro “Jerzy Rzedowski,” Querétaro, México (QMEX). Data





**Figure 1.** *Hampea integerrima* Schlechtendal, 2.5 km SW Xalapa, Veracruz, 1,348 m asl, 19° 30' 50'' N; 96° 56' 30'' W; A. Portion of flowering branch of small tree. B. Close up of fasciculate, staminate flowers.





**Figure 2.** Herbarium specimen of *Hampea breedlovei* Fryxell from Cerro Ahk'ulbal Nab, from municipality of Tila above Peltalcingo, Chiapas, Mexico Only known specimen series collected from a site other than type locality from the herbarium of California Academy of Sciences (CAS). Photograph by Rebecca Peters, California Academy of Science.

from these herbaria were cross-referenced with that of the online national Mexican data base of the National Commission for the Knowledge and Use of Biodiversity (CONABIO 2016). Observations and collection data by the authors conducted during the last 25 years were also incorporated into the data base. Distribution data was evaluated and data points selected based the author's validation of species identity and quality of locality data.

A total of 218 records were used to generate the niche models, the total records used per species were: *H. breedlovei* Fryxell, 9; *H. integerrima* Schltdl., 36; *H. latifolia* Standl., 8; *H. longipes* Miranda, 12; *H. mexicana* Fryxell, 12; *H. montebellensis* Fryxell, 8; *H. nutricia* Fryxell, 47; *H. rovirosae* Standl., 16; *H. stipitata* S. Watson, 30; *H. tomentosa* (C.Presl.) Standl., 10; and *H. trilobata* Standl. 30.

*Environmental variable selection for modeling of potential distribution.* We considered 20 variables to generate the ecological niche models: 19 climatic variables and a variable for soil type. The climatic variables used were specific to Mexico using information from climatic stations for the period 1910 to 2009, in turn represent annual averages, seasonality and extreme factors potentially correlated with the presence of the species (Cuervo-Robayo *et al.* 2013). All variables were used in raster format with a 1 km<sup>2</sup> resolution. The soil map used was "Conjunto de Datos Vectoriales Edafológico", scale of 1:250,000, Serie II (INEGI 2016)

To insure independence of variables (Tsoar *et al.* 2007), a selection of the most important variables from the 20 initial set was performed, which in turn resulted in lowered inter-variable correlations based on a Pearson correlation matrix for the variables using SPSS 20 (IBM 2011). A coefficient of ( $r$ ) > 0.7 in the resulting matrix was selected to identify the most correlated variables, and variables that showed the lowest correlation coefficients ( $r$ ) < 0.7, were used to generate the niche models for the species (Table 1).

*Algorithm parameters.* Potential distribution and environmental suitability predictions for species were performed with the Maximum Entropy Algorithm program (Maxent<sup>®</sup>; Version 3.3.3k) (Phillips *et al.* 2006). Algorithm widely used to understand the relationship between environmental variables and the presence of species (Elith *et al.* 2011).

The program's default settings used were: regularization multiplier in one, convergence threshold in 10<sup>-5</sup> and the maximum number of background points in 10,000 (which serve as pseudo-absences for Maxent analyzes) was maintained. A maximum of 1,000 iterations (Phillips *et al.* 2006) were chosen and the selection of the Extrapolate and Clamping options, which are used to generate future predictions, was omitted.

*Hampea integerrima*, *H. rovirosae*, *H. trilobata*, *H. nutricia* and *H. stipitata*, had between 16 and 47 presence records, with which 10 replicates were generated per species, using the "random seed" and "subsample" options and a random test percentage of 20 %, used in similar works (Lodoño-Murcia & Sánchez-Cordero 2011). This allowed the program to use that per-

**Table 1.** Description of the variables used to generate the niche models in Maxent in determination of potential distribution of species of *Hampea* in Mexico.

CODE	BIOCLIMATIC VARIABLES
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	Isothermality ((BIO2/BIO7) × 100)
BIO4	Temperature Seasonality (standard deviation × 100)
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO17	Precipitation of Driest Quarter
Edaphology	Soil classification

centage to generate a Receiver Operating Characteristic (ROC) curve for each model, with an associated value of AUC (area under the curve) for both sets of data, with 80 % to generate the model and 20 % to test it (Phillips & Dudik 2008). Models with an AUC above 0.75 were considered to be potentially good predictive models (Elith *et al.* 2002, Phillips *et al.* 2006). Based on the above criteria, only one model of the 10 replicates generated by species was chosen with those with an AUC higher than 0.85 (Marmion *et al.* 2009).

For the species with fewer than 15 records, *H. breedlovei*, *H. latifolia*, *H. longipes*, *H. mexicana*, *H. montebellensis* and *H. tomentosa*, all records available for each species were used to generate each of the models, without using 20 % of them as a test within the program and without generating replicas. In these cases, the criteria to make ecological niche predictions only required presence records and thus, was less sensitive to the record numbers (Hernández *et al.* 2006), and in some cases, five records was sufficient to generate a useful model (Pearson *et al.* 2007).

The ecological niche spatial predictions generated with Maxent have a scale of 0 (not suitable) to 1 (highly adequate), this probability influences the distribution of the species (Phillips *et al.* 2006). In all models, the logistic output format and the ACII format for the predictions were selected which allowed for a simpler interpretation of the model. The Jackknife analysis was also used to examine the contribution of each environmental variable (Phillips & Dudik 2008).

*Threshold cut selection.* Although there are different alternatives to determine optimal threshold selection to transform the resulting probability into absence-presence data on a map (Freeman & Moisen 2008), there are no set rules to determine an optimal threshold (Hu & Jiang 2010). Due to characteristics of the collection records and based on recommendations of Freeman & Moisen (2008), a threshold corresponding to the 10th percentile was chosen, removing from the final projection 10 % of the distribution predicted by Maxent for the final models of each species.

*Determination of the category of risk.* The conservation status of species of *Hampea* in Mexico was evaluated using criteria given in the Methods of the Evaluation of Risk of Extinction of plants (MER-Plantas) of the Mexican Ministry of Environment and Natural Resources (NOM-059-SEMARNAT-2010, SEMARNAT 2010). The four criteria of this method of the evaluation include: Criteria A, characteristics of the geographic distribution; Criteria B, habitat characteristics; Criteria C, intrinsic biological vulnerability, and Criteria D, impact of human activity. The details for evaluation of these criteria and the assignation of points are given in Nom-059-SEMARNAT-2010-Anexo Normativo (SEMARNAT 2010). The amplitude of distribution (Criteria A.1) was calculated using the area of the potential distribution of each species calculated in the present work, in proportion to the total surface area of Mexico. The final variables used for the analysis of distributions were based on the independence of all variables with only those with a Pearson correlation of  $r < 0.8$ , used in the final analysis. The number of populations (Criteria A.2) was determined counting separate, non-overlapping data points (3 mm) discernable on a map of 1: 4,000,000 (SEMARNAT 2010). The number of biogeographic provinces and vegetation types that species occurred was determined by mapping data points on the map of the biotic provinces (CONABIO 2016) and vegetation types (CONABIO 2016) as given in the MER Criteria (SEMARNAT 2010) on a scale of 1:4,000,000.

## Results

Table 2 presents the evaluation of the four criteria of MER-Plantas and point system for all species of *Hampea* in Mexico. Based on the evaluation of the criteria and the assigned points, each species was categorized within a category of risk of extinction (Table 2). The species, *H. montebellensis*, presently listed as “Endangered” in the NOM-059-SEMARNAT-2010 (SEMARNAT 2010), as well as, *H. breedlovei* and *H. longipes* were categorized as “At Risk of Extinction” under the MER-Plantas criteria. The species, *H. latifolia* was categorized as “Threatened” and *H. stipitata*, *H. mexicana*, and *H. tomentosa* were considered as “Subject to Special Protection.” The species, *H. nutricia*, *H. intergerrima*, *H. trilobata* and *H. rovirosae* were not categorized in a threatened category and considered of least concern for conservation measures.

**Table 2.** Criteria of Risk Category (MER-Plantas)<sup>1</sup> for species of *Hampea* (Tribu Gossypieae: Malvales: Malvaceae) reported from Mexico. Species abbreviations: breed= *H. breedlovei*; interg= *H. intergerrima*; longi= *H. longipes*; monti= *H. montebellensis*; nutri= *H. nutricia*; stipi= *H. stipitata*; trilo= *H. trilobata*; latif= *H. latifolia*; mexic= *H. mexicanus*; tomte= *H. trilobata* and rovir= *H. rovirosae*. Conversation status abbreviations SEMARNAT (2010): P=En Peligro de Extinción (Risk of Extinction); A=Amenazada (Threatened); Pr=Sujeto a Protección Especial (Subject to Special Protection); MP= Menor Preocupación (Least Concern).

Criteria	Species of <i>Hampea</i>										
	Section <i>Hampea</i>								Section <i>Standleya</i>		Section <i>Eohampea</i>
	breed	interg	longi	monti	nutri	stipi	trilo	latif	mexic	tomte	rovir
<b>A. Characteristics of the Geographic Distribution</b>											
A.1. Area Distribution	3	3	3	3	1	3	1	3	2	2	2
A.2. Number populations	3	1	2	3	0	1	1	2	2	2	1
A.3. Biogeographic provinces	3	2	2	2	2	2	2	2	2	2	2
A.4. Population representation	0	0	0	0	0	0	0	0	0	0	0
Sum/Proportion	9/11 0.82	6/11 0.55	7/11 0.64	8/11 0.73	3/11 0.27	6/11 0.55	4/11 0.36	8/11 0.64	6/11 0.55	6/11 0.55	5/11 0.45
<b>B. Characteristics of the Habitat</b>											
B.1. In various vegetation types	3	0	2	1	0	2	1	2	1	2	2
B.2. Specialized habitat	0	0	0	0	0	0	0	0	0	0	0
B.3. Dependent on Primary Habitat	1	0	1	1	0	1	0	1	1	1	0
B.4. Needs particular regime of disturbance	0	0	0	0	0	0	0	0	0	0	0
B.5. Limits of range in altitude	3	2	2	1	1	1	2	1	2	1	2
B. Sum/Proportion	7/9 0.78	2/9 0.22	5/9 0.56	3/9 0.33	1/9 0.11	4/9 0.44	3/9 0.33	4/9 0.44	4/9 0.44	4/9 0.44	4/9 0.44
<b>C. Intrinsic Biological Vulnerability</b>											
<b>C.1 Demographic Characteristics</b>											
C.1.1. Total # of Individuals	2	0	0	2	0	0	0	2	1	1	0
C.1.2. Recruitment	0	0	0	0	0	0	0	0	0	0	0
C.1.3.a. Density dependent reproduction	0	0	0	0	0	0	0	0	0	0	0
C.1.3.b. Clonality	1	1	1	1	1	1	1	1	1	1	1
C.1.3.c. Population decline	1	0	1	1	0	0	0	1	1	0	0
C.1.3.d. High variation fecundity	0	0	0	0	0	0	0	0	0	0	0
C.1.3.e. Dioecious	1	1	1	1	1	1	1	1	1	1	0
C.1.3.f. Gregarious/ Synchronous flowering	1	0	1	1	1	1	0	0	1	0	0
C.1.3.g. Few propagules	0	0	0	0	0	0	0	0	0	0	0
<b>C.2 Genetic Characteristics</b>											
C.2.1. Molecular Variation	0	0	0	0	0	0	0	0	0	0	0
C.2.2. Genetic Structure	0	0	0	0	0	0	0	0	0	0	0
C.2.3. Amount genetic variation	0	0	0	0	0	0	0	0	0	0	0
C.2.4. Population differentiation	0	0	0	0	0	0	0	0	0	0	0
<b>C.3 Specialized Biotic Interactions</b>											
C.3.1. Requires nurse plant	0	0	0	0	0	0	0	0	0	0	0
C.3.2. Requires host organism	0	0	0	0	0	0	0	0	0	0	0
C.3.3. Specific pollinator required	0	0	0	0	0	0	0	0	0	0	0
C.3.4. Specific dispersal agent required	1	1	1	1	1	1	1	1	1	1	1
C.3.5. Myrmecophile required	0	0	0	0	0	0	0	0	0	0	0
C.3.6. Specific mycorrhiza association	0	0	0	0	0	0	0	0	0	0	0
C.3.7. High biotic mortality (predator or pathogen)	0	0	1	0	0	0	0	0	0	0	0
C. Sum/Proportion	7/23 0.30	3/23 0.13	6/23 0.26	7/23 0.30	4/23 0.17	4/23 0.17	3/23 0.13	6/23 0.26	5/23 0.22	4/23 0.17	2/23 0.09
<b>D. Impact of Human Activity</b>											
D.1. Effect of anthropogenic disturbance	1	1	1	1	-1	0	-1	1	1	1	-1
D.2. Level of anthropogenic impact on habitat	3	3	3	3	1	3	1	3	3	3	0



Table 2. Continuation.

Criteria	Species of <i>Hampea</i>										
	Section <i>Hampea</i>							Section <i>Standleya</i>			Section <i>Eohampea</i>
	breed	integ	longi	monti	nutri	stipi	trilo	latif	mexic	tomte	
D.3 Global effect on habitat deterioration in future	1	1	1	1	0	0	0	0	0	0	0
D.4 Effect of direct use of species	0	0	0	0	1	0	1	0	0	0	0
D.5 Propagation <i>ex situ</i>	0	0	0	0	0	0	0	0	0	0	0
D. Sum/Proportion	5/10 0.50	5/10 0.50	5/10 0.50	5/10 0.50	1/10 0.10	3/10 0.30	1/10 0.10	4/10 0.40	4/10 0.40	4/10 0.40	-1/10 -0.10
<b>Total Sum of Proportions (A-D)</b>	<b>2.4</b>	<b>1.4</b>	<b>2.0</b>	<b>2.1</b>	<b>0.7</b>	<b>1.5</b>	<b>0.9</b>	<b>1.7</b>	<b>1.6</b>	<b>1.6</b>	<b>0.9</b>
<b>Conservation Status<sup>1</sup></b>	<b>P</b>	<b>PM</b>	<b>P</b>	<b>P</b>	<b>PM</b>	<b>Pr</b>	<b>PM</b>	<b>A</b>	<b>Pr</b>	<b>Pr</b>	<b>PM</b>

1/ SEMARNAT (2010)

2/ Section arrangement based on Jones *et al.* (1997).

## Discussion

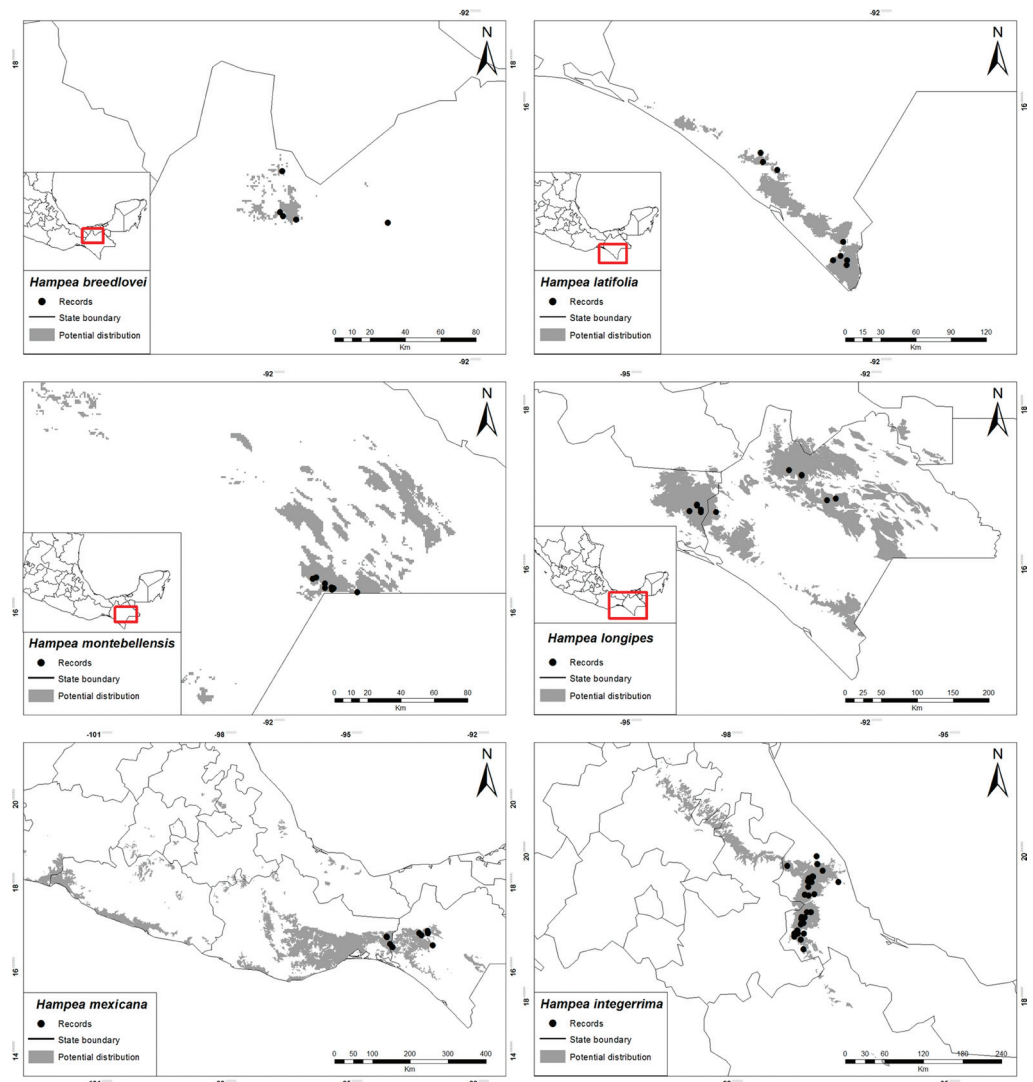
*Criteria A. Characteristics of the geographic distribution.* *Hampea breedlovei* had the smallest area of distribution, calculated as the potential distribution, of analyzed species of *Hampea*, and represented 0.02 % of the Mexican territory (Criteria A.1 = 3; Figure 3, upper left). Initially, this species was only known from the type locality when described by Fryxell in 1977 which was listed as: Mexico: Chiapas: Municipality of Rayon, in the Selva Negra 10 km above Rayon Mezcalapa along road to Jitotol. Although 10 separate collection sites appear in the Bios CONABIO data base (CONABIO 2016) within 15 km of the type collection site, some of these points apparently represent the same samples that were assigned different coordinates. Only two sites are not within the vicinity of the type collection: the first is one specimen 12 km S of Tila (Municipality: Tila) above Petalcingo, Chiapas at 1,700 m (Figure 2) and the second reported is from Veracruz, municipality of Acajete, west of Xalapa. This latter record is almost certainly a misidentification of *H. integerrima* given that this latter species is common in the western area of Xalapa (Figure 1, personal observation, RWJ).

*Hampea latifolia* was the species with the second smallest distribution representing 0.14 % of the Mexican territory (Criteria A.1 = 3, Figure 3, upper right). This species is an endemic of the Soconusco region of southeastern Chiapas and adjacent departments of Retalhuleu and Suchitupéquez in southwestern Guatemala. Within Mexico, only four specimens were found in the National Autonomous University of Mexico (UNAM) herbarium and only one collected after 1980. In Chiapas, Jones (1994) observed five trees in forest fragments and in cacao plantations near the town of Palo Seco in the municipality of Tapachula, and seven trees from 11 to 19 km north the municipal seat of Mapastepec, in the foothills of the Cerro El Triunfo, near sites recorded for the MEXU herbarium collections.

*Hampea montebellensis* is another species with very limited distribution occurring within 0.15 % of the Mexican territory (Criteria A.1 = 3, Figure 3, middle left). The species has only been found from central and eastern Chiapas from 900 to 1,500 m in moist forests (Fryxell 1988). Of the 44 specimen records in the CONABIO data base (CONABIO 2016), only four of the localities were not from within or in the vicinity of the Lagunas de Montebello National Park.

*Hampea longipes* had a potential distribution that covered 0.99 % of the Mexican territory (Criteria A.1 = 3, Figure 3, middle right). Individuals of this species have been well collected in the state of Chiapas and Oaxaca, with 95 records in the CONABIO data base (CONABIO 2016). Recorded collection of this species indicates that it is endemic to the highlands (“Los Altos”) of northern Chiapas and also found at elevations above 1,000 m in the adjacent Chiapas region of eastern Oaxaca. Although, the potential distribution suggests that this species may occur in the Sierra Madre de Chiapas, no herbarium specimens from the region were found and flora studies (El Triunfo) do not mention species of *Hampea* (Martínez-Meléndez *et al.* 2008, Pérez-Farrera *et al.* 2012). Specimens of *Hampea* in the central highland region of Oaxaca





**Figure 3.** Potential distribution of six species of *Hampea* in Mexico: Upper left, *Hampea breedlovei* Fryxell; upper right, *Hampea latifolia* Standley; middle left, *Hampea montebellensis* Fryxell; middle right, *Hampea longipes* Miranda; bottom left, *Hampea mexicana* Fryxell; bottom right, *Hampea integerrima* Schlechtendal.

have been identified as both *H. longipes* and *H. integerrima*, but no fruiting specimens were observed in herbaria to verify species identity from this state.

The potential distribution of *H. mexicana* presented here (Figure 3, lower left) represents 1.74 % of the Mexican territory ( $A1 = 2$ ). This distribution is within the central Depression of Chiapas, extending into the Chimalapa region of eastern Oaxaca in seasonally dry forests, from 800 to 1,000 m. However, there are no records of the species from central Oaxaca and Guerrero as indicated by the potential distribution. Also specimens misidentified as *H. stipitata* were frequently found in various herbaria, especially from the Lacandon region giving the erroneous impression that the distribution of *H. mexicana* encompasses northern and northeastern Chiapas.

The distribution of *H. integerrima* in the southern Sierra Madre Oriental (SMO) and tropical portions of the Neovolcanic axis in Veracruz within populated areas near the montane forests around Córdoba and Xalapa, Veracruz (Figure 3, lower right) has resulted in this species being one of the most collected of the genus. The species has not been reported much further north than 20° latitude, although the potential distribution suggests that suitable humid montane habi-

tat extends north to Tamaulipas and covers 0.38 % of the national territory (Criteria A.1 = 3). Additionally, the potential distribution extends from the SMO through the Neovolcanic Axis into Oaxaca, but there are only a few specimens from this state in herbaria and all samples seen were vegetative, making identification difficult. Trees were observed in the field in Veracruz by the authors including on the western edge of Xalapa, near the Cascada de Texolo, the slopes of Cerro Orizaba, and in the outskirts of Córdoba.

*Hampea stipitata* is relatively well represented in herbaria (CONABIO 2016) although its distribution covers only 0.33 % of Mexico (Criteria A1 = 3), suggesting that the species is common in portions of its distribution. This species is restricted to southern Mexico in lowland tropical forests of southeastern Veracruz, northeastern Oaxaca into the Lacandón region of Chiapas (Figure 4, upper left) and extends into the Petén region of Guatemala. The distribution of the species also extends south from the lowland areas of Lacandón region to the west central region of Chiapas, reaching forests at altitudes close to 1,000 m in the municipalities of Beriozábal and Ocozocoautla.

*Hampea trilobata* is essentially a Yucatán peninsula endemic (Figure 4, upper right). There are more specimens of this species in herbaria of Mexico than all other species, an indication of its relative high abundance, especially considering it is not a showy tree. Its distribution covers 7.00 % of the Mexican territory (Criteria A1 = 1)

*Hampea rovirosae* is the only species with a marked disjunct distribution (Figure 4, middle left). It is a lowland species being found in humid tropical forests of extreme southern Veracruz, throughout Tabasco, northwestern Chiapas and southwestern Campeche but also reported from the Soconusco region of the Pacific coast of Chiapas near Puerto Madero (Bodegas-Valera *et al.* 1977). The species covers 1.20 % of the Mexican territory (Criteria A.1 = 1).

The potential distribution of *H. tomentosa* is one of the more extensive that we calculated for the genus, covering 3.18 % of the Mexican territory (Criteria A.1 = 2, Figure 4, middle right). However, the species is poorly represented in herbaria with only 36 recorded specimens in the CONABIO data base (CONABIO 2016), and was difficult to find in the field (RWJ, personal observation), suggesting low population densities.

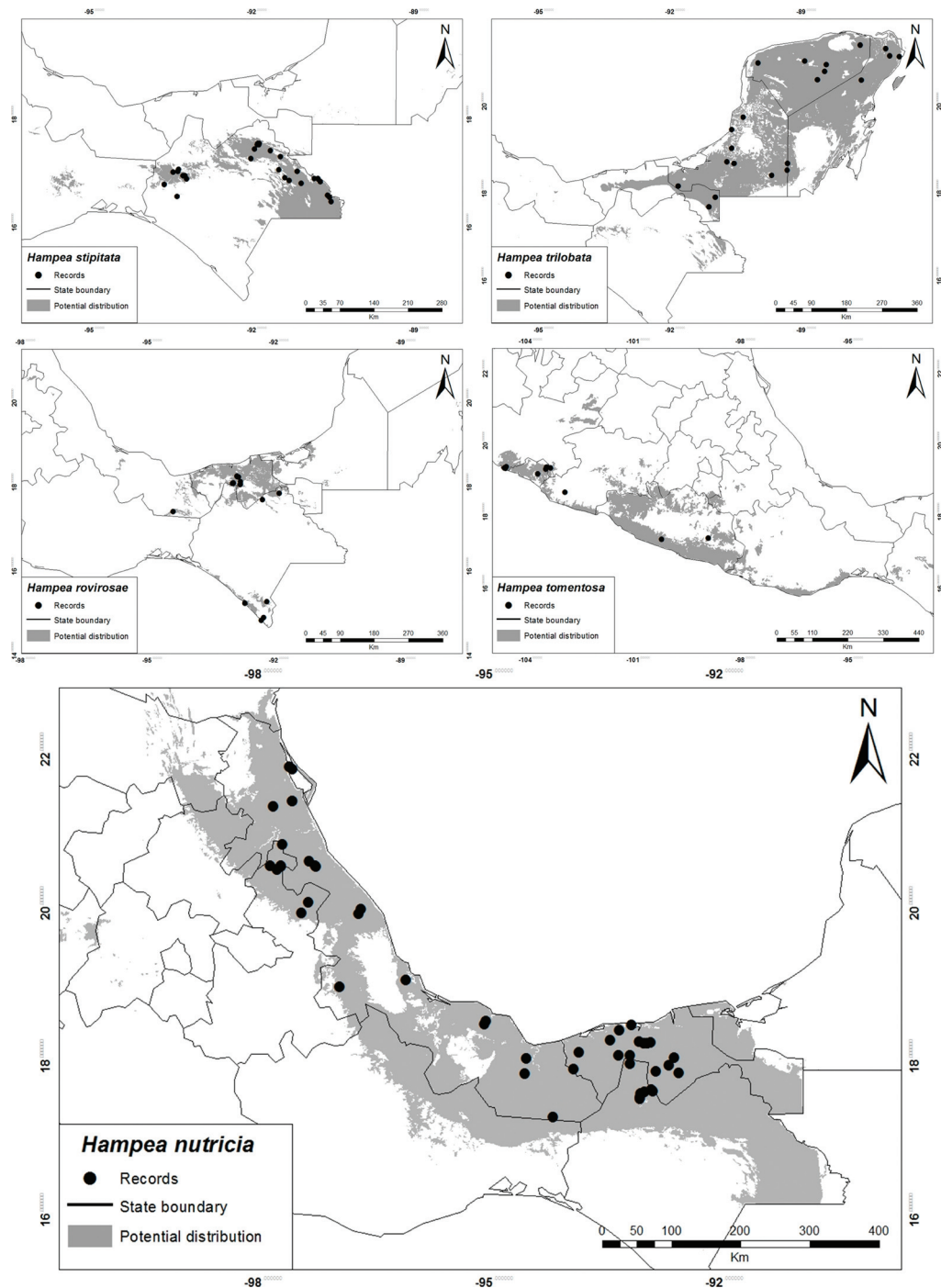
The distribution of *H. nutricia* is one of the largest for the genus, ranging from northern Chiapas and Tabasco, eastern Puebla, and along the gulf coast of Veracruz, north almost to 22° latitude (Figure 4, lower center) and covers 7.94 % of Mexico (Criteria A.1 = 1). It is mainly a lowland species but is also found in lower montane rain forests below 1,000 m (Fryxell 1988).

The number of populations and their presence in biotic provinces constitute Criteria A.2 and A.3, respectively. Two species had only one to three recorded populations (A.2.a = 3): *H. breedlovei* (2 populations) and *H. montebellensis* (2). Four species had four to eight populations (A.2.b = 2): and included: *H. longipes* (7), *H. latifolia* (4), *H. mexicana* (5), and *H. tomentosa* (7). Species with nine to 25 populations (A.2.c = 1): were: *H. intergerrima*, *H. stipitata*, and *H. trilobata*. The only species with greater than 26 populations (A.2.d = 0) was *Hampea nutricia*. All species were found in two or three biogeographic provinces which places them all in Criteria A.3 = 2.

None of the populations of species of *Hampea* in Mexico have what can be considered peripheral or extralimital distributions (Criteria A.4). Only five of the species, *H. latifolia*, *H. mexicana*, *H. trilobata*, *H. longipes*, and *H. stipitata* are not endemic to Mexico, and although these species have distributions that extend into Central America, a significant proportion of the populations, as suggested by areas of distribution and specimen records, are in Mexico (Fryxell 1979, 1988).

**Criteria B. Characteristics of the Habitat.** Species of *Hampea* in Mexico were found from one to five different vegetation types (Criteria B1). *Hampea breedlovei* was only recorded from cloud forests of northern Chiapas (B.1.a = 3). Species recorded from two vegetation types were *H. montebellensis*, *H. longipes*, *H. stipitata*, *H. latifolia* and *H. rovirosae* (B.1.b = 2). Those found in three vegetation types (B.1.c = 1) were, *H. trilobata*, *H. mexicana*, and *H. tomentosa*. *Hampea intergerrima* and *H. nutricia* were reported from four and five vegetation types, respectively.

Several species of *Hampea* were considered to be dependent on primary habitat to sustain populations (Criteria B3) based on collection records and observations in the field. These spe-



**Figure 4.** Potential distribution of five species of *Hampea* in Mexico: upper left, *Hampea stipitata* S. Watson, upper right, *Hampea trilobata* Standley; middle left, *Hampea rovirosae* Standley, middle right, *Hampea tomentosa* (Presl.) Standley, lower center, *Hampea nutricia* Fryxell.

cies were: *H. breedlovei*, *H. longipes*, *H. mexicana*, *H. montebellensis*, *H. stipitata*, and *H. latifolia*. For *H. breedlovei*, *H. longipes*, and *H. montebellensis*, these species are restricted to humid, montane habitats and no observations were reported or observed of individuals outside such habitat. For the primarily lowland or mid-altitude species, *H. stipitata*, *H. mexicana* and *H. latifolia*, individuals were invariably found associated with relatively undisturbed lowland tropical forests, although at times within small fragments. Never were individuals of these spe-



cies observed in recently disturbed vegetation or in open areas as is frequently found with *H. nutricia*, *H. trilobata*, or *H. rovirosae*.

Species of the genus *Hampea* are relatively restricted in their range of altitude in Mexico (Criteria B.5). However, only *H. breedlovei* was considered to be restricted to an interval of less than 200 m in altitude ( $B.5 = 3$ ), based on collection records and data given by Fryxell (1988). Reported altitudinal ranges (Fryxell 1988) and field observations indicated that *H. integerrima*, *H. longipes*, *H. mexicana*, *H. trilobata*, and *H. rovirosae*, although each were found at different altitudinal zones, are limited to an altitudinal range from 200 to 500 m ( $B.5 = 2$ ). *Hampea montebellensis*, *H. nutricia*, *H. stipitata*, *H. latifolia* and *H. tomentosa* had the greatest ranges in altitude, from 500 to 1,000 m ( $B.5 = 1$ ).

Two of the MER-Plantas habitat criteria did not apply to species of *Hampea* in Mexico. None of the species can be considered to have a highly specialized habitat (Criteria B.2). Likewise, there was no evidence that a species required a particular regime of disturbance for population maintenance (Criteria B.4).

**Criteria C. Intrinsic biological vulnerability.** - Quantitative field data for the demographic characteristics (Criteria C.1) of species of *Hampea* is lacking. However, it was considered possible to calculate population densities estimates for *H. breedlovei* (C.1.1) because of its highly reduced area of distribution. The calculated population density of *H. breedlovei* required to surpass criteria C.1.1.b (5,000 individuals) is 13.7/km<sup>2</sup>, or one tree per 7 ha, based on the predicted area of distribution. However, only 12 collections are reported for this species. Eleven of these are reported from the Selva Negra region above Rincón Chamula which has been highly altered and progressively fragmented with an almost complete reduction in forested area (Ramírez-Marcial *et al.* 2001, Cayuela *et al.* 2006). Only one other collection record exists outside the Selva Negra area from the isolated Cerro Ahk'ubal Nab, above Petalcingo (Figure 2), which is a forested area of less than 15 km<sup>2</sup>. Given the small area of distribution, the reduced number of collections and the present loss of habitat, it is highly improbable that there presently is a population density of 13.7 trees/km<sup>2</sup> of *H. breedlovei* in the northern highlands of Chiapas. Thus, we conservatively categorized Criteria C1 as less than 5,000 individuals ( $C.1.b = 2$ ). Although other species probably have reduced populations as well, there was insufficient data to estimate population sizes ( $C.1.b = 0$ ).

Other demographic characteristics (C.1) were as follows. Recruitment of seedlings were observed in most species with no data for the remainder, thus for all,  $C.1.2 = 0$ . There is also no evidence of factors involved with density dependent reproduction ( $C.1.3a$ ) in *Hampea*, nor is there evidence of clonality ( $C.1.3.b = 1$ ) (personal observation, RWJ). All species except *H. rovirosae* are dioecious (Fryxell 1979), thus  $C.1.3.e = 1$  for all species except *H. rovirosae* (0). There is no evidence of high variation in fecundity,  $C.1.3.d = 0$  for all species. Fruiting in *Hampea* is not characterized by few propagules ( $C.1.3.g$ ) and is often prodigious for large trees (Fryxell 1979, personal observation, RWJ).

There is evidence of population decline ( $C.1.3$ ) for several species. Significant destruction of the type habitat of *H. breedlovei* is discussed previously. The destruction of the type habitat *H. montebellensis* within the Montebello National Park due to fires and deforestation habitat is well documented (Román-Cuesta & Martínez-Vilalta 2006, Ramírez-Marcial *et al.* 2010, personal observation, RWJ). Study sites reported for *H. longipes* by Jones & Baro-Peruyero (2002) in the municipality of Tenejapa have also been deforested along the Yoshib River. Deforestation due to agricultural activities has occurred in the Tapachula area of Chiapas, where Bodegas *et al.* (1977) reported the presence of *H. rovirosae* and *H. latifolia*. Subsequently, populations of *H. rovirosae* have not been found. Several individuals of *H. latifolia* were found near the Bodegas collection sites (Jones 1994) but only within small forested fragments on the edge of cacao plantations or close to dwellings. Also, populations of *H. latifolia* in the lowland watershed of the Mapastepec River (MEXU, Jones 1994) are also in highly disturbed sites due to increased human populations along the river, and corresponding deforestation and agricultural activities that have intensified seasonal flooding and consequent damage to the floodplain.

Evidence of synchronous flowering ( $C.1.3$ ), is reported by Fryxell (1988); who gives general flowering periods for species, and writes that for the genus, "flowering is definitely seasonal"

(Fryxell 1979). Jones & Baro-Peruyero (2002) followed the phenology of populations of *H. montebellensis*, *H. longipes* and *H. mexicanus* in Chiapas and reported that flowering periods of both sexes occurred over a period of less than three months for these species. Stansly (1985) reported similar flowering periods for *H. nutricia* in Tabasco. However, *H. trilobata* has been collected with flowers in all months of the year (Herbario CICY 2018), and flowering is apparently not synchronous and for extended months in *H. rovirosae*, *H. intergerrima* and *H. tomentosa*.

No data is available for the following genetic evaluation (Criteria C.2) for the amount of heterocigosity, genetic structure, amount genetic variation, and population differentiation; thus all criteria were assigned zero (Criteria C.2.1-C.2.4.). Five of the seven specialized biotic interactions (Criteria C.3) have not been reported for *Hampea*. There is no data or the response was negative for important interactions with nurse plants, a parasitic interaction with a host plant, a specific pollinator, obligate myrmecophilia, or strict dependence on mycorrhizal association. All species, except *H. breedlovei*, were observed in the field and there was no evidence of clonal reproduction.

The two specialized biotic interactions pertinent to species of *Hampea* have to do with specific dispersal agents and high biotic mortality agent for one species. *Hampea* is unique within the cotton tribe for the presentation of the seeds within a white aril in a hanging open, fruit capsule (Figure 2), a trait considered an adaptation to dispersal by vertebrates (Howe & Smallwood 1982). Birds have been reported feeding on seeds of *Hampea* (Fryxell 1979, Marini & Cavalcanti 1998) indicating that the dispersal of seeds apparently requires a frugivorous vertebrate (C.3.3 = 1). For another specific biotic interaction (C.3.7 = 1), Jones & Baro-Peruyero (2002) report that the herbivorous beetle, *Anthonomus palmeri* Jones & Burke (Curculionidae) can destroy over 90 % of the flower buds of *H. longipes* which may reduce plant fecundity.

**Criteria D. Impact of Human Activity.** Three lowland species are apparently favored by anthropogenic disturbance (Criteria D.1 = -1): *H. nutricia*, *H. trilobata*, and *H. rovirosae* (Fryxell 1969, 1988, personal observations, RWJ). In the case of *H. nutricia*, individuals are common on roadsides and often used as shade trees in patio and used in fence rows (Fryxell 1979). *Hampea trilobata* and *H. rovirosae* are also favored by disturbance and occur on the edge of clearings near dwellings and roadsides. Although the lowland species, *H. stipitata*, is common along roadsides in the Lacandón region of northeastern Chiapas, it is apparently not benefited by disturbance (D.1 = 0), as are *H. nutricia*, *H. trilobata*, or *H. rovirosae* and is more restricted to less disturbed lowland and montane tropical rainforests (Fryxell 1988). The final lowland species, *H. latifolia* is apparently negatively affected by disturbance (D.1 = 1), as it is confined to small forest remnants and riparian vegetation within the highly developed agricultural region of the Soconusco (Fryxell 1988, Jones 1994).

Based on herbarium data and observations in the field, all remaining species were considered negatively affected by disturbance (D.1 = 1). This is especially evident in the montane species, *H. breedlovei*, *H. montebellensis*, *H. intergerrima* and *H. longipes*, which have not been reported from disturbed habitats. Given their rarity and their observed association with the relatively undisturbed habitats, the mid-altitude and dry forest species, *Hampea mexicana* and *H. tomentosa* are also considered negatively affected by human disturbance.

Anthropogenic disturbance of habitats (Criteria D.2) was considered to negatively affect to some degree all species of *Hampea* in Mexico, except *H. trilobata*. Of the most affected, *Hampea breedlovei* is restricted to cloud forest habitats of Northern Chiapas, of which few remain (Ramírez-Marcial *et al.* 2001). Cayuela *et al.* (2006) estimated that there are only 4,650 ha of primary cloud forest left in northern Chiapas; and noted that all forests were outside of protected areas and subject to high levels of deforestation (D.2 = 3). Although *Hampea longipes* has a greater distribution than *H. breedlovei*, it is also present in the temperate and cloud forest habitats of northern Chiapas and thus, affected by high levels of deforestation (D.2 = 3).

Three species are found in areas of relatively high human population densities and heavily impacted by human activity (D.2 = 3), based on analysis by González-Abraham *et al.* (2015). *Hampea intergerrima* is found in the heavily populated regions of the eastern portions of the Neovolcanic axis of central Mexico. *Hampea mexicana* is found in scattered forest and riparian fragments, principally within the central depression Chiapas that also has a high level of hu-

man impact and *H. tomentosa*, which is found on the relatively highly populated Pacific coast regions from Guerrero to southern Jalisco.

*Hampea montebellensis* is apparently restricted to the humid forest types within the vicinity of the Lagunas de Montebello National Park which have been significantly impacted (D.2 = 3). Although the park is a protected area, fires occurred in there during the El Niño years of 1998 and in 2003 (Román-Cuesta & Martínez-Vilalta 2006). Deforestation has also occurred in order to facilitate tourist activities near lakes of the reserve, as well as from typical clearing of land for extraction and agricultural activities, although some reforestation efforts have been made (Ramírez-Marcial *et al.* 2010, personal observation, RWJ).

*Hampea latifolia* is an endemic of the Soconusco region which is considered to have one of the highest levels of human impact within Mexico, principally associated with the tropical lowland forest (González-Abraham *et al.* 2015). Because *H. latifolia* is a tropical forest species, the anthropogenic impact on this species is considered to be high (D.2 = 3).

The habitat where *H. stipitata* is found is primarily the Lacandón region of northeastern Chiapas. Although much of this region is now protected, deforestation from the 1960s to 1990s was estimated to be as high as 40 % (Bray *et al.* 2008). Deforestation rates have dropped in the last 20 years but conservation initiatives are complicated by ethnic tensions, poverty and land-tenure problems (Calleros-Rodríguez 2017). Populations of *H. stipitata* in central Chiapas (municipality of Berriozabal) are also threatened by high deforestation rates and population pressure in this region (D.2 = 3).

Although *H. rovirosae* and *H. nutricia* are tolerant of disturbance, their habitats are among the most impacted by human activity (González-Abraham *et al.* 2015). These species are considered to be moderately affected by habitat loss in some populations (D.2 = 1). *Hampea trilobata* occurs in some of the least disturbed habitats of the Yucatán peninsula with low human impact on habitats (D.2 = 0).

We considered that all montane species, *H. breedlovei*, *H. montebellensis*, *H. intergerrima* and *H. longipes*, will be negatively impacted by the global effect on habitat deterioration in the future (Criteria D.3) due to climate change (D.3 = 1). Climate models predict that of 68 % of Mexican cloud forests will be lost by 2080 (Ponce-Reyes *et al.* 2012). The remaining species of *Hampea* were considered to be in habitats less affected by global effects or capable of adapting to changes given the seasonality of their present habitat (D.3 = 0).

The effect of direct use of species (Criteria D.4) on species of the genus *Hampea* is apparently minimal. The most cited direct use of most species is the fashioning of crude rope made from dried, unprocessed bark (Fryxell 1969). This use is reflected in the common name of *Hampea*, “majagua,” which is often a general term for a variety of plants from which the bark is used for this same purpose (Fryxell 1969, Cobos *et al.* 2009, Velázquez *et al.* 2009, Aranguren & Márquez 2011). The wood of *Hampea* trees is light and apparently not used much in construction (Fryxell 1969). Thus, we considered there was no effect of direct use of species (D4), except for moderate use for rope of *H. nutricia* and *H. trilobata* (D.4 = 1). Also, we found no mention of the fruits being used for human consumption or evidence of species of *Hampea* being propagated *ex situ* or cultivated (D5 = 0).

## Conclusions

Based on a detailed evaluation of the criteria of MER-Plantas (SEMARNAT 2010), seven species of the genus *Hampea* in Mexico were in a category of risk. Three species were categorized as “Risk of Extinction”: *H. montebellensis*, *H. breedlovei* and *H. longipes*. Of the other four species, *Hampea latifolia* was categorized as “Threatened” in our analysis and *H. stipitata*, *H. mexicana*, and *H. tomentosa* were categorized as “Subject to Special protection”. Formal requests will be made to SEMARNAT to change the status of these five species to their respective categories based on the results of our analysis. Also, the information presented in this study can be used to evaluate the species for inclusion in the IUCN Red List (IUCN 2017).

The first step in the conservation of *H. breedlovei* is to verify that the species still exists. The Cerro Ahk’ubal Nab in the municipality of Tila may be the only site left which may maintain populations of the species. Similarly, current population estimates are needed for the other



at-risk species: *H. montebellensis*, *H. longipes*, *H. latifolia*, *H. stipitata*, *H. mexicana* and *H. tomentosa*. For all species, and especially those in the highlands of Chiapas, many of the populations are in areas presently under control of indigenous or independent political groups with which collaboration would be essential to initiate and establish *in situ* conservation efforts.

The three endangered species, *H. montebellensis*, *H. breedlovei* and *H. longipes*, could serve as flagship species for cloud forests habitats of Chiapas. This is especially pertinent for the appropriately named, *H. montebellensis* which is restricted to the Lagunas de Montebello National Park and surrounding areas. Information about the species could be provided to tourists and residents of the park through printed material or on-line, and individual trees could be identified in the field with permanent plaques highlighting the unique and endemic nature of the species. The species could also be used in the present reforestation programs for the park (Ramírez-Marcial *et al.* 2010), given that other species of *Hampea* have shown potential in reforestation programs in Costa Rica (Marquis & Clark 1989).

These five species need to be included in regional and national *in situ* conservation programs for the preservation of sites with populations of these species, as well as, *ex situ* conservation programs for the cultivation in nurseries and botanical gardens and the inclusion in germplasm preservation, and maintenance. However, little information is available for *ex situ* conservation programs for propagation of *Hampea*. The first author has grown several trees of *H. trilobata* from rootstocks and the Central American species, *Hampea appendiculata* (D.Sm.) Standley has been grown from seedlings in outdoor experimental plots (Marquis & Clark 1989). Fryxell (1979) reports that, "based on limited data," seeds of *Hampea* lose their viability in approximately a year, suggesting that they are intermediate between orthodox and recalcitrant seeds. Only two species were found to be in international seed banks, *H. nutricia* and *H. appendiculata*, in the Kew Gardens seed collection (Royal Botanic Gardens Kew 2018). Much more information is needed for the successful inclusion species of *Hampea* in *ex situ* conservation programs and germplasm preservation.

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