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NON-DETRIMENT FINDINGS REPORT ON *GUAIACUM SANCTUM* IN MEXICO

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I. Background information on the taxa

1. BIOLOGICAL DATA

1.1. Scientific and common names

Guaiacum sanctum, Linnaeus (1753). Most authors identify four or six species in the genus Guaiacum. Four different synonyms have been recognized for G. sanctum:

1. *Guaiacum multijugum* Stokes (1812).
2. *Guaiacum guatemalense* Planch. ex Vail & Rydberg likely to be an hybrid between *G. sanctum* and *G. coulteri* (Porter 1972).
3. *Guaiacum sloanei* Shuttl. ex A. Gray (Gray 1897, Vail & Rydberg 1910).
4. *Guaiacum verticale* Orteg. (Gray 1897, Vail & Rydberg 1910).

Guaiacum sanctum is commonly called lignum vitae in English, and guayacan or palo santo in Spanish. Guaiacum coulteri, a very similar species to G. sanctum, is also called guayacan or lignum vitae.

1.2. Distribution

Guaiacum sanctum is found in Mexico, Nicaragua, Puerto Rico, the Dominican Republic, the United States (Florida), Costa Rica, Guatemala, Bahamas, Haiti, Cuba, Honduras, El Salvador, Trinidad and

Tobago, and the Turks & Caicos Islands. In some of these countries, *G. sanctum* has become endangered or is virtually extinct. The Mexican populations cover a greater portion of the species' natural range than those in any other country. There is no data available for the global population. However, a worldwide analysis of the tropical dry forest estimated a remaining range of 131,087 km^2 for North and Central America including Mexico. In general this coincides with presence information of G. sanctum, and we could consider this a very rough estimate of the world distribution area of *G. sanctum* (Miles *et al*. 2006).

The distribution of *Guaiacum sanctum* in Mexico was estimated based on an ecological niche modelling approach using the Genetic Algorithm for Rule-set Prediction (GARP) (Stockwell & Noble 1992, Peterson *et al*. 1999, Stockwell & Peters 1999, Anderson et al. 2003, Anderson & Martinez-Meyer 2004). Based on presence data and environmental information, GARP models species' responses to environmental conditions and projects the model in geographic space. Data on species' presence and absence obtained from field observations, interviews, literature and herbarium reviews may be used to test and refine the historic distribution models, and these can be combined with land-use data to describe the current distribution of a species. In this case we used data from 161 sites where *G. sanctum* is known to occur and 15 environmental variables.

The model generated by GARP was filtered in Arcview 3.3 (ESRI 2002) to generate an approximation to the historic distribution of the species (Anderson & Martinez-Meyer 2004). We included only those areas where there is a strong likelihood that the species is present based on herbarium information, literature sources and field surveys. The first filter removed biogeographic provinces where the species had never been recorded, using the Mexican biogeographic provinces map (CONABIO 1997). A second cut was applied by using a potential vegetation map (Rzedowski 1990) to remove vegetation types where the species has not been recorded. Thirdly, only those states where *G. sanctum* or *G. coulteri* have been collected or recorded previously were retained within the final distribution maps for the two species.

The final GARP model predicted the presence of *G. sanctum* in five states of southeast Mexico (Oaxaca, Chiapas, Campeche, Quintana Roo and Yucatan; Figure 1). The species is generally confined to tropical scrub and deciduous, semi-deciduous and evergreen forests in three main regions: (i) the coast and Isthmus of Tehuantepec in Oaxaca, (ii) the Central Depression in Chiapas, and (iii) a considerable part of the states of Campeche, Quintana Roo and Yucatan. Our model estimated a total distribution of *G. sanctum* in 2000 of appro-

ximately 95,400 km^2. About 88% of this distribution is within the Yucatan Peninsula in a roughly continuous distribution. *Guaiacum sanctum* overlaps with the distribution of G. coulteri in coastal regions of Oaxaca, Sierra Madre del Sur and the Isthmus of Tehuantepec.

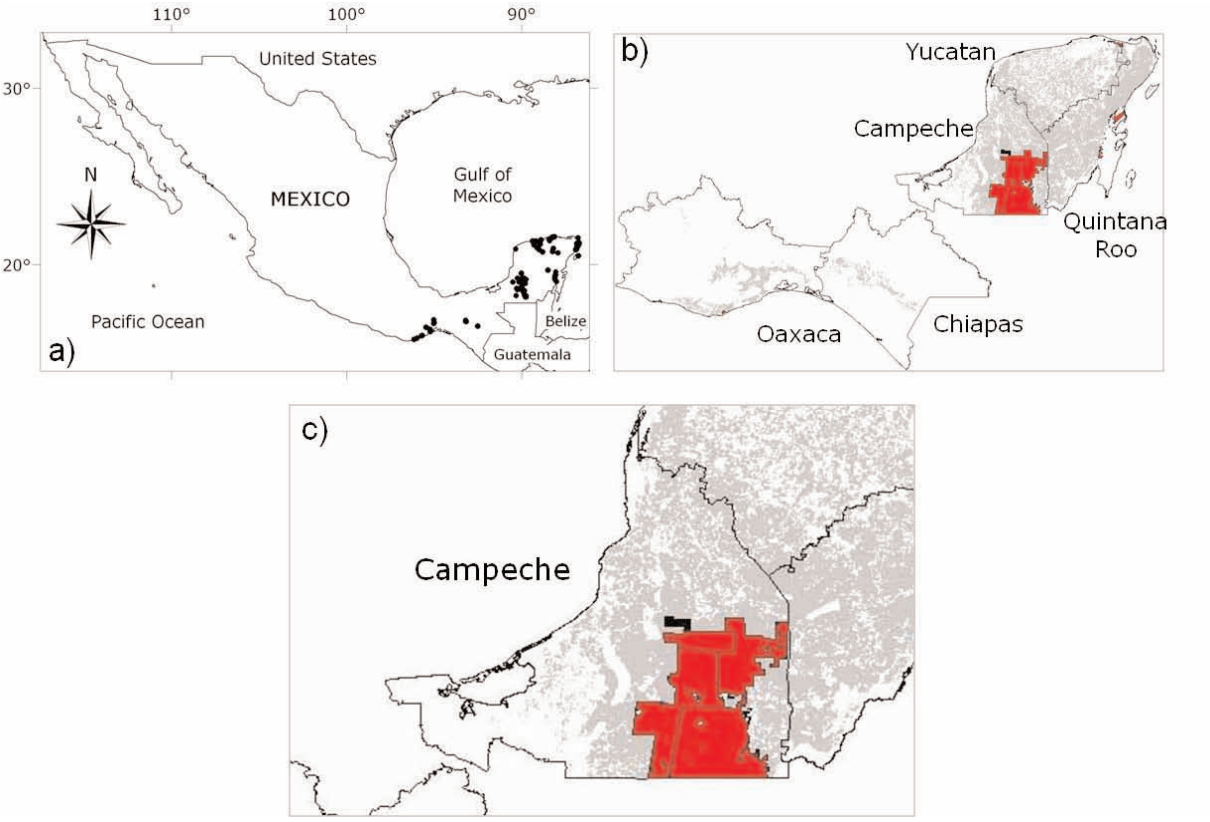

Figure 1. Distribution of *G. sanctum*. a) Confirmed presence information is showed with filled circles b) Potential distribution of G. sanctum in 2000 obtained based on ecological niche modelling (light gray), natural areas where the species is protected are show in red c) Campeche State showing in black, the area where forest management is still underway (Ejido Pich Forest Reserve).

Land use change has generated a rapid increase in fragmentation of forests, measured as the change in number of small fragments and the area they occupy. In the period 1990-2000 the number and area of tracts of continuous forest (>100 km^2) declined at rates of 3.99% year-1 through fragmentation and creation of new patches of forest, agriculture-pasture and human settlements of small size (0.1, 1 and 10 km^2). The total area occupied by fragments of forest declined by 2232.4 km2 yr^{-1}. Especially, in Chiapas and Yucatan states the populations are very fragmented due to agriculture and pasture conversion. The greatest area of presence of *G. sanctum* is found in central-south

Campeche, where the Calakmul Biosphere Reserve and the Balam-Kin and Balam-Ku state reserves protect about 12,000 km^2. These three reserves are connected with many communal reserves (*tierras ejidales*) possessing extensive forest reserves. Together they represent the most important areas for *G. sanctum* in terms of distribution and abundance.

1.3 Biological characteristics

1.3.1 *General biological and life history characteristics of the species*

Guaiacum sanctum L. (Zygophyllaceae) is an evergreen tree that grows up to 25-30 m in height and 60 cm diameter at breast height (dbh). Its leaves are paripinnate and opposite with 4-12 oblong to obovate leaflets. The crown is much dispersed. The very attractive flowers are solitary or in terminal panicles with blue-violet petals 0.7-1.2 cm long and yellow stamens. Fruits are capsules 1.5-2.0 cm long, winged, and turning yellow-orange when ripe. Seed are enclosed by an intensely red aril (Jimenez 1993, Chavarria *et al*. 2001, Grow & Schwartzman 2001).

Mortality

The highest mortality rates are in small individuals and decline with increasing tree size. Seedlings and juveniles (<150 cm height) may present a mortality rate between 5-20% year-1 while adults (>1 cm dbh) present very low mortality. Within a population of 3,000 individuals >1 cm dbh in Central Campeche, only two stems >5 cm dbh died during the period 2003-2008.

Size, growth and age

Guaiacum sanctum can be classified as a shade tolerant and slow-growing species over its life cycle. For example, in two different sites during three years of measurement in central Campeche, we found height growth for seedlings (<50 cm height) of 2-4 cm year-1 and for juveniles (50-150 cm height and <1 cm dbh) a height growth of 3-8 cm year^{-1}. For adults 1-40 cm dbh we measured growth rates of 1.5-2.3 mm year^{-1}. Based on these measurements, we estimate that the age of trees 35-40 cm dbh is between 280-390 years.

Additionally, radiocarbon estimations indicate ages between 377-460 ± 11-55 years for trees 60-64 cm dbh with diameter increments of 1.6-2.0 mm year^{-1}. These growth rates obtained from radiocarbon dating indicate very similar rates to those estimated from direct measuring methods (Brienen unpub. data). Similar growth rates have been found in Palo Verde, Costa Rica (Eric Ribbens pers. comm.). Therefore, we can fairly affirm that *Guaiacum sanctum* is a slow-growing species.

Based on interviews with local people, large trees (up to 70 cm dbh) were common in the past in central Campeche, but now most large trees have been harvested and the largest that we have found in the area of Calakmul, Campeche are no more than 55 cm dbh. However, even larger trees (90 cm dbh) have been observed in the Central Depression of Chiapas near Tuxtla (Gutierrez pers. obs.).

Reproduction and regeneration

Guaiacum sanctum populations flower twice a year, first in February-March and then in June-July. Fruit production occurs between May-June and August-September. Fruits are capsules containing 1-3 seeds. Probability of reproduction of *G. sanctum* increases with dbh. The smallest reproductive trees are 1 cm dbh, which corresponds to an age of 30-70 years according to the age-size estimates presented above.

Fruit production increases exponentially with tree size, with the smallest trees (1-4.9 cm dbh) producing about 10 fruits and the largest trees (>35 cm dbh) producing >10,000 fruits. However, there are low density populations of adult trees areas in Calakmul Biosphere Reserve with lower fruit production, which might indicate a lack of pollinators or low self-compatibility (Bawa & Crisp 1980, House 1992). The pollinators of G. sanctum are unknown, but floral morphology (the purple color of the petals and yellow anthers) suggests pollination by bees. Every fruit has two to four lobes that potentially produce one seed each, but fruits from low adult density areas usually produce only one seed. Fruits in high adult density areas have a mean of 2.5 seeds. In contrast, we have detected isolated reproductive trees in areas of the Central Depression of Chiapas that have high fruit production and up to 70-80% seed viability indicated by seed germination and x-ray seed tests. However, the density of seedlings in this area is very low, which likely indicates predator effects on seeds or seedlings (Gutierrez & Lopez unpub. data).

The regeneration of *G. sanctum* along its distribution range is highly variable. For example, in the centre of the range regeneration in undisturbed forest was very high, with densities of 1,500-15,000 seedlings ha^{-1}, whereas near the limits of its distribution (Oaxaca, Yucatan and Quintana Roo) densities of only 23-142 seedlings ha^{-1} were found. The underlying causes of these differences are not known, but it is clear that the more marginal populations require monitoring and protection from land use in order to ensure their long-term persistence.

Guaiacum sanctum is able to regenerate after small disturbances, such as selective logging. For example, we recorded continuous recruitment of seedlings for two years after harvesting. However, regeneration was 40-50% less in logged areas than in undisturbed

forest. Additionally, we recorded higher regeneration of *G. sanctum* than other tree species and we found that it dominates the community regeneration process. Following the demography and population dynamic of two 0.5-ha plots in recent logging, old logging and protected areas, the population growth rate of the species was | >1.0 for the three populations. This indicates that even after timber harvesting, the populations are still growing. The plots in recently and old–logged forest included logging gaps, skid trails, logging roads and log landings. A high proportion (~80%) of individuals cut or damaged during harvesting were able to re-sprout, but this response depended on the diameter and height at which damage occurred. We have observed that individuals cut higher up the stem were more able to re-sprout than individuals cut at the base. Individuals >10 cm dbh were unable to re-sprout. In the case of *G. sanctum*, sprouting may help to minimize the negative impacts of logging.

1.3.2 *Habitat types*

In Mexico, *Guaiacum sanctum* grows in scrub, semi-deciduous and evergreen tropical forest on karstic soils. It grows on karstic hills from 5 to 600 masl and in localities with no more than 1500 mm of annual rainfall. In semi-deciduous and evergreen tropical forest in the south of Campeche and some areas in Chiapas, it can grow up to 25-30 m height, but in scrub tropical forests of north Yucatan Peninsula it only grows to 3-4 m and never reaches more than 20 cm dbh. This is probably an effect of nutrient-poor karstic soils and very low annual rainfall (<550 mm).

1.3.3 *Role of the species in its ecosystem*

In some of the deciduous, semi-deciduous or evergreen tropical forests of south Mexico, G. sanctum is a very important species in number of individuals and in biomass. Especially in Campeche, our studies estimate that an adult tree (>40 cm dbh) is 350-400 years old and we consider that these individuals represent an important store of carbon. Thus, considering the species' abundance, wide distribution and high biomass in some forest of Campeche, we can expect that its multiple roles in ecologic function like fixing and storing carbon, nutrient and water fluxes, soil conservation, and source of food for animals, are very important. For example, many birds and mammals eat the fruits and seeds of G. sanctum, or trees are used for perches, nesting or protection. Based on *G. sanctum*'s flower type and massive flowering, it is very likely that the species is also an important resource for pollinators.

1.4 Population:

1.4.1 Global population size

The Mexican populations seem to be the core populations where stem densities are particularly high. The number of individuals in the surveyed localities varied from 130 to 1500 ha^{-1} potentially reproductive individuals (>1 cm dbh), and our estimate of total distribution indicates that Mexican populations cover about 95,400 km^2. If we are very conservative and consider the lower density of individuals (130 individuals ha^{-1}) for the total distribution (95,400 km^2), we obtain a population size greater than the limits required for the IUCN Endangered category (>10,000 individuals).

The abundance of the species is variable throughout its distribution area, with the highest densities per hectare in the Yucatan Peninsula. In Central Campeche, densities of up to 1200 ha^{-1} potentially reproductive individuals (>1 cm dbh) have been registered (Lopez 2008). In contrast, towards the edges of its distribution (Oaxaca, Yucatan and Quintana Roo), densities of only 150-470 individuals ha^{-1} have been found. The lowest densities have been registered in the state of Chiapas with at most <10 ha^{-1} reproductive individuals. In other areas of Chiapas, where herbarium information indicates historical presence of the species, forests have been reduced, fragmented or eliminated. Locally, *Guaiacum sanctum* can be relatively patchily distributed, and it is especially confined to karstic soils with moderate to strong slopes. In some areas the boundary between porous karstic soils and adjacent mixed seasonally flooded forest (*bajo mixto*) is associated with a transition from high densities of *G. sanctum* stems to very low density or total absence within a distance of just 5-10 m.

1.4.2 *Current global population trends*

___increasing __X__decreasing ____ stable ____unknown

1.5 Conservation status

1.5.1 *Global conservation status* (according to IUCN Red List)

___Critically endangered ___Near Threatened
_X_Endangered ___Least concern
___Vulnerable ___Data deficient

The global conservation status of *Guaiacum sanctum* is Endangered (ENC2a) and many countries of its natural distribution consider it a threatened species (CITES 2000, Chavarria *et al* 2001, Vivero et al. 2006,).

1.5.2 *National conservation status for the case study country*

For the case of Mexico, we consider that the species should be considered as Near Threatened, because it has had habitat loss of 28.2% in the last three generations, and the extent of its geographic range and population size in Mexico (95,421.6 km^2 and >10,000 individuals, respectively) exceed the limits required for the "Endangered" category. Therefore the species is not facing a high risk of extinction, but it is likely to reach the Threatened category in the near future (IUCN 2007). We acknowledge that the conservation status of the species may be very different in other countries. In Guatemala and Costa Rica, *G. sanctum* has been assessed as Vulnerable (VU A2ad) and Endangered, whereas in El Salvador and Florida *G. sanctum* is considered endangered or nearly extinct, respectively. By contrast, the Cuban populations apparently are abundant (Jimenez *et al*. 1993, CITES 2000, Vivero *et al*. 2006, Dertien & Duval 2008). There are also important regional differences between the Mexican populations: habitat loss has been much greater in Yucatan, Chiapas and Oaxaca than in the core populations in Campeche and Quintana Roo.

G. sanctum has been considered a threatened species in Mexico since 1994 (NOM-059-SEMARNAT-2001), specifically in the "Species under special protection" category. However, our results suggest that new categorization of the conservation status is required. Under the criteria for the Mexican method of Risk Evaluation (SEMARNAT 2002), a score of 11 was obtained for *G. sanctum*, which indicates that the species should be considered as Endangered and up-listed from the current category of risk (Special Protection) to endangered. The current risk category differs with the IUCN category of endangered.

1.5.3 *Main threats within the case study country*

___No Threats
_X_Habitat Loss/Degradation (human induced)
___Invasive alien species (directly affecting the species)
_X_Harvesting [hunting/gathering]
___Accidental mortality (e.g. Bycatch)
___Persecution (e.g. Pest control)
___Pollution (affecting habitat and/or species)
___Other_____
___Unknown

The main threats for *Guaiacum sanctum* in Mexico are HABITAT LOSS/DEGRADATION OF HABITAT provoked by human activities, especially the conversion from forest to agriculture-pasture lands and human settlements.

OVERHARVESTING of *Guaiacum sanctum* has reduced its abundance in some areas, but currently does not represent a threatening factor. Local use of the species is present in some communities, but at very low levels and we do not consider this a threat for the long-term persistence of the species. In general, illegal logging for commercial purposes is rare, but its effects cannot be discounted. For example, in September 2008 a small amount of *G. sanctum* timber was confiscated in a small community of Yucatan, near Merida (Dzitia), because of lack of authorization for harvesting.

With regards to POLLUTION, no effects have been reported for *Guaiacum sanctum*. However, there are some forested areas with presence of Guaiacum sanctum near cities (specifically Tuxtla Gutierrez in Chiapas) where urban growth seems to threaten the long-term persistence of the species. We have witnessed district development in areas with presence of *Guaiacum sanctum*. Other areas near Tuxtla Gtz, in a state reserve, present very poor regeneration even when trees produce abundant seeds. This probably indicates that seeds or seedlings suffer high predation or mortality.

2. SPECIES MANAGEMENT WITHIN THE COUNTRY FOR WHICH CASE STUDY IS BEING PRESENTED

2.1 Management measures

2.1.1 *Management history*

Different sources indicate that G. sanctum has been traded during the past four to five centuries. *G. sanctum* has historically been heavily exploited for its medicinal properties, especially for the treatment of syphilis and arthritis, which ensured an important market and resulted in reductions in its abundance in many locations (CITES 2000). It was also used as a laxative, anti-inflammatory, diuretic, and diaphoretic. Preliminary studies indicate that it also might have anticancer properties (Chavez 2001). Minimal medicinal use continues through use in local remedies. However, an international but probably irregular trade of *G. sanctum* for medicinal purposes persists, and a variety of products can be obtained online (*www.herbalremedies.com/, www.globalherbalsupplies.com/, www.abchomeopathy.com/*), but the origin of these products is unknown. Some are advertised as *G. officinale* of Mexican origin. However, this species is not present in Mexico and it is probable that these products are derivatives of *G. sanctum* or *G. coulteri* and apparently under unregulated trade. *Guaiacum sanctum* is also sold and planted as an ornamental tree and seeds can also be bought over the internet.

Currently the more important trade is for timber products. The high density and resin content of the wood confer auto-lubricating properties that make it suitable for the ship-building industry (Jiménez 1993, CITES 2000, Chavarría *et al*. 2001). Exploitation of *G. sanctum* for the timber industry in Mexico is mainly from the state of Campeche, but this activity it has been reduced. The most important period of industrial extraction occurred during 1960-1990 with trade to European, Asian and North American countries representing about 3000 tons year^{-1}. However, more recently the trade has declined significantly because G. sanctum timber has been replaced by plastic substitutes.

During 1987-1998 the amount traded was only 117 tons year^{-1} on average, with a maximum of 270 tons and a minimum of 10 tons. For some time timber from Cost Rica was also traded internationally, but since 1978 Mexico has been the only exporter of lignum vitae timber under CITES regulations. Japan, France and the US have re-exported *G. sanctum*, but apparently most of this was of Mexican origin. This is in part due to a reduction in the demand for the timber, but also because stocks have been depleted and the species is classified as nearly extinct or endangered in other countries within its natural range (CITES 2000).

The International Union for the Conservation of Nature has classified *Guaiacum sanctum* as an endangered species (ENC2a) due to its threatened conservation status within most of the natural range. Anecdotal evidence suggests that this classification is appropriate for populations of *G. sanctum* on the Caribbean Islands and for some countries in Central America (CITES 2000). For example, in El Salvador, *G. sanctum* is considered to be extinct in the wild and in Guatemala it is considered as a Vulnerable species (VU A2ad; Vivero *et al*. 2006). The best available evidence suggests that G. sanctum is threatened in eleven countries, although quantitative assessments have rarely been conducted (CITES 2000, Vivero *et al*. 2006).

Guaiacum sanctum has been included in CITES Appendix II since 1975 to control the international timber trade. However, from 1985-2003 all parts and derivatives were subject to control, with the exception of seeds and pollen, seedlings or tissue cultures obtained in vitro, cut flowers, or artificially propagated plants. Since 2003 all species in the genus have been included in Appendix II, meaning that CITES controls international trade for all parts and derivatives of plants of the genus (Oldfield 2005).

Guaiacum sanctum has been considered a threatened species in Mexico since 1994 (NOM-ECOL-059), especially in the "Species under special protection" category. For any proposed logging activity, special

permits and a management program are required. The last logging management program in Mexico was carried out during 1990-2005 in the Ejido Pich and Ejido Dzibalchen Forest Reserve, both in the southern state of Campeche with about 8,000 ha under management. A new program was recently granted to Ejido Pich with about 3000 ha to be managed during 2009-2024.

2.1.2 *Purpose of the management plan in place*

At the moment there is no management plan being carried out in Mexico, but a recently approved one will start by approximately March 2009. This management plan is for timber exploitation in the southern state of Campeche, specifically in the community Ejido Pich. This management program was planned by a timber enterprise in commercial agreement with the community (Ejido Pich). The purpose of this program is the exploitation of timber under non-detrimental methods for the long-term survival of this species in Mexico.

2.1.3 *General elements of the management plan*

The elements of the management plan include: i) Sustainable exploitation of *Guaiacum sanctum*. This includes selective logging of commercial trees >37.5 cm dbh, with the least possible impact at the moment of felling, skidding and transport of logs. ii) Reduced environmental impact to trees remaining in the forest, soil, flora and fauna. iii) Restoration or induced regeneration in case of negative impacts of harvesting. iv) Monitoring of demography and population dynamics.

2.1.4 *Restoration or alleviation measures*

In general, any management plan for timber extraction includes four different components: restoration, reforestation, prevention of damages, and control of damages.

The management plan intends to carry out restoration techniques if negative impacts are provoked by harvesting. The managers indicate that seeds of the species will be collected and dispersed. Additionally, they will also produce seedlings and saplings in shade houses and then plant them in gaps generated by harvesting. However, studies of the demography, population dynamics, regeneration in logging gaps, and germination indicate that silvicultural treatments are likely to be unnecessary. Additionally, the slow growth of the species indicates that seedling and sapling production is likely to be difficult and therefore not recommended.

2.2 Monitoring system

There is still no well-defined monitoring plan. The logging company which will carry out the management plan proposed to establish a series of permanent plots at pre-harvested, harvested and protected sites to follow demographic patterns and population dynamics of the species. For this monitoring, the demographic schedules are planned to be followed for ten years with annual censuses during the first two to three years and then a biennial census. This demographic data will provide the basis for population dynamics to be estimated using matrix modelling. This monitoring will allow approximate determination of the effects of harvesting on population dynamics, and represents a good scenario for setting up an experiment examining the impacts of different percentages of harvest damage to small individuals and commercial adults. As the management plan also includes other species, some other effects can also be evaluated.

However, there is still no funding available to establish this monitoring programme and the managers together with the community and probably some academic institutions will apply for financial support from the Mexican Forestry Commission or other institutions.

2.2.1 *Methods used to monitor harvest*

Though the monitoring program has yet to be properly established because the management program will begin in March 2009, it is likely to be developed with participation by scientists, forest managers, and the Ejido Pich community. Monitoring will include the establishment of permanent plots in i) pre-harvest, ii) post-harvest, and iii) undisturbed populations where all individuals will be tagged and measured. Two hectares (in four 0.5-ha plots) in each population type will be established. In harvested populations two to three annual censuses will be completed and then biennial censuses will be completed for 8-10 years. Survival, growth in height and diameter, probability of reproduction, and fecundity rates will be followed. Population dynamics studies will be carried out using matrix modelling, simulating different harvesting systems to propose better management of the species.

Rapid assessment will also be completed throughout the logged area to determine the rate of harvested trees, the remaining stock, and the potential for regeneration at the landscape level.

2.2.2 *Confidence in the use of monitoring*

Permanent plots and matrix modelling have been widely used to understand the dynamics of stage-structured populations in evolutionary studies, in research on the control of weedy and invasive plants, and in the conservation or management of populations of a wide

range of species (Silvertown *et al.* 1993, Caswell 2000, de Kroon *et al.* 2000, Heppell *et al*. 2000, Franco & Silvertown 2004, Davis *et al*. 2004). Matrix modelling simulations of management interventions in populations of tropical woody plants have also been used to give recommendations on the restoration or exploitation of plants (Olmsted & Alvarez-Buylla 1995, Ratsirarson *et al*. 1996, Svenning & Macía 2002, Zuidema & Boot 2002). Furthermore, matrix models can be used to conduct elasticity analysis, which allows comparison of the relative contribution of different stage-specific vital rates (survival, growth and fecundity) to the population growth rate (de Kroon *et al*. 1986, Heppell *et al*. 2000, Caswell 2000). Elasticity analysis is useful for identifying potential management targets because it can detect life stages and vital rates with the greatest impact on the population growth rate, which helps the decision-making process (de Kroon *et al*. 2000, Heppell *et al*. 2000, Caswell 2000). To our knowledge, there have been no studies evaluating the effects of field-scale commercial harvesting on the population response of slow-growing tropical timber species. This issue is very important for the establishment of both general and site-specific management recommendations.

2.3 Legal framework and law enforcement

Guaiacum sanctum has been listed in CITES Appendix II since 1975. In 2000, the species was proposed to be listed in CITES Appendix I, but insufficient data were available to justify this status change. In 2003 all species in the genus were included in Appendix II to control international trade for all parts and derivatives of plants of the genus (CITES 2002, Oldfield 2004).

G. sanctum has also been considered a threatened species in Mexico since 1994 (NOM-ECOL-059), specifically in the "Species under special protection" category. However, our results suggest that new categorization of the conservation status is required for this species. Under criteria for the Mexican method of Risk Evaluation (SEMARNAT 2002), a score of 11 was obtained for *G. sanctum*, which indicates that the species should be considered as Endangered and therefore should be up-listed from the current category of risk (Special Protection), which differs from IUCN's category of endangered.

We consider that Mexican populations of *G. sanctum* should remain listed on CITES Appendix II to help reduce pressure on *G. sanctum* populations from timber exploitation and international trade. This measure would indirectly ameliorate demand for *G. coulteri*, which is occasionally substituted for *G. sanctum* (CITES 2000). By contrast, an up-listing to Appendix I as previously proposed would impose difficulties for international trade, reduce interest in forest management, and

provoke increased risk of land conversion (CITES 2000). This work would have to follow regulations imposed by the Mexican environmental authorities (SEMARNAT 2002), and timber exports would remain subject to CITES regulations (CITES 2000).

3. UTILIZATION AND TRADE FOR RANGE STATE FOR WHICH CASE STUDY IS BEING PRESENTED.

3.1 Type of use

Wild populations of *Guaiacum sanctum* have historically been heavily exploited for its medicinal properties, resulting in reduced abundance in many locations. Nowadays the international market for medicinal use has nearly vanished. However, some products derived from the bark, leaves and roots continue to be traded over the internet, but the origin of these products is uncertain. Many of these products are advertised as derivatives of *G. officinale* and of Mexican origin. However, this species is not present in Mexico and we might assume that these products are derived from *G. sanctum* or *G. coulteri*.

In some small villages in the Yucatan Peninsula *G. sanctum* is still used for medicinal purposes, but apparently only for domestic use. Medicinal properties include the use against syphilis and, in general, sexually transmitted diseases as well as arthritis, gout and asthma. It is also used as a laxative, diaphoretic, diuretic, and for pain relief. None of these properties has ever been studied and confirmed scientifically.

G. sanctum was also used for railroad ties, but now this use has completely disappeared. One use which still occurs is for handicrafts at some villages in the state of Yucatan. No estimation of the extent of this use is available. A small shipment of G. sanctum was recently confiscated in a small village in Yucatan (Dzitia), which apparently was supplied illegally from the north of Campeche (A. Pani pers. comm.).

Sawdust, a waste by-product from sawmills, is used in some mosquito repellents (slow-burning coils) due to the wood's slow combustion rate. Chips and other wood waste are exported to Germany to be used together with other 42 different aromatic herbs for the preparation of the "Underberg", a traditional digestive.

Currently the most important trade is in timber products. *G. sanctum* timber's high specific gravity and its high resin content confer resistance to the attack of natural enemies and give the wood autolubricating properties that make it suitable for the ship-building industry (Jiménez 1998, CITES 2000, Chavarría *et al*. 2001). Internationally traded timber is totally of wild origin. During the last management program about 8000 hectares in the southern State of Campeche were exploited during the 1990-2005 period. Most of the

timber exploited during this management program was exported to European and Asiatic countries, especially Germany, Japan and the Philippines (Salmon pers. comm.).

Timber of *Guaiacum sanctum* has been included in CITES Appendix II since 1975. In 1985 all parts and derivatives were also included in the Appendix II listing. In 2000 it was proposed to up-list G. sanctum to Appendix I, but insufficient data were available to justify this status change. In 2003 during CoP12 (Santiago de Chile), all species in the genus were included in Appendix II. *G. sanctum* is also listed as a "Species under special protection" in the Mexican list of threatened species since 1994 (NOM-ECOL-059) and therefore for any proposed logging and trade, special permits and a management program are required.

3.2 Harvest:

3.2.1 *Harvesting regime*

The most important use of *G. sanctum* is for timber, and exploitation is under selective logging techniques. This means that only adults >35 cm dbh (>37.5 cm in the recently authorized management plan) are harvested. In central Campeche where all the management programs have been carried out in the last 18 years, *G. sanctum* abundance is high (up to 1200 individuals >1 cm dbh ha^{-1}). However, the density of commercial trees is only 8-12 ha^{-1}, and after discounting those distorted, split at the bottom, or difficult to access, only about 40-50% is commercially available. The estimation of the potential stock available for exploitation (m^3 ha^{-1} year-1) is based on the inventory of the population in 2% of the area proposed to be managed.

Generally, only the main log of a given tree (4-5 m) is extracted, leaving the rest of the stem and branches in the forest as these are not useful to the timber industry. These branches are sometimes used in the small-scale industry of handicraft production in the neighbouring state of Yucatan. Special permits are required to transport these small-scale quantities.

To extract logs a skid trail is created by cutting the trees standing in the way, including some *G. sanctum* individuals of sub-harvestable size. Trees of *G. sanctum* >10 cm basal diameter are unable to re-sprout. Harvesting is carried out during the dry season from approximately February to May.

Demographic studies and elasticity analysis indicate that *Guaiacum sanctum* populations in central Campeche are sensitive to harvesting damages to non-commercial adult trees (1-25 cm dbh). Computer simulations suggest that logging of commercial trees has a low impact

on the population growth rate (Ï). In contrast, small increases (>8%) in the mortality rate of non-commercial trees produce strong negative effects on the population growth rate.

3.2.2 *Harvest management / control* (quotas, seasons, permits, etc.)
To exploit any forest product in Mexico, a management program and special permits are required. As a new legal requirement, a population study must be undertaken to demonstrate the ability of the population to recover from exploitation and to assure that harvesting will not place a commercial species at risk.

In general, the management program includes a description of the inventory, estimation of the potential harvestable stock, description of logging methods, and explanation of how negative outcomes will be avoided.

In the recently approved management plan for *G. sanctum*, only adults >37.5 cm dbh were authorized to be harvested. The availability of these trees is approximately of 7-12 ha^{-1}. Depending on the quality of the logs (i.e., their length, straightness, and accessibility), about 40-50% of commercial trees are felled. Trees left in the forest represent an important source of seeds as they contribute a large percentage of the total number of seeds produced annually.

There is apparently good regulatory control over the management program. Some of the permits or authorizations required for this management program include: i) Authorization of the Environmental Department (Dirección General de Vida Silvestre-SEMARNAT-CITES Management Authority). ii) In the field, trees identified by loggers for harvest can be felled only after being visually authorized and marked by a forestry supervisor from the company which will carry out the management program. iii) Authorization of the legal representative of the Mexican Environmental Department (PROFEPA-SEMARNAT), which completes a field inspection to check the geographic coordinates of the area under management, diameter of trees felled, etc. iii) Permission to transport the timber from the field to the sawmill must be granted by the Mexican Environmental Department (SEMARNAT). This permission is for every truck carrying out *G. sanctum* timber. The truck may only contain commercial-sized logs and police departments may stop and ask for this permission. If the driver fails to show valid permission, police may confiscate timber and truck. iv) Authorization to transport timber products from the sawmill to the port for export. v) An NDF from the Scientific Authority (CONABIO). vi) CITES certificate for exporting. If any irregularity is found, the company is fined or legal actions may be taken and the authorization program can be revoked.

All of these permits are necessary to control the harvesting process and to promote conservation of the species. However, sometimes all of these permits or authorizations seem tedious due to bureaucracy and may take a long time, delaying the whole process. Thus, this may provoke a lack of interest of managers and the communities in forest management and paradoxically bring negative consequences, as communities may become interested in other forms of land use associated with simpler legal processes.

NOTE: For this species, the last two management programs (and earlier ones) were reviewed by the Scientific Authority before the harvesting authorization was given by the Dirección General de Vida Silvestre-SEMARNAT.

3.3 Legal and illegal trade levels

Although there are no estimates of the extent of illegal logging for international trade, it is likely to be very low or non-existent given the reduction of *G. sanctum*'s use. The legal international trade has decreased in recent years and further reduction is expected in the coming years. For example, during 1987-1998 the most important company (Transforesta) exported about 117 tons year^{-1} on average, with a maximum of 270 tons and a minimum of 10 tons. Table 1 show the Mexican exports from 1999 to 2006 registered in the trade database (UNEP-WCMC-CITES 2008), this exportation were mainly to France, Great Britain and the US.

Table 1. Mexican exports of Guaiacum sanctum, as recorded in the UNEP-WCMC CITES Trade Database.

Product	Unit	1999	2000	2001	2002	2003	2004	2005	2006
Carvings	kg	1	0	20	0	0	0	0	0
Logs	m3	0	1	0	0	0	<.01	0	7.1
Powder	m3	0	0	0	0	0	0	0	7
Sawn wood	m3	1	6	7	41.1	162	56	18	141.2
Sawn wood	kg	0	0	0	1090	746	1	25	0
Timber	m3	171	314	148	232	0	149	99	29.2
Timber	kg	0	0	2	0	4	750	3767	225
Timber pieces	m3	0	0	0	0	0	0	0	14

According to our interviews and field work, illegal logging is very low or non-existent and mainly for local use. However, minor commercial use cannot be discounted. For example, *G. sanctum* is used for handicrafts and recently a small shipment in Yucatan was confiscated. Even if illegal logging exists, the volumes involved are very low and likely to have minimal impact on populations. Locally, medicinal use persists in

some villages in Yucatan Peninsula, but this seems to be more for domestic use and there is no trade. Over the internet is possible to find derivatives of *Guaiacum* advertised with medicinal properties, but the origin and authenticity of these products are not clear.

II. Non-detriment finding procedure (NDFs)

1. IS THE METHODOLOGY USED BASED ON THE IUCN CHECKLIST FOR NDFS?

___yes __X__no

2. CRITERIA, PARAMETERS AND/OR INDICATORS USED

The NDF for Guaiacum sanctum is based on the following criteria:

1) Biological criteria
   a. Distribution and abundance
   b. Population
      i) Number of commercial trees per hectare
      ii) Population structure
      iii) Estimation of seed production
      iv) Growth in diameter at breast height (dbh) and height
      v) Probability of reproduction and seed production
      vi) Population growth rate (Ï) obtained from permanent plots
      vii) Effects of simulated harvesting based on population modelling
      viii) Hollow trees (10%)

2) Harvesting and management criteria
   a. Harvesting area
   b. Management methods
      i) minimum cutting diameter
      ii) cutting methods
      iii) cutting periods
      iv) opening paths for extracting trees

3. MAIN SOURCES OF DATA, INCLUDING FIELD EVALUATION OR SAMPLING METHODOLOGIES AND ANALYSIS USED

3.1 Sources of data

The Scientific Authority of Mexico uses two main sources of data for making NDF for Guaiacum sanctum.

i) CIEco UNAM study

A four-year study on "Abundance, distribution and conservation status of *Guaiacum sanctum* L. in Mexico" where the conservation status of the species in Mexico and the effects of timber harvesting on the population was assessed (see Annex). The study was developed by a group of scientists from the Centro de Investigaciones en Ecosistemas at the National Autonomus University of Mexico (CIEco UNAM), led by Dr. Miguel Martínez Ramos with support from CONABIO (Scientific Authority). CONABIO was responsible for coordination and administration of the project as well as for co-financing part of it, and therefore maintained communication with researchers, made periodic evaluations of project reports, and assisted with available resources (e.g., information systems, species localities database).

The study assessed the current distribution and abundance of the species. Demographic patterns (survival, growth and fecundity rates) and population dynamics (population growth rate and elasticity analysis) in managed and unmanaged areas were followed according to criteria established by Caswell (2000) (see Annex).

The study included modeling of harvesting scenarios and gave concrete recommendations:

A matrix model was generated for the species assuming populations are stable (growth, mortality and fecundity constant through time). After a defined number of iterations of the model, the future size structure was projected using different extraction percentages and recruitment values. The model suggested that a cut (harvest) rate of 50% of trees with ?35 cm dbh once every 10 years can maintain the population in equilibrium if recruitment is guaranteed.

A computer-based simulation was carried out to explore the possible results of different (hypothetical) selective logging scenarios of *Guaiacum* populations. Based on elasticity analysis it was determined that the most important life stages for the population growth rate (Ï) are adults 1-25 cm dbh; these individuals are even more important than adults >35 cm dbh. This simulation did not consider aspects such dry years, severe storms, pests and diseases, and especially germination of seeds and survival of sub-adults and adult trees.

Based on these simulations, it can be concluded that the extraction of commercial trees may not have a significant impact on the population growth rate. For example, for any extraction percentage of commercial trees (20%-100%), if small trees are left standing, the model suggests that Ï will be reduced only between 0.7% and 1.1% of its original value in the absence of commercial logging. On the other hand, if no commercial trees were extracted but a sustained annual extrac-

tion of small trees (above 9%) was carried out, Ï would fall below 1 (equilibrium) and the population could decline towards extinction over the long term. This means that commercial logging for *Guaiacum sanctum* must take into consideration a maximum extraction rate (i.e., due to damages) of not more than 4% of small trees (1-25 cm dbh). On average, for a sustainable harvest of 40% of commercial trees, the maximum extraction percentage of small trees would be around 7.3% annually. Extraction programs should therefore be planned carefully to prevent damages to small (sub-commercial) size classes.

As a general conclusion, simulations based on populations from EPFR showed that resting periods between harvests of 15 or more years is fundamental for sustainable management of Guaiacum sanctum. Nevertheless, this result should be analyzed and defined on a case-by-case basis, and in relation to the proposed extraction percentage and to population survey results from sites that are to be harvested. In table 2 is summarized the key management recommendations for G. sanctum, obtained from the demographic can population dynamic study.

In this study it was also determined how harvesting affect the short-term dynamics and regeneration of *G. sanctum* at the local gap level in order to provide management recommendations and long-term conservation guidelines for exploited populations. To achieve this aim the demographic attributes (mortality, growth and recruitment) of *G. sanctum* populations under managed and unmanaged areas were studied. This study found that logging reduced stem density and residual tree basal area at a local scale, but our study suggests that harvesting of *G. sanctum* had only minor short-term effects on the dynamics and regeneration of the tree community. Guaiacum sanctum seedling abundance and rates of growth, mortality and recruitment were sensitive to the effects of harvesting, but the demographic attributes of adults were unaffected by logging. Re-sprouting was an important attribute of the resilience of *G. sanctum* and other species to disturbances such as timber harvesting in this forest. We conclude that logging of *G. sanctum* had a lower impact at the population and community levels than in other documented harvesting operations. The low impact arises because only one species is logged, and the density of trees of commercial size is low enough that widespread damage to the tree community is avoided. It is important to mention that this study was a t the level gap and therefore did not include any damaged outside of the gap (for example other trees cut in the skid trail).

Table 2. Key optimum attributes for *Guaiacum sanctum* management, based on a demographic and population dynamic study in the Ejido Pich Forest Reserve, Campeche, Mexico.

Attribute	**Optimum rate**
Commercial Adult trees extraction (%)	<50
Mortality of non commercial trees (%)	<8
Frequency of harvesting (years)	>15
Population growth rate (i)	>1

ii) Management programs prepared by the proponents

For any proposed logging operation a management program should be completed and presented. A management plan must contain: specific objectives, short, medium and long-term goals, physical and biological description of the area and sampling methods, a chronogram of activities, management measures for specimens, populations and the habitat, contingency measures, a vigilance program, and a targeting system to identify specimens.

For the most recent management plan evaluated and authorized in 2008, a "Population study" was also required. This mainly consisted of a statistical study describing the population structure and some general tendencies of the population based on life tables. The population study was based on data from 2%-area sampling within the proposed management area (approximately 60-ha inventory). Exploratory inventories were done within the forest management areas and 100% censuses were done in the forest management plots.

3.2 Analysis of the information and definition of the NDF

In Mexico, all harvesting requests for national and international trade are accompanied with a management program. Management programs for this species are reviewed by the Scientific Authority before the harvesting authorization is given.

The process is as follows:

- First, the SA verifies that the harvesting area proposed by the management plan is where management can be done. The CIEco UNAM study elaborated a GARP analysis to identify areas requiring protection, restoration, and where management might be possible. Since the species has a non-homogeneous distribution, censuses prior to harvesting are required to identify low-density areas where harvesting might not be sustainable.
- The SA revises the information given in the population study of the management program. All biological parameters (population struc-

ture, growth in diameter at breast height, probability of seed production, and population growth rate) are compared with results from the study done by researchers of CIEco UNAM.
- The amount and characteristics of the specimens to be extracted are compared with recommendations derived from the harvesting modeling included in the CIEco UNAM study.

4. EVALUATION OF DATA QUANTITY AND QUALITY FOR THE ASSESSMENT

The study on population dynamics done by researchers from CIECO UNAM, and their close working relationship with the SA, has helped to generate better knowledge of the species, its behavior, and the effects of extraction on the population.

This study represents the most detailed and only available population dynamics information for the species in Mexico or elsewhere.

To evaluate the conservation status of the species, the study completed an intensive herbarium review, completed rapid field assessments, and, to evaluate the effects of timber harvest, established three 1-ha permanent plots in recently logged, old logged, and protected forest populations. The demography and population dynamics have been followed during three years. Researchers also collected regeneration data in logging gaps created by harvesting and compared the effects with undisturbed forest.

Having data derived from population research like this has helped to identify the essential elements to be considered in an NDF, such as population parameters (periodic measures and sustainable indicators) and the development of sustainable methods for the species' management and logging.

The study also collected presence-absence information in 220 different localities. However, only 11 rapid field censuses were completed throughout *G. sanctum*'s potential distribution and this may limit the conclusions. The demography study was completed in only three 1-ha plots, which represent a local scale study, but field observations through the central Campeche region suggest that the permanent plots may roughly represent the situation in this region. However, these results should be considered with caution for the purpose of generalization.

Based on results from this project, CONABIO called for the creation of an evaluation group including relevant government agencies, scientists, and industry to follow up on the implementation of management recommendations derived from the study. A National Workshop on Conservation, Management and Sustainable Use of Lignum Vitae (*Guaiacum sanctum*) was held in Mexico City on October 11-12, 2006. The workshop was organized by the Scientific Authority (CONABIO)

with the support of the Management and the Enforcement Authorities, with the main objective of establishing guidelines and coordination mechanisms to promote the conservation and sustainable use of *G. sanctum* in Mexico. To accomplish this, participants (stakeholders from academic, productive and government sectors) focused on: obtaining a first diagnosis of the species at a national level in order to define priority areas for conservation, restoration, and sustainable use; defining general guidelines for the management and sustainable use of the species, trying to strengthen the legal regulations in place; and defining mechanisms for institutional coordination through which there can be a follow-up on the national conservation, use and monitoring programs of wild populations of lignum vitae and its habitat.

5. MAIN PROBLEMS, CHALLENGES OR DIFFICULTIES FOUND ON THE ELABORATION OF NDF

The demographic studies represent powerful tools to explore the effects of perturbations such as timber harvesting and future population trends. However, to determine these effects it is necessary to complete detailed censuses in the medium or long term. This may take a long time to generate, which is not always possible when concrete recommendations are required in the short term.

The taxonomy of the genus is still unclear and identification problems might appear where *G. sanctum* and *G. coulteri* are both present due to the high degree of similarity between them. If reproductive structures are not present is very difficult to tell them apart. As well, some taxonomists indicate that these species may be hybridize, further complicating their identification. In the Yucatan Peninsula, only *G. sanctum* has been collected. Genetic studies will provide information on the taxonomy of the genus and may help to differentiate populations. However, timber of both species may be practically indistinguishable and illegal logging of *G. coulteri* cannot be ignored as it may be traded as *G. sanctum*.

6. RECOMMENDATIONS

The ecologic information available for *G. sanctum* in Mexico provides insights on the conservation of the species in Mexico and might be used for improving its management and in future non-detriment finding procedures. Simulations suggested that logging of commercial trees (> 35 cm dbh) had a low impact on the population growth rate for a harvesting intensity of <50% of all stems. In contrast, small increases (< 8%) in the mortality rate of non commercial trees (1-25 cm dbh) generated strong negative effects on Ï. Simulations also suggest that

an optimum sustainable harvesting regime depends on a combination of very low damage to non commercial trees (2-8 %), low-medium harvest levels (<50%), and rotation periods of 15 years.

The demographic and population dynamic techniques are very time consuming and may take a long time to evaluate the effects of timber harvesting. However, the evaluation of the population structure can be very informative and static studies can be completed. Based on those, the commercial stock and regeneration of the species can be evaluated.

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