Review of the taxonomy, biology, ecology, and the status, trend, and population structure, of *D. cochinchinensis and D. oliveri* in Choam Ksant district, Preah Vihear province, Cambodia

Integrating the Development of Guidelines and Incentives for Piloting the Establishment of Small-scale Private *Dalbergia* Plantations with the Determination of a Non-detriment Findings Report in Preah Vihear Province in Cambodia

Forestry Administration

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Forestry Administration (FA)
#40 Preah Norodom blvd.
Phnom Penh, Cambodia
Tel: (855-23) 214 651
Fax: (855-23) 212 201
Website: https://fa.maff.gov.kh/

CITES Tree Species Programme
Web Page: https://cites-tsp.org/

Financial Support: The European Union and CITES Tree Species Programme

Authors: Say Sinly, Chheang Dany, Hort Sothea, Kim Sobon, Pang Phanit and Lim Sopheap,

Cambodia Project Team and Contributors to the Technical Report:
Dennis J. Cengel, Neab Keng, Vann Vean, Phoung Sophea, Kong Kongkea, Buor Vuthy, Sin Chandara, As Brosden, Nuon Sithun, and Ouch Sineth

Editors: Dennis J. Cengel and Chheang Dany

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Executive Summary

This report is a compilation of the information gathered on the taxonomy, biology, ecology, and the status, trend, and population structure, of *Dalbergia cochinchinensis and Dalbergia oliveri* in Choam Ksant management district in Preah Vihear province in Cambodia. This information was gathered over the course of one year as a component of the project directed at "Integrating the Development of Guidelines and Incentives for Piloting the Establishment of Small-scale Private Dalbergia Plantations with the Determination of a Non-detriment Findings Report in Preah Vihear Province in Cambodia."

D. cochinchinensis is widely distributed in provinces throughout the country, but its population size is thought to have dramatically declined with mature individuals considered to be 'very rare' outside of strictly protected areas. *D. oliveri*i is sparsely distributed in provinces throughout the country, as well, and while the size of its population is also unknown and there are no systematic population estimates that exist for either species, both of these populations are considered to be 'severely depleted.' Indeed, mature trees of both of these species are reported to be 'very rare' even in protected areas and each of the species is considered to be "critically endangered."

These conditions are reflected in estimates of the average population densities of *D. cochinchinensis* and *D. oliveri* in the Choam Ksant management area. The average population density of *D. cochinchinensis* was estimated to be 113.1± 64.5 plants/ha and, of those 113.1 plants/ha, 87.2 plants/ha, on average, were seedlings and 23.3 plants/ha, on average, were saplings. There were only 2.6 plants/ha with diameters > 5 cm. The average wood volume of *D. cochinchinensis* was also very low (0.139 m^3/ha), which is indicative of the requirement for more effective restoration efforts if the species is to continue to survive in its natural forest habitat in Cambodia.

In a similar manner, the overall average population density of *D. oliveri* was 234.5 ± 191.5 plants/ha and, of those 234.5 plants/ha, 145.4 plants/ha, on average, were seedlings and 88.4 plants/ha, on average, were saplings. There were only 0.8 plants/ha with diameters > 5 cm. The average wood volume of *D. oliveri* in its natural forest habitats, moreover, was only 0.308 m^3/ha in deciduous forests and 0.197 m^3/ha in semi-evergreen forests.

The negative exponential relationship between population density and diameter distribution that was exhibited by *D. cochinchinensis* in the inventory assessment approximates a standardized reverse J-shape curve, which represents underlying structural conditions conducive to the reproductive sustainability of the species occurring in natural forest habitats. The maximum DBH that was recorded for *D. cochinchinensis* in natural habitats was only 20 cm, however, which, together with the very low average wood volume of *D. cochinchinensis* (0.139 m^3 /ha), underscores the requirement for even more stringent restrictions on the harvesting of the species.

In a similar manner, the negative exponential relationship exhibited between population density and diameter distribution by *D. oliveri* also approximates a standardized reverse J-shape curve. Despite the presence of this relationship, though, the sustainability of this species seems also to be very much threatened by the small number of large DBH trees – less than one per hectare - that were observed during field observations in natural forest habitats. Those and related observations provide compelling evidence that it is unlikely that the current distribution of dbh classes would allow for sufficient recruitment and regeneration to replace trees that had been removed as the

result of illegal harvesting in the past. Those conclusions suggest that the harvesting of this species should be strictly prohibited while every effort is made to protect remaining mother trees.

It is understood that one of the most critical consequences of the heavy logging and harvesting of both of the *Dalbegia* species has been the dramatic decline in the populations of both of these species. Unregulated logging, combined with forest degradation and the loss of habitat, has been severely threatening the existence of both of these species throughout the project area. It is as a result of these and other related factors that include the seasonal human-induced burning of seedlings, saplings, and trees of both of these species that a negative Non-detriment Findings Report associated with the harvesting of these two species would have to be rendered.

The genetic conservation of both these species will continue to depend on efforts to conserve the species through forest restoration and planting activities and effective measures to maintain their populations in forest habitats. If these countervailing measures are not undertaken to maintain and restore that remaining and lost habitat, the populations of both of these species will continue to decline.

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Acronyms

asl	Above sea level
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CF	Community Forestry
CTSP	Cambodian Tree Seed Program
COP	Conference of the Parties
DBH/dbh	Diameter at Breast Height
DFSC	Danida Forest Seed Centre
EIA	Environmental Investigation Agency
EN	Endangered
IUCN	The International Union for the Conservation of Nature
FA	Forestry Administration
NDVI	Normalized Difference Vegetation Index
NDF	non-detriment findings
UNEP-WCMC	The UN Environment World Conservation Monitoring Centre
VU	Vulnerable

1. Introduction

Cambodia's natural forests, which have been declining during the past several decades, have been under the management of the state and, until recently, there has been limited recognition and encouragement associated with the establishment of private forest plantations. The emphasis of this study on the establishment of small-scale private plantations of *Dalberia. cochinchinensis* and *Dalbergia. oliveri* responds to the instances of illegal logging of the species that has been occurring throughout Southeast Asia, which accentuates the relevance to the project of both the CITES Tree Species Programme and the listing of endangered tree species in CITES Appendix II.

Rosewood, which in international markets includes *D. cochinchinensis* and *D. oliveri*, as well as several other species of *Dalbergia*, together with a few other genera, has become the world's most trafficked wild product and CITES has recently placed the 300 species of rosewood under trade restrictions. In recognition of these developments, an initiative has surfaced in Cambodia to support public-private plantations of *D. cochinchinensis* and *D. oliveri*, with interest from both the private sector and among local farmers. The primary objective of this study was "to develop an initial non-detriment findings (NDF) report on *D. cochinchinensis* and *D. oliveri,* as well as institutionalize an enabling environment to support the establishment of small-scale private plantations of the species."

2. Taxonomy

2.1 *Dalbergia cochinchinensis*

Scientific name:	*Dalbergia cochinchinensis*
Class:	Magnoliopsida
Order:	Fabales
Family:	*Fabaceae* (Leguminosae)
Subfamily:	*Papilionoideae* (*D. cochinchinensis*)
Genus:	*Dalbergia*
Common names:	Rosewood, Siamese Rosewood, Thailand Rosewood, Vietnamese Rosewood, Burma rosewood
	Cam Lai
Khmer Name	Kranhaoung
Cambodian Commercial grade: Luxury	
CITES Appendix:	II
IUCN Red List:	Vulnerable (VU)

Scientific synonym: *Dalbergia cambodiana* is a synonym of *D. cochinchinensis* (IUCN, 2008[1]). Following CITES CoP16 in 2013, *D. cochinchinensis* was listed in Appendix II (CITES, 2014 (COP16[2])). *D. cambodiana* was separated from *D. cochinchinensis* since both species were recognized as accepted names according to The Plant List.

[1] IUCN Red List. Dalbergia cochinchinensis, Siamese rosewood. IUCN 2008: T32625A9719096.

[2] CITES. NOTIFICATION TO THE PARTIES: Trade in Siamese rosewood (*Dalbergia cochinchinensis*) from Thailand. Dated 4/7/2014.

2.2 *Dalbergia oliveri*

Scientific name: *Dalbergia bariensis*

Class: Magnoliopsida

Order: Fabales

Family: *Fabaceae* (Leguminosae)

Genus: *Dalbergia*

Common names: Rosewood, Siamese Rosewood, Thailand Rosewood, Vietnamese Rosewood, Burma rosewood

Cam Lai

Khmer Name Neang Nuon

Cambodian Commercial grade: Luxury

CITES Appendix: II (2 January 2017[3])

IUCN Red List: Endangered (EN)

Scientific synonyms: Lock and Heald (1994) considered *D. laccifera* and *D. prazeri* to be synonyms of *D. oliveri*, while *D. bariensis*, *D. dongnaiensis, D. duperreana*, and *D. mammosa* were considered to be separate species. Chính et al. (1996) and the IUCN Red list (Nghia, 1998) also recognized *D. bariensis, D. mammosa*, and *D. oliveri* as separate species. In contrast, Van Sam et al. (2004) considered *D. bariensis, D. dongnaiensis, D. duperreana*, and *D. mammosa* to be synonyms of *D. oliveri.* More reliably, as the result of identification by means of DNA barcoding in 2015, Hartving confirmed *D. oliveri* to be well supported as monophyletic (n = 8) in a study that included two specimens from Cambodia, where the name *D. bariensis* is used. He also strongly suggested that the name *D. oliveri* be used consistently across the distribution range, as suggested by Niyomdham et al. (1997).

3. Forest Habitats in the Study Area

Forests in the study area of Choam Ksant district are representative of seven cover types. The majority of forestland is deciduous forest, which makes up 54% of the total area of the district, followed by evergreen forest, which makes up14.5% of the total area of the district, semi-evergreen forest, which makes up 11.8% of the total area of the district, and bamboo and regrowth, which make up 1.3% and 0.1%, respectively, of the total area of the district (Table1).

Table1. Forest cover types in Choam Ksant district.

Forest type	Area (ha)	Area (%)
Deciduous Forest	204,449	54.2
Evergreen Forest	54,589	14.5

[3] CITES. Checklist of CITES Species: *Dalbergia oliveri.Retreived from:* https://checklist.cites.org/#/en/search/cites_appendices%5B%5D=II&output_layout=alphabetical&level_of_listing=0&show_synonyms=1&show_author=1&show_english=1&show_spanish=1&show_french=1&scientific_name=Dalbergia+oliveri&page=1&per_page=20

Semi-Evergreen Forest	44,294	11.8
Bamboo	4,929	1.3
Forest Regrowth	337	0.1
Rubber plantations	189	0.1
Non-forest land	68,154	18.1

Source: Forestry Administration Forest Cover 2014.

The deciduous forest is located in lowland areas that extend throughout most of the Choam Ksant forest landscape, which is flooded during the rainy season, while the mixed deciduous forest, semi-evergreen forest, and evergreen forest are situated in the southeast, southwest, and northern parts of the district along the Dang Rek mountain range that forms part of the international boundary between Cambodia and Thailand, and in the northeast and eastern parts of Choamksan district, Preah Vihear province, as well as along streams.

Deciduous forest dominates the lowland plains of the Choam Ksant forest landscape. Its trees are relatively short, in general, compared to those in semi-evergreen forests and evergreen forests and in their natural state rarely attain DBH's > 1 m. The predominant tree species in the deciduous forest have large leaves that form a characteristic feature of this forest type. There is considerable variation within deciduous forests, nevertheless. The Choam Ksant forest landscape is particularly noteworthy for its extensive areas of savannah-like deciduous forest where the population density of trees is very sparse. Other variations that are rather extensive throughout the forest landscape include relatively dense deciduous forests dominated by Dipterocarp species of trees.

There is also considerable variation in the understory of deciduous forests. Savannah areas characteristically have sparse and relatively short patchy cover. The deciduous forests on riparian terraces, in contrast, often have dense tall grass that attains heights of up to 2 m. Small deciduous bamboo patches (Arundinaria spp.) provide the ground cover in some areas, as well.

The deciduous forests are adapted to fire and their understories usually burn every year. The majority of fire generally occurs in the early dry season as the result of anthropogenic activities. Despite the frequency of fire, the deciduous forest community appears to be well adapted to its occurrence, presumably because its frequency has been high for a considerable period of geologic time.

The evergreen forests and the semi-evergreen forests in Choam Ksant district have been modified by logging, which has resulted in the near-complete removal of their upper canopies that has apparently resulted in major alterations in their forest structure and composition. Retrospective assessments of the original character of these forests are, thus, rather difficult. The more obvious, generally relatively mature, evergreen and semi-evergreen forest tracts are typically dense formations growing in rich soil with often thick and tangled understories.

The semi-evergreen forests cover relatively large areas and exhibit the greatest variation in structure and composition. This is at least, in part, because the definition of evergreen forest has yet to be clarified and in current discussions it includes forests that were previously classified as mixed deciduous forests. The semi-evergreen forests vary from apparently evergreen-dominated stands often with an understory that, in patches, could be considered typical of pure evergreen forests with a more open understory, but often also have a high sapling density that forms a dense lower canopy.

The more classical semi-evergreen forests grade into and occur in patches in forest areas that are heavily dominated by deciduous forest. To what extent this feature is a result of selective logging for commercially more valuable evergreen tree species is unclear. Their canopy covers are also variable and

their understories are often relatively sparse and frequently burned. In areas that are less frequently burned, patchy bamboo stands dominate.

Observations during flora inventories indicated that forest fires occur even in mixed deciduous forests and evergreen forests and semi-evergreen forests. Those fires may burn out the seedlings of *D. cochinchinensis and D. oliveri*, although additional research is required to confirm that observation.

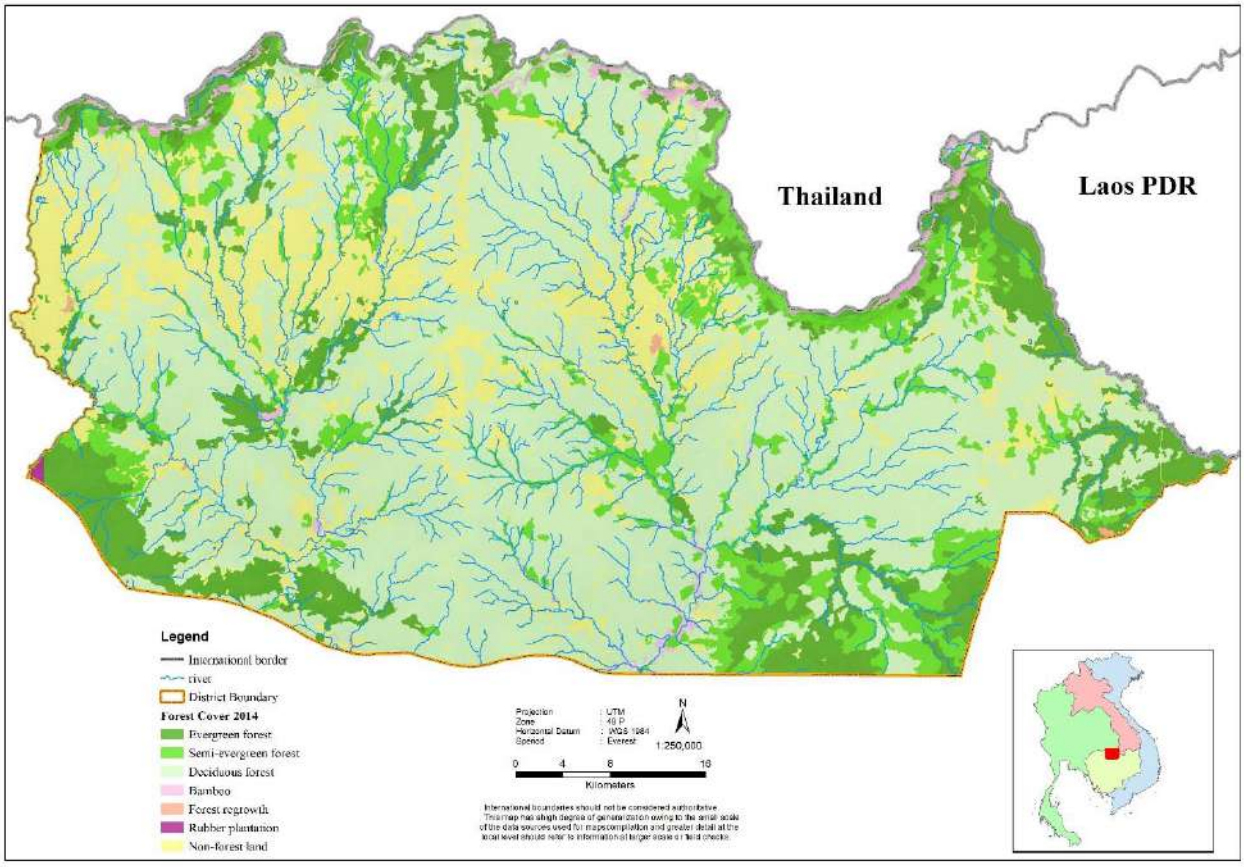

Figure 1. Forest cover of Choam Ksant district in 2014

4. Biology

4.1 *Dalbergia cochinchinensis*

Dalbergia cochinchinensis is a large tree that grows up to 30 m tall and reaches 60-120 cm in diameter. The tree's bark is light yellow and its canopy is ramified. Its leaflets are oval and alternate and its inflorescence is axillary with white flowers (Tan Dung, 1996). This species can be identified by its pinnate leaves, which generally have 7 – 9 leaflets, the uppermost of which are the largest (CTSP, 2004). It produces flowers in May and June with fruits ripening in November through January (DFSC, 2000). Its pod is long and tapering and consists of 1 or 2 seeds with one kg composed of about 35,000 seeds. The maturity of the seeds is recognizable when the pod becomes dark brown. The fruits are often collected as soon as the color turns from green to yellow in order to avoid impending damage from insects. Its pods may be collected by cutting or shaking the branches so that the pods will fall on the ground. Covering the ground with canvas around the base of the tree assists in the collection of the seeds (Joker, 2000). Once the pods have been collected, they are dried in direct sunlight for about two days. Seeds may then be extracted from the pods using a seed thresher, although care is required to avoid damage to the seeds. The seeds may also be extracted from the dried pods manually. Once they are clean,

the seeds should be dried in the sun for one day before sowing or storage. The dried seeds may be stored in a sealed container (e.g., a plastic bag) under room conditions for about five years (CTSP, 2003).

D. cochinchinensis is shade-tolerant when young, but this quality gradually declines with age. The species in its natural setting has a slow growth rate and natural regeneration is often poor, although it does regenerate well through coppicing. The diameter growth of the heartwood of 20-year-old trees reaches, on average, only about 3 cm. The species is pollinated by insects, but often produces a self-pollinated crop, which results in limited genetic variation observed within each natural population. There is a rather low percentage of young seedlings that attain maturity (CITES, 2013).

Figure 2. Planted Trees of *Dalbergia cochinchinensis* regrown from cut stumps

The wood of *D. cochinchinensis* is heavy, hard, and durable with a density of 0.98 – 1.06 g/cm^3 (Richter et al., 2014). It is red-colored with prominent, beautiful veins and it is resistant to termites (CTSP, 2001). Growth ring boundaries are indistinct or absent, highlighting its much sought-after heartwood that varies in color from that of brown leather to violet or streaked blackish brown purple. The tree's sapwood can be distinguished from its heartwood by the latter's distinct coloration.

Figure 3. *Dalbergia cochichinensis* observed fruiting in December

4.2 *Dalbergia oliveri*

Dalbergia oliveri grows up to 30 m in height and 90 cm in diameter (Tan Dung, 1996). Its bark is gray and its branches are stout and slightly pubescent. Its leaves are pinnately compound having 13 to 17 leaflets, although occasionally there are 9-11 or 19-21 leaflets, which are arranged alternately. Its inflorescence, which is corymbose-paniculate, axillary or nearly terminal, is 10-20 cm long and 7.5-15 cm wide. The inner part of its flower is white and its fruit is flat, 6-7 cm long and 1.7 cm wide, consisting of 1 seed, although sometimes the pod may have 2 or 3 seeds (CTSP, 2001).

The tree starts flowering in Cambodia during May to July and the fruit becomes ripe from November to January. The seed is orthodox and can be stored in cool dry places for several years. It is brown with an oval shape that is 10 mm long and 6 mm wide. There are about 6,100 seeds per kilogram. The young pods of the species are green, but they will turn a dark brown when ripening. The fruits must be collected immediately when they start to mature to protect them impending damage from insects. The best season for seed collection is in December and January when collectors cover the ground around the base of a mother tree with canvas prior to shaking the tree's branches to make the seeds drop. The cutting of small branches provides another, simpler, method of collecting the seeds. The seed pods are dried under sunlight for 2-3 days before the seeds are extracted by threshing. Damaged seeds are separated by removing those that sink when placed in water from those undamaged seeds that float. The undamaged seeds are dried under sunlight for one day prior to storing them in a cold room at 10^{o} C (CTSP 2003).

Individual trees of this species often produce many seeds, but natural regeneration is often poor due to low germination rates and/or disadvantageous weather and site conditions. This species' trees generally grow slowly in both natural and man-made forests (CTSP, 2001).

Figure 4. A: Seeds of *Dalbergia oliveri*; B: Ripened fruits of *Dalbergia oliveri* (Photo: Norn Narong And Kim Sobon (2014)); C: Trees of *Dalbergia oliveri* in the yard of the Neak Bous Temple in the study area

The growth ring boundaries of *D. oliveri* are indistinct or absent. Growth increments are sometimes distinct, but not conspicuous, delimited as they are by a reduction in pore size and the number of rings in the latewood. The species' heartwood is brown, red, or yellow incorporating shades of lemon-pink or red-scarlet to reddish-brown. The color of its sapwood is distinct from that of its heartwood and its wood is heavy and hard with a density of 0.90 - 0.98 g/cm^3 (Richter et al., 2014).

5. Distribution and Ecological Habitats

5.1 Distribution of *Dalbergia cochichinensis*

Dalbergia cochinchinensis is widely distributed in Cambodia, including in the provinces of Kampong Thom, Kampung Speu, Preah Vihear, Ratanakiri, Pursat, Siem Reap, Kratie, Koh Kong, Stung Treng, and Modulkiri (Sareth K., 2002). Its population size is unknown, but it is thought to have dramatically declined with mature individuals considered to be 'very rare' outside of strictly protected areas (UNEP-WCMC, 2018).

5.2 Habitat of *Dalbergia cochichinensis*

Dalbergia cochinchinensis thrives in mixed deciduous forest and sometimes in seasonal evergreen and riparian forests, occasionally in pure stands. It can be found at altitudes of up to 2000 m above sea level (asl), but it is primarily concentrated at 400-500 m asl. The species grows well under full-sun conditions and prefers fertile and deep sandy clay or calcareous soils along streams. It requires uniform rainfall that ranges from 1200-1650 mm per year, but it is also drought tolerant (Joker, 2000).

5.3 Distribution of *Dalbergia oliveri*

Dalbergia oliveri occurs in Cambodia, Laos, Thailand, and Vietnam (Dy Phon, 2000). In Cambodia, the species is sparsely found in Kratie, Preah Vihear, Kampong Thom, Ratanakiri, Stung Treng, Pursat and Siem Reap provinces (Sareth K., 2002).

5.4 Habitat of *Dalbergia oliveri*

Dalbergia oliveri occurs individually or in groups of 5-10 trees in evergreen or semi-evergreen forests dominated by *Lagerstroemia* and Dipterocarp species. The presence of the species ranges below 900 m and it is normally found near streams and in foothills. The tree is able to grow under the shade when young, but it has to be exposed to more sunlight when mature (CTSP, 2001).

Figure 5. Regrowth of *Dalbergia oliveri* from its mother stump cut illegally in Semi-evergreen forest

6. Status and Trends

While the sizes of the populations of *D. cochinchinensis and D. oliveri* in Cambodia are unknown and there are no systematic population estimates that exist, both of these populations are considered to be 'severely depleted.' Mature trees of both species are reported to be 'very rare' even in protected areas and the two species were regarded to be "critically endangered" in a 2012 report by Cambodia's Forestry Administration (UNEP-WCMC, 2018).

6.1 *Dalbergia cochinchinensis*

6.1.1 National Trend

The largest remaining population of *D. cochichinensis* was reported to be a seed source in Siem Reap province. That population was considered to be fairly well protected, although some trees were reported to have been felled with the remainder having dbh's of 20-25 cm. The second largest population was reported to be in Leap Kuy Community Forest in Kampong Speu Province. It consists of 200 trees found in a natural forest that extends across 107 ha. Other known populations of *D. cochinchinensis* exist in Damrey Chak Thlork Community Forest in Kampung Speu province covering 15,000 ha, O Soam Community Forest in Kampong Thom province consisting of 50-100 trees of 10-15 cm dbh, and Tbeng Lech Community Forest in Siem Reap province consisting of about 10 trees, although the largest tree was illegally cut in 2017 (UNEP-WCMC, 2018).

There are some population estimates that are also available from studies that have been conducted on a local scale. The results of a study conducted under the Cambodia Seed Project in 2003, which recorded the number of *D. cochinchinensis* trees for seed sources in Cambodian natural forests, reported that the average number of trees per hectare was only 1.34 in natural forests in Sre Nauy commune in Siem Reap province. In a related survey conducted in 2007 in the lowland forests of Stung Treng province, it was revealed that illegal logging had led to the local extinction of the species. Similarly, there have been five 14-day long botanical surveys that have been conducted in Samkos in the Central and Eastern Cardamom Mountains since 2015 and during that period there has been only a single *D. cochinchinensis* individual, a root sucker that had survived felling and the removal of the root of the mother tree that has been reported. Rangers have commented that all of the *D. cochinchinensis* trees "had been felled for the rosewood trade" in the Southern Cardamom Mountains, as well. Scientists contacted by the Environmental Investigation Agency (EIA) involved in field and genetic studies on the species in 2016 have also noted that the number of *D. cochinchinensis* trees in the country was "dramatically decreasing" and that "field guides in Cambodia reported in 2015 that many of the populations sampled from 2010-2012 no longer exist due to deforestation and logging."

6.1.2 Study Area

The population density of *D. cochinchinensis* in Choam Ksant district was estimated in this study on the basis of its presence in different levels of interrelated subplots and plots. In extablishing those estimates, seedlings of *D. cochinchinensis* were regarded as plants with a height < 1 m and a DBH < 5 cm, while saplings were defined as plants with a height > 1 m and a DBH < 5 cm. Since *D. cochinchinensis* was recorded most often in mixed deciduous forests, as well as in dry deciduous forests, the population estimates and estimates of wood volume were determined from trees observed in those forest types.

The average population density of *D. cochinchinensis* estimated in the study was 113.1± 64.5 plants/ha and, of those 113.1 plants/ha, 87.2 plants/ha, on average, were seedlings and 23.3 plants/ha, on average, were saplings. There were only 2.6 plants/ha with diameters > 5 cm. The average wood volume of *D. cochinchinensis* was also very low (0.139 m^3/ha), which is indicative of the requirement for more

effective restoration efforts if the species is to continue to survive in its natural forest habitat in Cambodia.

The small numbers of large trees recorded during the systematic inventory of both *Dalbergia* species in Choam Ksant district were primarily attributable to the illegal logging occurring over much of the past fifteen years, notwithstanding the relatively high numbers of seedlings that were also recorded. Field observations conducted during spot checks of the distribution of both of the species revealed, moreover, that large trees with diameter of 15-30 cm were only observed in the Preah Vihear Temple World Heritage Forest and at the front gates of community houses close to the border with Thailand. It appears that villages in those areas maintain large trees in their home gardens because they not only recognize the extraordinary value of the wood of those two species, but they also want to conserve those trees for their children. The conservation of those trees will provide significant seed sources of local *D. cochinchinensis*, as well.

6.2 *Dalbergia oliveri*

6.2.1 National Trend

Dalbergia oliveri is reported to be found in the northeastern provinces of Kratie, Ratanakiri, and Stung Treng; in the Northern provinces of Preah Vihear and Siem Reap; in the western province of Pursat; and in the central province of Kampong Thom. Its populations in the country are considered to consist of very few mature or large individual trees and are characterized as "seriously threatened" on the basis of the species' potential uses and the IUCN's conservation criteria and at risk of extinction if no effective conservation measures are more completely implemented and enforced. It has, as a result, been selected as a priority tree species for gene conservation in Cambodia, as well as under the Asia Pacific Forest Genetic Resources Program, which aims to encourage the conservation and management of forest genetic resources throughout the region.

Seeds of *D. oliveri* can be obtained from a number of identified seed sources in natural forests, such as in Pal Hal commune in Tbeng Meanchey district in Preah Vihear province or in Prognel commune in Phnom Kravanh district in Pursat province. The remnant forest surrounding Boeung Yak Loam in Rattanakiri province is also the habitat of a number of mature trees of *D. oliveri* where seed collection is possible (UNEP-WCMC, 2014).

6.2.2 Study Area

Similar to the methodology that was used with *D. cochinchinensis*, the population density of *D. oliveri* was estimated on the basis of its presence in different levels of interrelated subplots and plots. Since *D. oliveri* was recorded most often in deciduous forests, mixed deciduous forests, and semi-evergreen forests, the population estimates and estimates of wood volume were determined from trees in those two forest habitat types (deciduous and semi-evergreen).

The overall average population density of *D. oliveri* was 234.5 ± 191.5 plants/ha and, of those 234.5 plants/ha, 145.4 plants/ha, on average, were seedlings and 88.4 plants/ha, on average, were saplings. There were only 0.8 plants/ha with diameters > 5 cm.

The average population density of *D. oliveri* in the deciduous forests was 294.5 ± 258.3 plants/ha and, of those 294.5 plants/ha, 198.4 plants/ha, on average, were seedlings and 95.2 plants/ha, on average, were saplings. There were only 0.8 plants/ha with diameters > 5 cm.

The average population density of *D. oliveri* in the semi-evergreen forests was 70.1 ± 0.7 plants/ha and, of those 70.1 plants/ha, 69.6 plants/ha, on average, were saplings. There were no seedlings and only 0.6 plants/ha with diameters > 5 cm.

The average wood volume of *D. oliveri* in its natural forest habitats was only 0.308 m^3/ha in deciduous forests and 0.197 m^3/ha in semi-evergreen forests.

It is understood that one of the most critical consequences of the heavy logging and harvesting of both of the *Dalbegia* species has been the dramatic decline in the populations of both of these species. The populations remaining in the natural forests in the study area are primary composed of seedlings and saplings. There were neither mature trees nor mother trees that were observed during the systematic inventory of both of these species. Unregulated logging, combined with forest degradation and the loss of habitat, has been severely threatening the existence of both of these species throughout the project area. The genetic conservation of these species will continue to depend on efforts to conserve the species through forest restoration and planting activities and effective measures to maintain their populations in forest habitats.

7. Population Structure and Dynamics

The recorded population density and structure of both *D. cochinchinensis* and *D. oliveri* accounted for the occurrence of every plant that was recorded and counted from preliminary spot checks, observations of planted trees, and systematic surveys conducted in the study area in Choam Ksant district. Collectively, there were no more than 30 trees of *D. cochinchinensis* per diameter class and no more than 25 trees of *D. oliveri* per diameter class that were recorded.

The negative exponential relationship between population density and diameter distribution exhibited by *D. cochinchinensis* that was developed in the inventory assessment approximates a standardized reverse J-shape curve, which represents underlying structural conditions conducive to the reproductive sustainability of the species occurring in natural forest habitats (Figure 6). The maximum DBH that was recorded for *D. cochinchinensis* in natural habitats was only 20 cm, however, which, together with the very low average wood volume of *D. cochinchinensis* (0.139 m^3 /ha), underscores the requirement for more effective conservation efforts.

In a similar manner, the negative exponential relationship between population density and diameter distribution exhibited by *D. oliveri* that was developed in the inventory assessment also approximates a standardized reverse J-shape curve (Figure 7). Despite the presence of this relationship, though, the sustainability of this species seems to be very much threatened by the small number of large DBH trees – less than one per hectare - that were observed during field observations in natural forest habitats. Those observations provide compelling evidence that the harvesting of this species should be strictly prohibited while every effort is made to protect remaining mother trees.

The field observations from the inventory assessment that were conducted during the study indicate that the distributions of the dbh classes of both of the *Dalbergia* species were unlikely to allow for sufficient recruitment and regeneration to replace trees that had been removed as the result of illegal harvesting in the past. There are a very small number of mature trees with diameters > 20 cm that were recorded and the fruiting patterns of those trees remaining under natural conditions often result in sporadic reproduction.

The seedlings of both of the species are threatened seasonally by human-induced fire, moreover, although the mortality rates of those seedlings as the result of fire are currently unknown. It is probable that instances of deforestation, habitat fragmentation, and illegal logging will continue to pose substantial threats to the species since the fertile soils in semi-evergreen forests, as well as in areas close to riverbanks, are favorable to the production of agricultural crops by local communities, which impede the natural recruitment and regeneration of both of the species. The deforestation and forest clearance associated with agriculture production, as well as settlement and other infrastructure development, were observed throughout the project area and if those trends continue unabated, the inevitable result will be further losses of habitat for both species. It is as a result of these factors that a negative Non-detriment Findings Report associated with the harvesting of these two species would have to be rendered.

If countervailing measures are not undertaken to maintain and restore remaining and lost habitat, the populations of both of these species will continue to decline.

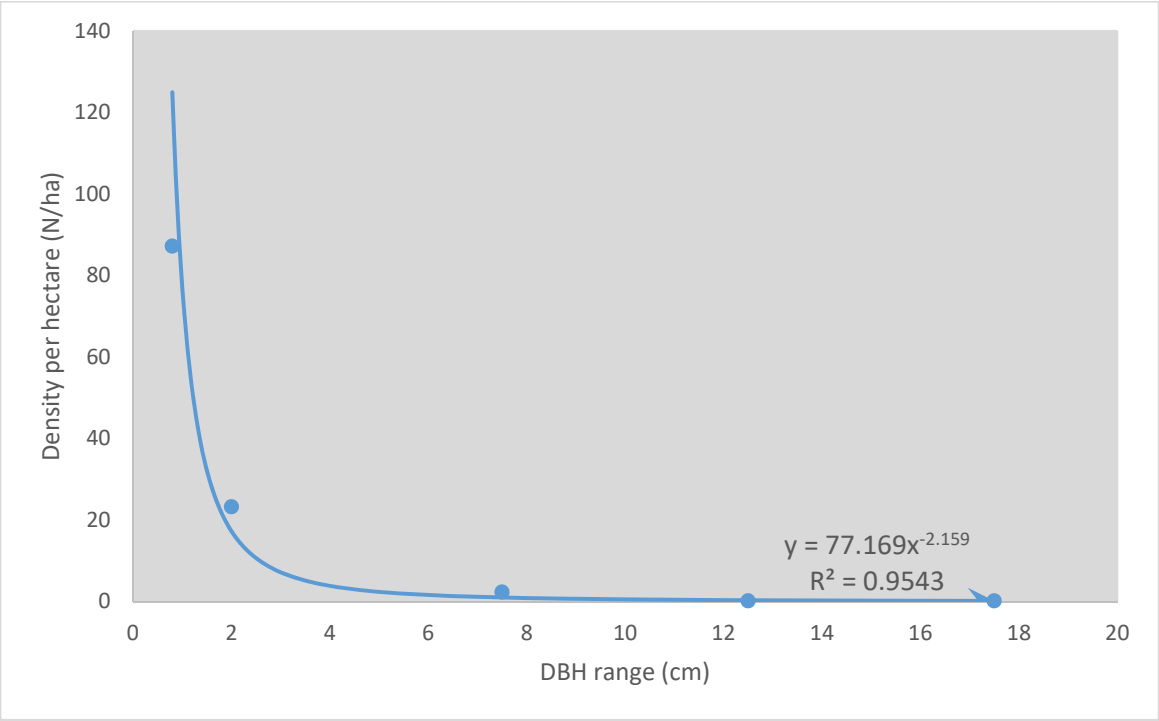

Figure 6. The population density and diameter distribution represented in the reverse J-shape curve for *D. cochichinensis*

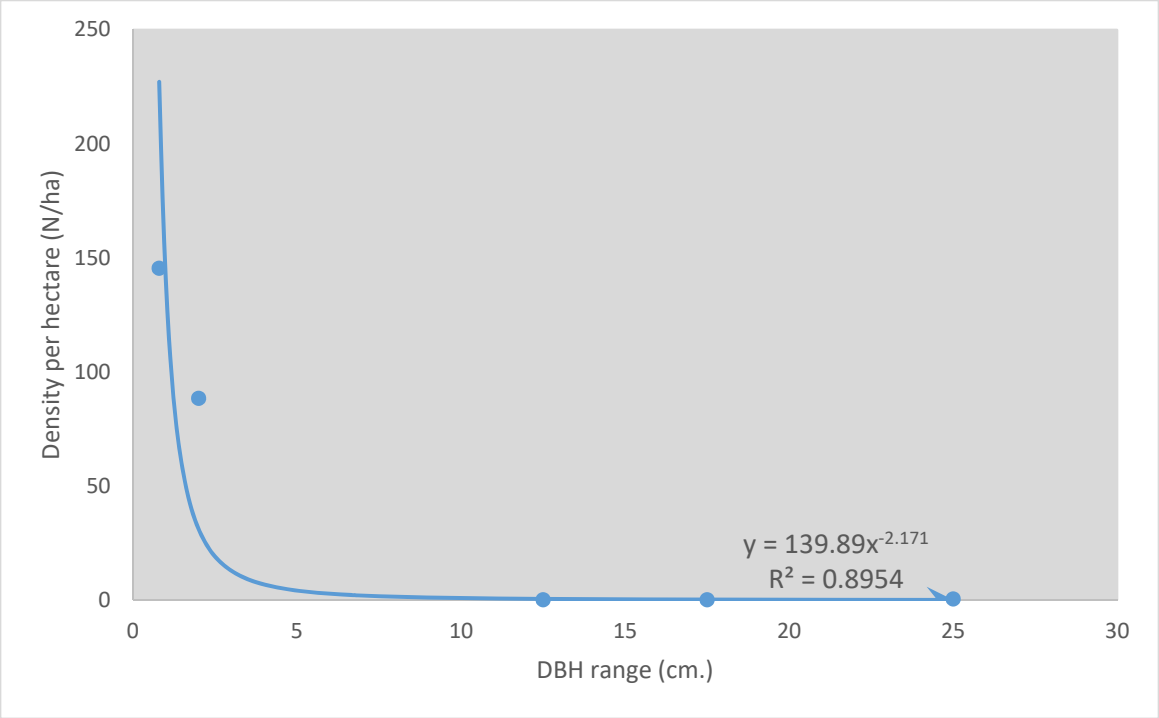

Figure 7. The population density and diameter distribution represented in the reverse J-shape curve for *D. Oliveri*

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