

Report

# Impacts of Unsustainable Mahogany Logging in Bolivia and Peru

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**ABSTRACT.** Although bigleaf mahogany [*Swietenia macrophylla* King (Meliaceae)] is the premier timber species of Latin America, its exploitation is unsustainable because of a pattern of local depletion and shifting supply. We surveyed experts on the status of mahogany in Bolivia and Peru, the world's past and present largest exporters. Bolivia no longer has commercially viable mahogany (trees > 60 cm diameter at breast height) across 79% of its range. In Peru, mahogany's range has shrunk by 50%, and, within a decade, a further 28% will be logged out. Approximately 15% of the mahogany range in these two countries is protected, but low densities and illegal logging mean that this overestimates the extent of mahogany under protection. The international community can support mahogany conservation by funding park management and by encouraging independent verification of the legality of mahogany in trade. Our findings demonstrate that a systematic expert survey can generate reliable and cost-effective information on the status of widespread species of concern and help to inform appropriate management policy.

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## INTRODUCTION

Mahogany logging has attracted international concern because it is commercially unsustainable (CITES 2002a). It can also harm indigenous peoples (Watson 1996), catalyze subsequent deforestation (Veríssimo et al. 1995), and threaten the viability of the species (Snook 1996). Attempts to improve the management and secure the conservation of mahogany have included boycotts (Hering and Tanner 1998), logging moratoria, and the promotion of sustainable forest management (CITES 2002a, Grogan et al. 2002). Despite these efforts, the threat to mahogany populations remains, and concerned parties have attempted to secure protection for the species under the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) four times since 1990. This objective was finally realized in November 2002, when bigleaf mahogany was listed on CITES Appendix II (CITES 2002b). CITES scientific authorities in exporting countries will now be required to verify that mahogany shipments are not detrimental to the survival of the species (CITES 2002b: Article IV, Paragraph 2) and do not harm mahogany's ability to maintain itself throughout its range at a level consistent with its role in the ecosystem (CITES 2002b: Article IV, Paragraph 3).

One of the main obstacles to generating the international will to take action to reverse the plight of mahogany has been the difficulty in accurately assessing the status of mahogany populations. Typically, an assessment of the population status of a tree species would require on-the-ground inventories across its range. However, because mahogany's range is very large, i.e., from Mexico to the southern Amazon basin (Lamb 1966), traditional systematic forest inventory techniques would be prohibitively expensive. In the absence of systematic assessments, a wide range of divergent and contradictory claims about the status of mahogany populations has prevented scientific consensus and the subsequent formulation of appropriate policies.

In this paper, we present a systematic and rigorous expert-survey methodology that can be used to collect information over large areas at a low cost. We applied this methodology to assess the conservation status of mahogany in Bolivia and Peru. These two countries represent different snapshots in the logging trajectory of local depletion and shifting supply that has typified mahogany's exploitation across its entire range (Robbins 2000). Mahogany logging began in Bolivia in the late 1960s. As a result of overharvest and increasing regulation (Management Authority of Bolivia 2001, TRAFFIC 2001a), Bolivia's exports

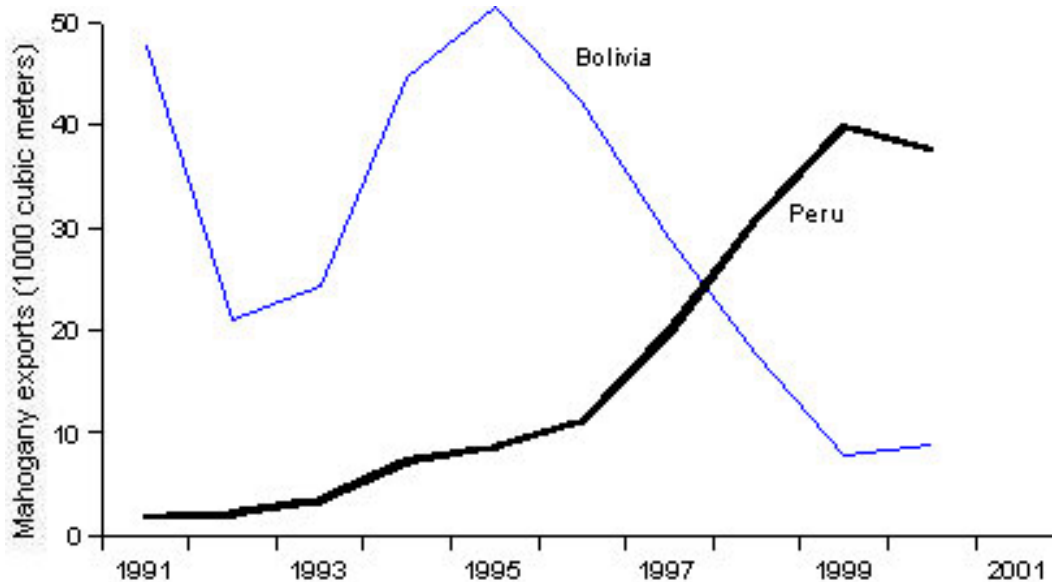
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dropped precipitously in the late 1990s (Fig. 1). Logging has now shifted to Peru, where exports have increased dramatically. Our study documents a species

depleted or under threat across its entire range in the two countries, providing significant support for the decision to list bigleaf mahogany on Appendix II.

**Fig. 1.** Exports of sawn mahogany to the United States between 1991 and 2001 from Bolivia and Peru as per CITES trade statistics derived from the UNEP-WCMC CITES Trade Database, UNEP, World Conservation Monitoring Centre, Cambridge, UK.



## METHODS

### Surveys

To conduct our surveys, we designed a structured questionnaire to assess the current status of mahogany, land use history, and planned anthropogenic activities in particular areas (Appendix 1). A steering committee that included scientists with experience in the forest ecology and management of mahogany and in related fields provided input to the design. Our project team included an in-country researcher who conducted the survey and gathered other relevant information such as the history of exploitation, production statistics, and the legal situation of the species. This article focuses on the results of the survey and forest cover analyses.

### Historic range

Prior to implementing our survey, we delineated mahogany's historic range. Using Lamb's (1966) map of mahogany's historic distribution, local researchers gathered information from the literature, herbarium specimens, government documents, vegetation and

elevation maps, and personal knowledge to produce a more accurate historical distribution for each country.

The historic range was then divided into a tractable number of relatively homogenous forest units referred to in the questionnaire as "mahogany conservation units" or MCUs. Of these, 68 were located in Peru (Fig. 2) and 40 in Bolivia (Fig. 3). The division was made based on administrative and land use boundaries as well as forest cover. For each forest unit, we used the questionnaire to interview individuals who had a direct knowledge of the status of mahogany. These experts included foresters, loggers, ecologists, community representatives, leaders of indigenous communities, and nongovernmental organizations (Appendix 2). For Peru, 124 experts completed 301 questionnaires, a mean of 4.4 questionnaires per forest unit (SD = 1.4). In Bolivia, 59 experts completed 134 questionnaires, a mean of 3.4 per forest unit (SD= 0.6). As a check on the experts, we examined the correlation among responses for each forest unit (see section below on *Concordance of results*).

Fig. 2. Forest units used for the survey of mahogany populations in Peru.

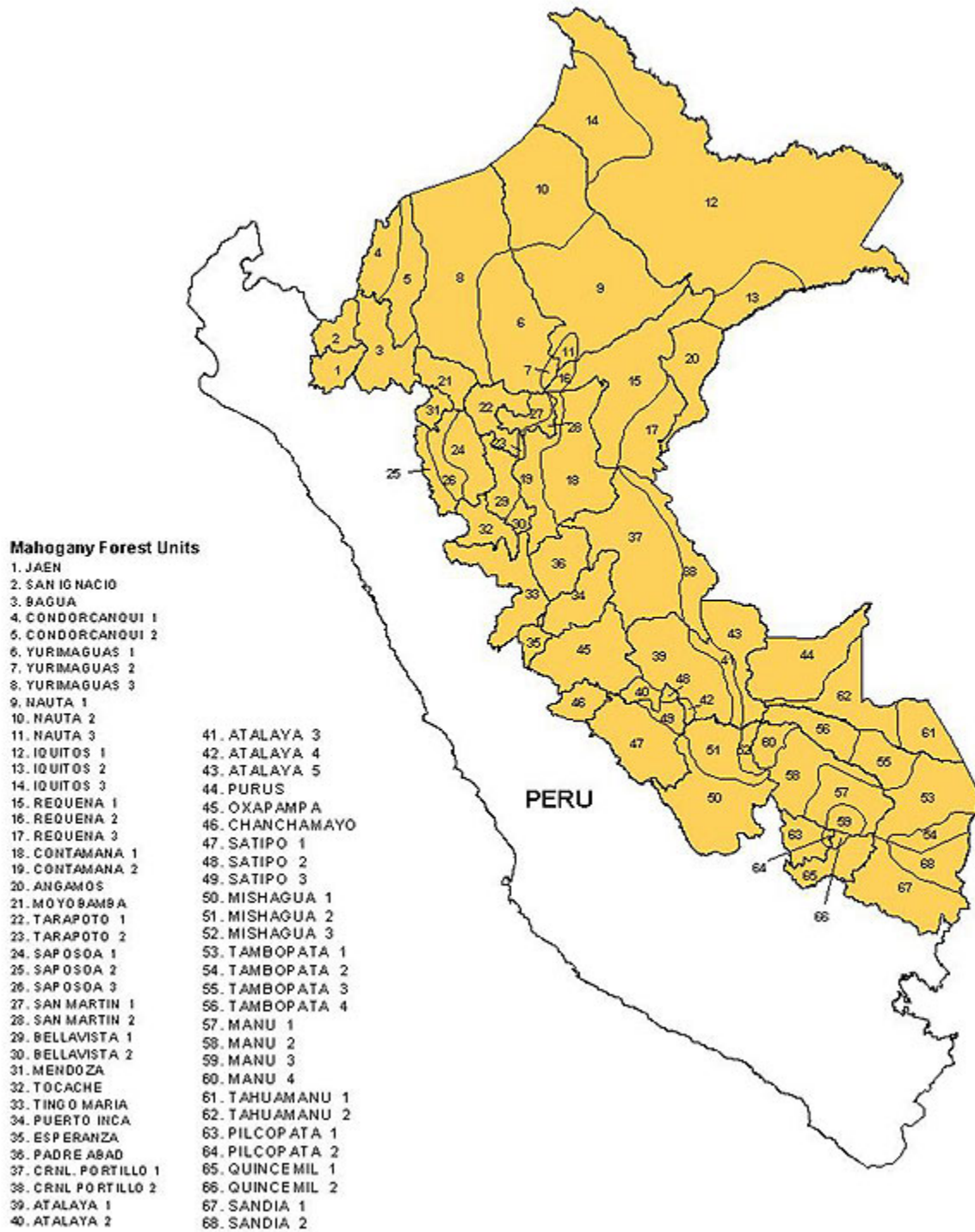
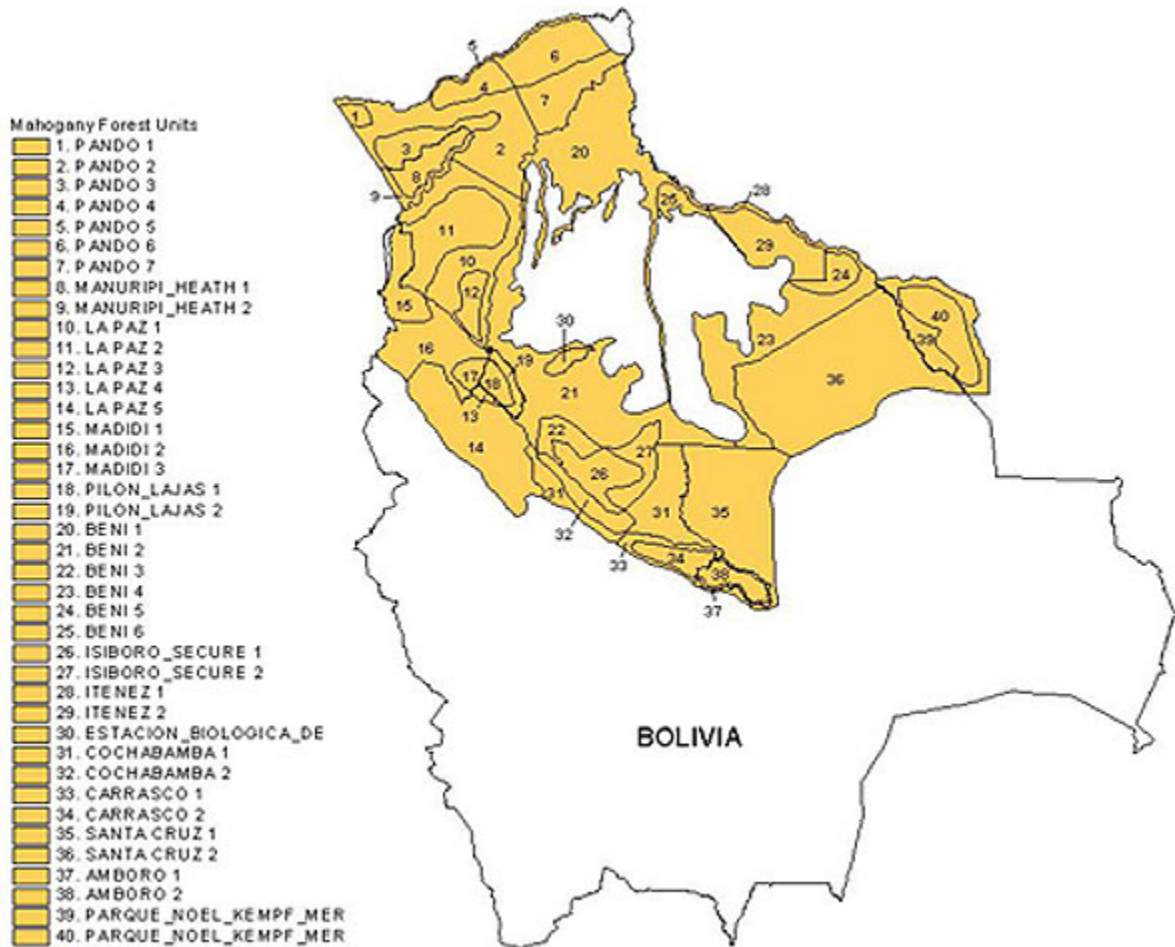


Fig. 3. Forest units used for the survey of mahogany populations in Bolivia.



### Forest cover within mahogany's range

To determine where mahogany could still be present, we used satellite imagery to identify areas that still retained forest cover within mahogany's historic range. For this purpose, we combined information from two data sets: (1) percent tree cover from the MODIS satellite, which is based on images collected from October 2000 to December 2001 at 500-m resolution (Global Land Cover Facility 2003), and (2) a global land-cover grid of 1000-m resolution, with data from 2000 produced by the Joint Research Centre (2003), the European Union's scientific and technical research laboratory. The MODIS data had more recent and accurate tree-cover data for Bolivia and Peru, and the Joint Research Centre grid provided a more extensive land-cover classification, making it possible to

distinguish between natural nonforested and deforested areas. Combining the two sources provided the most accurate description of forest cover in Bolivia and Peru.

### Definition of terms used in this study

#### Mahogany density

Unless otherwise stated, we use "density" to refer to the average density of mahogany over the entire forest unit, recognizing that there may be smaller areas with higher and lower densities within the unit. We divided density into the following categories, which represent the number of trees per hectare: absent (0), very low (< 0.01), low (0.01–0.1), medium (0.1–1), and high (> 1).



### Commercial tree size

Trees equal to or greater than 60 cm diameter at breast height (dbh) are considered to be of commercial size. Although the legal minimum commercial size varies by country, for the purpose of this study we used 60 cm as the smallest tree size that should be harvested under a sustainable management regime. The legal minimum diameter for harvest is 75 cm dbh in Peru and 70 cm dbh in Bolivia.

### Reproductive tree size

Trees greater than 30 cm dbh are considered to be of reproductive size, based on data from Gullison (1996) and Grogan (2001).

### Commercially viable population

Commercial viability depends on a number of factors, including: (1) the density of commercial-sized trees, (2) the value of mahogany, and (3) the cost of harvest and transport. For the purpose of this study, however, we conservatively focused on the first factor: experts considered a forest unit to be commercially viable if it contained stands of commercial-sized mahogany trees. Price and site accessibility were not considered in this definition because both may change rapidly given the nature of the logging infrastructure and technology.

### Commercially depleted population

A forest unit with an average density of zero commercial-sized trees was considered to be commercially depleted. These units may have some commercial-sized trees, but experts felt that they lacked sufficient stands of commercial mahogany for viable economic activity.

## RESULTS AND DISCUSSION

### Concordance of results

Our survey results indicated a high degree of agreement among respondents' answers when describing any given forest unit. For Bolivia, respondents were unanimous for 86% of the 1520 questions asked (40 forest units x 46 questions in the questionnaire). In only two cases did more than one respondent differ for a given question. In the case of Peru, respondents' answers were unanimous for 88% of the 3128 questions asked (68 forest units x 46 questions). In only 4% of the responses did more than one respondent differ. We also used correlation tests to determine the similarity in respondents' answers for four key questions. For each question, we randomly selected two responses for each of the 68 forest units in Peru and 40 units in Bolivia. For all four questions in both countries, responses were highly correlated, with  $r > 0.87$  for Bolivia and  $r > 0.90$  for Peru (Table 1). These findings suggest high confidence in the accuracy of the responses.

**Table 1.** The degree of concordance ( $r$  = correlation coefficient) among expert responses.

Survey question	Possible answers	Concordance	
		Bolivia	Peru
What is the current density of mahogany?	0, < 0.01, 0.01–0.1, 0.1–1, 1–10, > 10 trees/ha	$r = 0.91$	$r = 0.97$
How does current density compare to 20 years ago?	higher, same, lower, much lower	$r = 0.87$	$r = 0.95$
Distance to nearest sawmill?	_____ km	$r = 0.95$ (Fig. S13)	$r = 0.94$ (Fig. S14)
When will commercial logging take place?	current, 1–5 yr; 5–10 yr; > 10 yr	100% pairs agree	$r = 0.90$

## Sources of data used by respondents

Although published reports on the status of mahogany are scant, a great deal of knowledge is held by individuals who have direct experience with the species. Thus, in Bolivia and Peru we supplemented the 7% of total responses based on field plots (question 4b in Appendix 1) with the personal experience of respondents.

To evaluate a respondent's level of experience, we examined the number, length, and frequency of his or her visits to the forest unit, as well as how much of the area he or she was familiar with. For Bolivia, we found that 96% of respondents had visited the forest unit one or more times during the previous 2 yr, and 23% were year-round residents or had spent at least a year in the area. In addition, 63% of the surveys were completed by respondents who were familiar with more than 25% of the forest unit. In Peru, 99% of respondents had visited the forest unit within the previous 2 yr, 42% were year-round residents, 11% visited one to 12 times per year, and 74% had visited more than 25% of the forest unit (Appendix 2).

## Range reduction

As of 2001, 4% of mahogany's original range of approximately  $55 \times 10^6$  ha in Peru and 8% of the Bolivian range of  $30 \times 10^6$  ha had been deforested. Although forest cover in these two countries is relatively intact, our expert survey revealed that decades of selective mahogany logging have dramatically reduced the areas with commercially viable populations. In Peru, mahogany is already commercially depleted in 50% of its historic range (Table 2, Fig. 4A); compared to 20 yr ago, the experts said that mahogany density was either lower or much lower across 92% of its range. Furthermore, as mahogany populations diminish, loggers often resort to harvesting smaller size classes to maintain harvest volumes (e.g., Weaver and Sabido 1997). Unless harvest rates are rapidly reduced, experts predict that within 10 yr an additional 28% of the historic range in Peru will lose populations of mahogany  $> 30$  cm dbh (Figs. 4A and 5), leaving few stands of reproductive-sized mahogany outside of protected areas. Logging has proceeded to an even greater degree in Bolivia. The experts said that over the past 20 yr mahogany has been reduced across 97% of its historic range and is no longer commercially viable in 79% of its range (Fig. 4A).

## Protected areas

Given the uncertain contribution of logged populations to the long-term survival of mahogany (Appendix 3), we include only the mahogany populations located in protected areas in our assessment of the long-term conservation status of the species. Protected areas that prohibit logging, such as national parks, reserved zones, and protected forests, total 15% of mahogany's historic range in Bolivia and Peru (Fig. 4B, Table 2). Although these areas seem sufficiently large to ensure the conservation of mahogany in both countries, commercial-size mahogany ( $> 60$  cm dbh) does not occur at high densities ( $> 0.1$  tree/ha) in all of the protected areas, nor have all protected areas been effective at preventing illegal logging within their borders.

For example, Bolivia has approximately  $4.5 \times 10^6$  ha of protected areas that fall within mahogany's historic range (Table 2), but mahogany occurs at densities  $> 0.1$  tree/ha in only 36% of this area (Fig. 4B). In the past, both small-scale and industrial logging has occurred to varying degrees in all of the protected areas within mahogany's historic range. Illegal logging is currently occurring in at least two protected areas in Bolivia, representing 5% of the country's total range under protection.

Peru has approximately  $8.5 \times 10^6$  ha of protected areas, but in only 35% of this area is mahogany found at densities  $> 0.1$  tree/ha (Fig. 4B). Most of these populations are located in the Alto Purus Reserved Zone and the northwestern part of Manu National Park. Fourteen percent of the total protected area is currently being logged, and an additional 7% has been logged previously, including logging that may have occurred prior to the establishment of the protected area. Where logging is occurring, respondents indicated that commercial depletion is likely within 5 yr. In all but the remotest protected areas, ongoing vigilance and enforcement will be required to prevent neighboring logging from spreading into the protected areas.

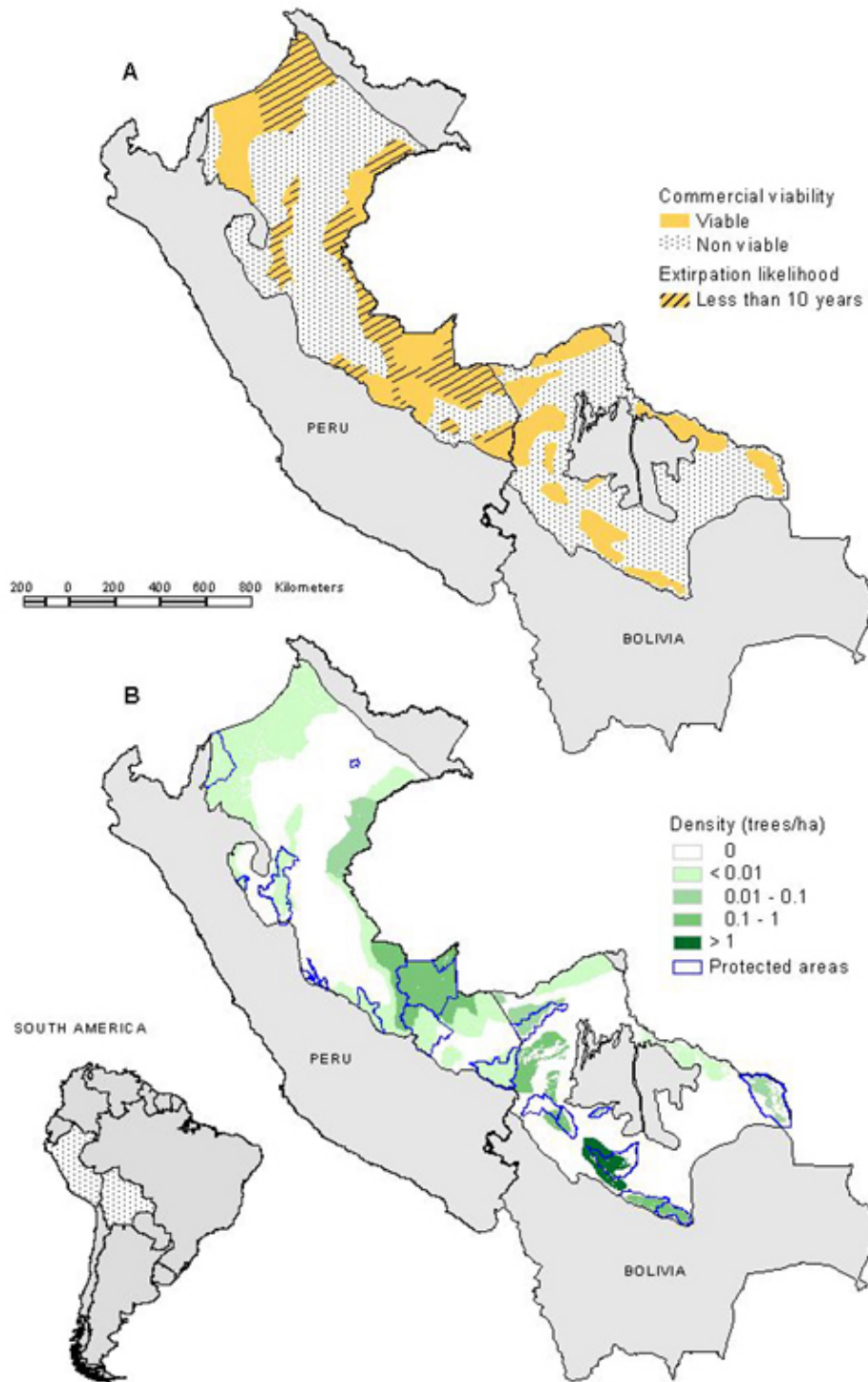
## Local depletion, shift in supply, and social impacts

Our systematic survey of mahogany populations suggests that Peru is set to follow the pattern of Bolivia, where the vast majority of mahogany's range has been overexploited to the point of commercial

depletion, thus supporting the decision to list bigleaf mahogany on Appendix II of the Convention on

International Trade in Endangered Species of Wild Fauna and Flora.

**Fig. 4.** Status of mahogany in Bolivia and Peru. A) Areas that currently lack commercial viability (trees > 60 cm dbh are absent) or that in 10 yr will lack reproductive populations (trees > 30 cm dbh); B) current density of commercial-sized trees (> 60 cm dbh) within historic range and in protected areas.



**Table 2.** The historic and present occurrence of mahogany in Bolivia and Peru.

	Million ha (% of historic range)	
	Bolivia	Peru
Historic range	30.3 (100)	55 (100)
Historic range with forest cover	28 (92)	53.5 (96)
Existing populations of mahogany	6.3 (21)	28 (50)
Historic range outside protected areas	25.8 (85)	47.4 (85)
0 trees/ha	19.5 (64.4)	26.8 (48)
< 0.01 trees/ha	2.8 (9)	15.7 (28)
0.01–0.1 trees/ha	0.7 (2)	2.3 (4)
0.1–1 trees/ha	2 (6.5)	2.5 (4.5)
> 1 tree/ha	0.8 (2.8)	...
Historic range within protected areas	4.5 (15)	8.5 (15)
0 trees/ha	1.9 (6.4)	0.9 (1.7)
< 0.01 trees/ha	...	4.5 (8)
0.01–0.1 trees/ha	1 (3.4)	...
0.1–1 trees/ha	1 (3.4)	3 (5.5)
> 1 tree/ha	0.6 (1.8)	...

Such an unfortunate outcome will not only impede Peru's ability to create a long-term sustainable forest industry, but it will also likely produce negative social impacts because the remaining large mahogany populations in Peru are found in areas of uncontacted indigenous cultures (Forero 2003). As logging increases in these areas, so will social disruption and violence. Such was the case in 2002 in the Peruvian Department of Madre de Dios. In June, the implementation of stricter terms for logging concessions caused violent protests against the government's National Institute of Natural Resources (INRENA) and the environmental group ProNaturaleza in Puerto Maldonado. The following month, a skirmish between loggers and Amerindians left a number of people wounded when the loggers invaded an indigenous reserve near Rio Las Piedras (Powers 2002a, 2002b).

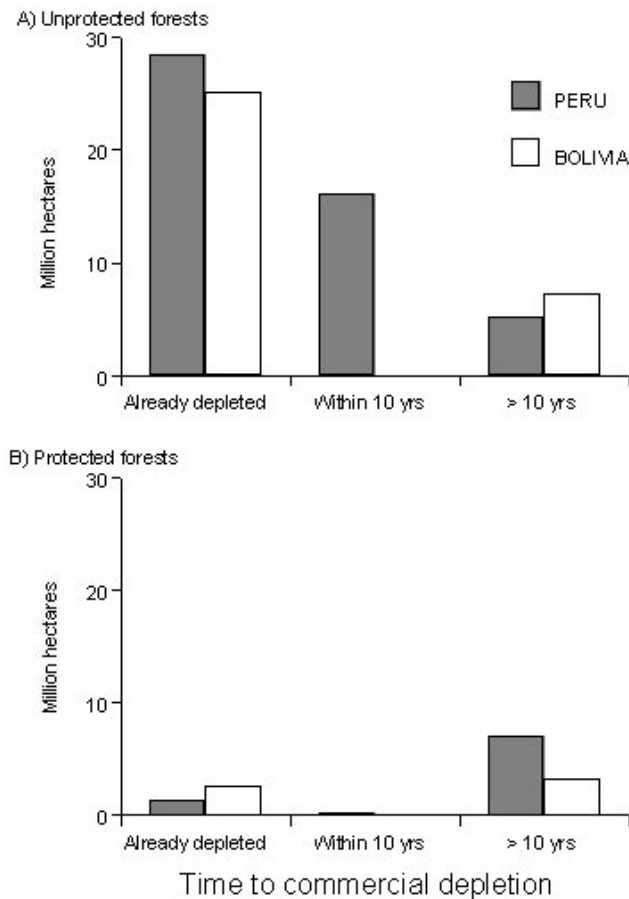
## CONCLUSIONS

Peru has two basic options to halt the unsustainable exploitation of its mahogany and meet its obligations under the new regulations in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It may emulate Bolivia's example, greatly increasing investment in the forestry sector to eradicate the 30–40% of all harvests that are illegal (Traffic 2001b) and to implement management plans that are consistent with the production of sustainable volumes of mahogany. Alternatively, Peru may follow Brazil's lead. Since 2001, when Brazil was faced with widespread illegal harvesting of mahogany, it has banned all trade until illegal logging can be brought under control and the basic requirements for sustainable forest management can be enacted.



However, given the pace and scale at which illegal harvesting is occurring in Peru, whichever alternative is chosen must be implemented very quickly, or the opportunity to maintain commercially viable populations outside of protected areas will be lost.

**Fig. 5.** Commercial depletion. The area within the range of mahogany in Peru (dark bars) and Bolivia (light bars) in which mahogany is already commercially extinct (trees > 60 cm dbh are absent), in which reproductive populations are likely to become extirpated within 10 yr (trees > 30 cm dbh will be absent), and in which it is unlikely to become commercially depleted within (A) unprotected areas and (B) protected areas.



On a more positive note, both Bolivia and Peru's protected areas still have the potential to maintain intact mahogany populations, provided that long-term support sufficient for effective management is available (Bruner et al. 2001). The situation will become increasingly urgent as new roads expand the

frontier, increasing the vulnerability of remote protected areas. The threat of illegal logging in protected areas can be reduced by implementing a system that tracks mahogany logs so that illegally logged trees can be eliminated from the marketplace, e.g., chain of custody, which independent forest certification such as by the Forest Stewardship Council may provide. Such tracking would support compliance with the listing of mahogany on CITES Appendix II. International buyers, who are mainly from the United States, should demand that suppliers provide such verification of legality. Further, the international community should provide financial assistance to help secure effective management of protected areas in the region (Gullison et al. 2000), which, in addition to providing a safety net for mahogany, also ensures the survival of thousands of other plant and animal species.

Our study has also demonstrated that prohibitively expensive field surveys should no longer be an excuse for failing to generate consensus on the conservation status and appropriate policy responses for any species, even one as widespread as mahogany. Expert surveys such as the one used in this study are rapid and inexpensive. In this case, it required only a few months for a small team to interview experts to assess the status of mahogany across some  $85 \times 10^6$  ha of its historic range in Bolivia and Peru. The results are also robust, as indicated by the high degree of concordance among a broad range of experts, including biologists, foresters, loggers, and community leaders. We expect that the application of expert surveys will become common in the future to assess and monitor commercial species of concern.

Responses to this article can be read online at:  
<http://www.ecologyandsociety.org/vol9/iss1/art12/responses/index.html>

## Acknowledgments:

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## APPENDIX 1. QUESTIONNAIRE

Each questionnaire was administered by Roberto Kometter

### Assessing the Conservation Status of Bigleaf Mahogany Across its Range

Date: \_\_\_\_\_

Respondent's name: \_\_\_\_\_

Respondent's occupation and employer: \_\_\_\_\_

Contact details (mailing address, email, telephone number, fax number):

Country: \_\_\_\_\_

Mahogany Conservation Unit (MCU) Identification Number: \_\_\_\_\_

MCU Size: \_\_\_\_\_(hectares)

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1. What is the legal status of the MCU? (Please check all that apply)

Indigenous reserve

Timber concession

Mining or petroleum concession

Protected area

Not zoned

Other (please describe) \_\_\_\_\_

FSC-certified? Yes  No

2. a) What is the ownership of the MCU? State owned

Privately owned

Community owned

2. b) Who are the specific owners and/or managers of the MCU in question?

3. Are property rights stable (i.e., legally defined, respected, and unlikely to change soon) within the MCU?

Yes  No  Please explain:

4. a) What is the current per-hectare density of commercial-sized mahogany trees in the MCU? Please give the **average** density for the total MCU. We define commercial sized trees as those with diameters equal to or greater than 60 cm diameter at breast height (dbh). If the density varies widely throughout the MCU for reasons other than natural clustering (for example, one half of the MCU has been logged and the other half is untouched), please provide separate answers for each region and indicate the location of these regions on the map.

Please check one density.

- |                  |                                     |                          |
|------------------|-------------------------------------|--------------------------|
| <b>Absent</b>    | (0 trees per hectare)               | <input type="checkbox"/> |
| <b>Very low</b>  | (fewer than 0.01 trees per hectare) | <input type="checkbox"/> |
| <b>Low</b>       | (0.01 to 0.1 trees per hectare)     | <input type="checkbox"/> |
| <b>Medium</b>    | (0.1 to 1.0 trees per hectare)      | <input type="checkbox"/> |
| <b>High</b>      | (1 to 10 trees per hectare)         | <input type="checkbox"/> |
| <b>Very high</b> | (more than 10 trees per hectare)    | <input type="checkbox"/> |

b) Is this information based on plot data? Yes  No

c) At the observed density, is mahogany considered to be commercially extinct? Yes  No

d) How does the current density of mahogany compare to the density 20 years ago? ( Please check one )  
 Higher  Same  Lower  Much lower

5. Who logged the MCU? (Please check all that apply)

	Legally	Illegally
Individuals or small groups	<input type="checkbox"/>	<input type="checkbox"/>
National companies	<input type="checkbox"/>	<input type="checkbox"/>
Multinationals	<input type="checkbox"/>	<input type="checkbox"/>
Unknown	<input type="checkbox"/>	<input type="checkbox"/>
Other: _____	<input type="checkbox"/>	<input type="checkbox"/>

6. Has the MCU been logged for other timber species? Yes  No

7. How many major points of access are there to the MCU?

	None (0)	Few (1-2)	Many (3+)
Roads accessible by logging trucks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Navigable rivers large enough to transport logs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8. How far is the nearest sawmill? \_\_\_\_\_ km  
 (Response should be "0" if a sawmill is located within the MCU)

9. Are any of the following activities likely to take place within or impact 25% or more of the MCU?  
 ( Check all that apply ). How soon?

	Currently occurs	1-5 years	5-10 years	10+ years
Conversion to agriculture	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Conversion to grazing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Commercial logging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Illegal logging	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fire	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dam building	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Road building	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other: _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please explain:

10. Please provide descriptive information about the area surrounding the MCU (up to about 10 km from the border of the MCU).

a) What percentage of the surrounding area is free from development? (Please check one)

0-25%	<input type="checkbox"/>
25-50%	<input type="checkbox"/>
50-75%	<input type="checkbox"/>
75-100%	<input type="checkbox"/>

b) In the area under development, what is the dominant land use?

Subsistence farming	<input type="checkbox"/>
Large-scale farming (e.g., plantations)	<input type="checkbox"/>
Ranching	<input type="checkbox"/>
Logging	<input type="checkbox"/>
Other: _____	<input type="checkbox"/>

c) Are property rights stable in the surrounding area? Yes  No

11. Can you suggest other sources that might provide relevant information on mahogany in this MCU (for example, forest owners, loggers, NGOs, indigenous representatives)?

12. In your personal opinion, if mahogany still exists in the MCU, is the species likely to become extirpated (i.e., the density of reproductive trees (greater than 30 cm diameter at breast height) is fewer than 1 per 100 hectares)? How soon?

0-5 years	<input type="checkbox"/>
6-10 years	<input type="checkbox"/>
> 10 years	<input type="checkbox"/>
Extirpation unlikely	<input type="checkbox"/>

Please explain:

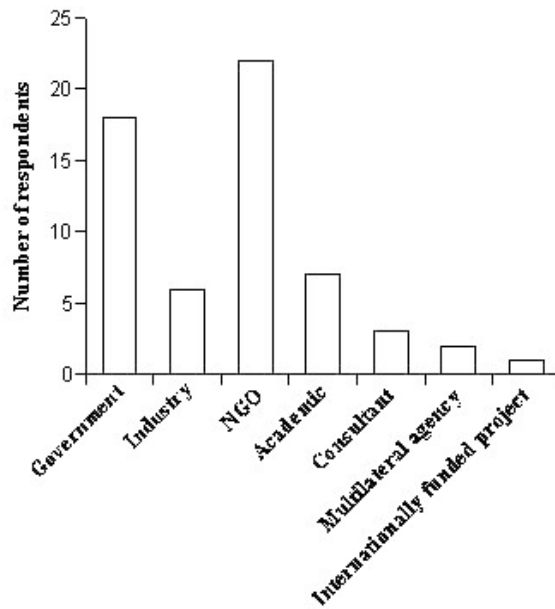
13. How effective are current efforts at conserving mahogany in your country as a whole?

	Not effective	Somewhat effective	Very effective
Protected areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sustainable forest management	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other: _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>





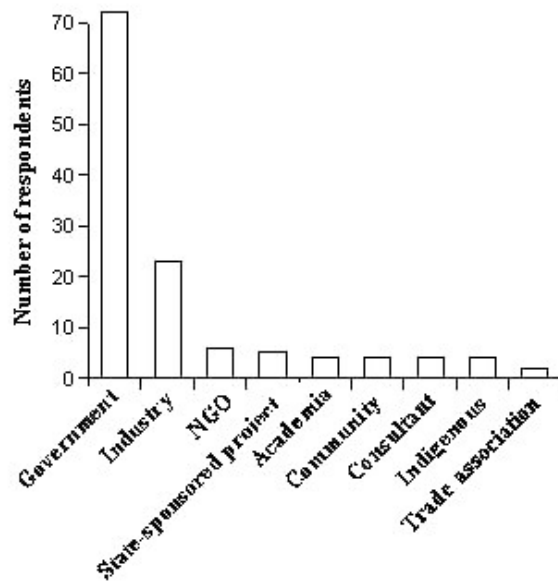
**Fig. A3.1.** Occupations of the 59 respondents from Bolivia.



### Peru

Most (58%) of the 124 respondents (Fig. A3.2) were government employees, e.g., managers of protected areas or employees of the National Institute of Natural Resources (INRENA). Industry provided the next largest group (19%). The remainder was drawn evenly from NGOs, academia, and other stakeholder groups (Fig. A3.2). For each forest unit, we interviewed an expert from INRENA and, for 91% of them, experts from the other stakeholder groups.

**Fig. A3.2.** Occupations of the 124 respondents from Peru.



## Resident expertise

### Bolivia

Approximately half of the respondents currently live or work within the forest unit in question or had been there within the last month (Fig. A3.3). Only 1% of the respondents had not been in the unit within the last 2 yr. Respondents who had lived in the forest unit for a year or more made up 23% of the surveys, 26% had spent from one to 12 months there, and the rest had visited for one week to a month (Fig. A3.4).

Fig. A3.3. Amount of time elapsed since respondents were last in the forest units in Bolivia.

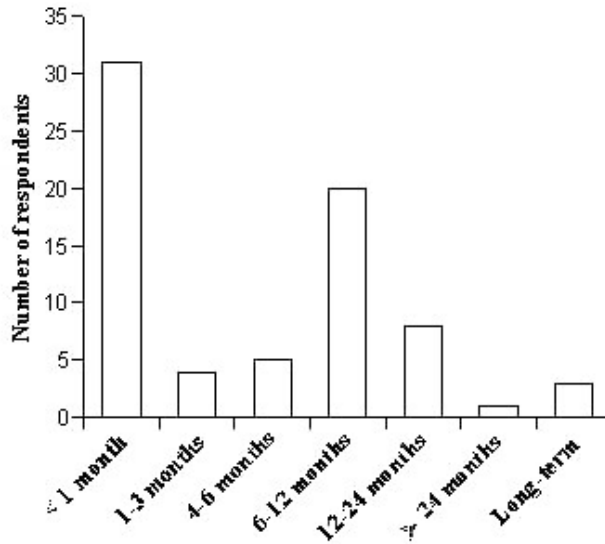
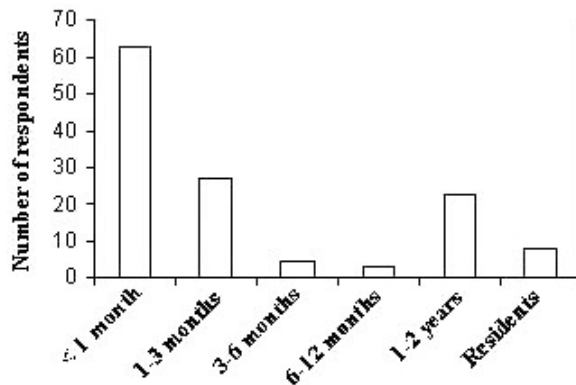
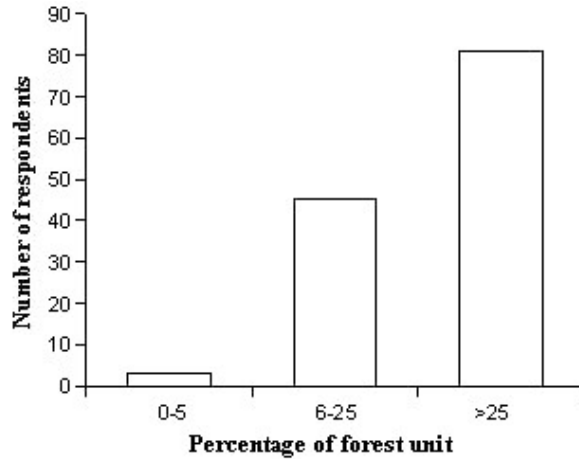


Fig. A3.4. Amount of time that respondents had spent in the forest units in Bolivia.



Further, 63% of the surveys were completed by experts who had visited more than a quarter of the unit (Fig. A3.5).

**Fig. A3.5.** Percentage of the forest unit in Brazil with which the respondent was familiar.



### Peru

More than two-thirds of the respondents currently live or work within the forest unit in question (Fig. A3.6). Only 1% of the respondents had not been in the unit within the last 2 yr. Residents made up 42% of the surveys (Fig. A3.7). Frequent (6–12 visits/yr) and regular (1–6 visits/yr) visitors together comprised another 11%. Further, 74% of the surveys were completed by experts who had visited more than a quarter of the unit (Fig. A3.8).

**Fig. A3.6.** Amount of time elapsed since respondents were last in the forest units in Peru.

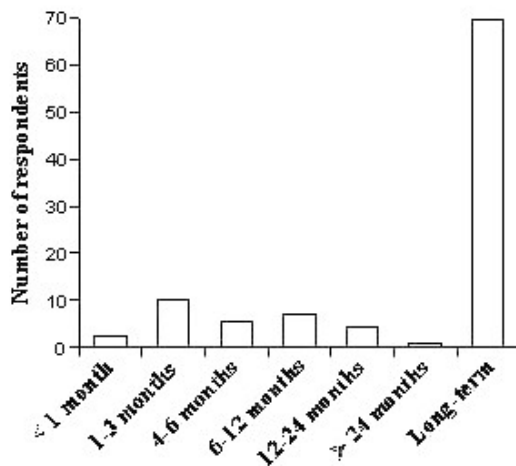


Fig. A3.7. Amount of time respondents had spent in the forest units in Peru.

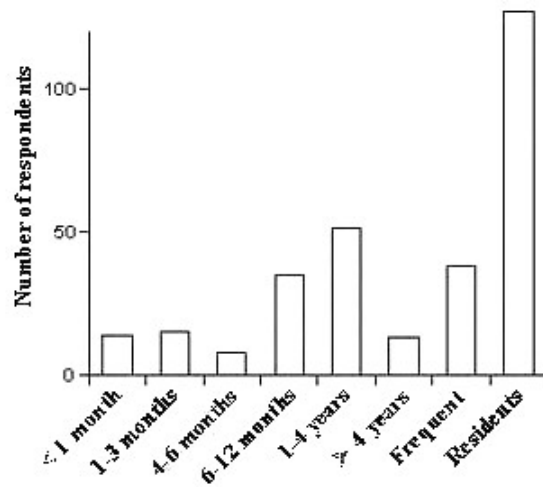
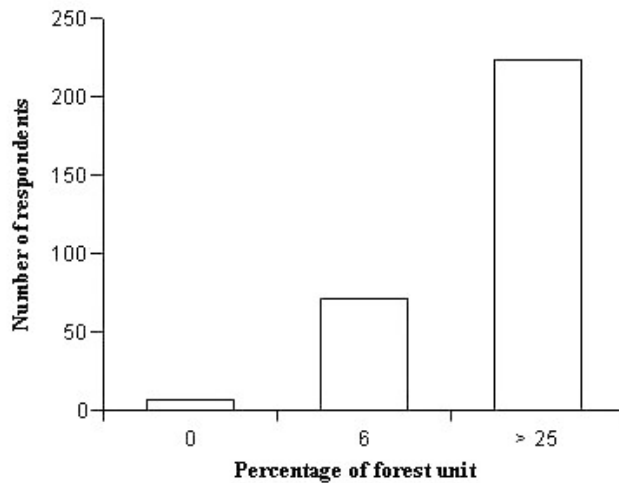


Fig. A3.8. Percentage of the forest unit in Peru with which the respondent was familiar.



### APPENDIX 3. BIOLOGICAL EFFECTS OF MAHOGANY LOGGING

Mahogany is a challenging species to manage sustainably. In late-successional forest, recruitment is driven by infrequent, large disturbances that create even-aged stands of trees (Snook 1996, Brown et al. 2003, Gullison et al. 2003). Therefore, in older stands, virtually an entire population of trees can be vulnerable to harvest, with few small trees to produce subsequent rotations of timber. In more open forests, along the edge of mahogany's range in Southern Brazil, recruitment appears less problematic (Brown et al. 2003). Given mahogany's capacity to grow well in open areas, the species may be ecologically suitable for management in secondary and degraded forests.

In general, however, the unmanaged harvest of mahogany in late-successional forest is thought to exceed the forest's capacity for regeneration and recruitment (Gullison 1996, Veríssimo and Grogan 1998). Sustainable harvest is unlikely without artificial regeneration (Brown et al. 2003). In addition to the obvious effects of reducing population abundance and size structure, i.e., harvesting the large adults, mahogany logging as currently done in Latin America is detrimental because (1) it reduces seed crops by removing reproductive trees and (2) the gaps created are too small to stimulate sufficient recruitment to replace the harvested adults (Snook 1993). Loggers, generally operating illegally, high-grade most (> 95%) trees of commercial size, down to 20 cm dbh in some regions, e.g., Belize (Weaver and Sabido 1997). Further, researchers working in logged forests have either failed to find regenerating mahogany or failed to determine if the regeneration is sufficient to replace the harvested adults. In Belize, for example, after centuries of extensive logging, it is uncommon to find a commercial-sized mahogany tree (Weaver and Sabido 1997).

### **Evidence of regeneration**

Quevedo (cited by Snook 1996) found some mahogany regeneration in gaps 2 yr after logging, but none after 9 yr. Veríssimo et al. (1995) found no trees 10–30 cm dbh in logged areas, similar to Dickinson and Whigman (1999) in the Yucatan. At eight *ejidos* in Mexico, although nine times more juveniles (< 15 cm dbh) exist after logging compared to adults (> 50 cm dbh) prior to logging, this represents substantially less basal area than the adults (Valera 1997). "Inventories carried out by personnel at UNAM Chajul biological station found no mahoganies at all 50 years after selective logging in that portion of the Selva Lacandona, Chiapas, Mexico ..." (G. Segura, *personal communication*; Snook 1993). After extensively examining 29 20-yr-old gaps created by felling mahogany trees in Chimanes, Bolivia, Gullison et al. (1996) found only two young mahogany trees that could be considered post-harvest regeneration. At a nearby site, they surveyed an additional 11 25-yr-old logging gaps and found only one tree that was classified as regeneration. In Para, Brazil, Grogan et al. (2003) found that 65% of 2- and 3-yr-old logging gaps contained mahogany seedlings. However, only two seedlings in these 40 gaps were growing vigorously, and, even then, it is not known whether they will reach the canopy and reproduce. Although Baima (2001) found high variation in juvenile density at four logged sites in Para (0.67–59 juveniles < 10 cm dbh/ha), most juveniles were in low light and unlikely to survive to the canopy. Of those in gaps, growth rates were high, but researchers had removed all competing vegetation every six months, and without this intervention it is not known whether the seedlings would have died from interspecific competition. Wang and Scatena (2003) found that mahogany seedlings were poor competitors with pioneer species. In early successional forests, however, there are areas that still have substantial populations after logging (Brown et al. 2003).

### **Evidence of genetic deterioration**

Genetic variation within Central American mahogany populations was high (88%), yet variation between populations was relatively low at 12% (Wang and Scatena 2003). This suggests a high amount of genetic exchange, i.e., pollen transfer, within local populations, although it may also reflect historical gene flow from periods when populations were less fragmented by deforestation (Gillies et al. 1999).

Logging reduces population size, especially the largest, flowering adults that are important sources of seeds. Grogan (2001) calculated that the harvesting of the commercial-sized individuals would reduce the population's seed crop by 85%. Further, logging increases inbreeding. Loveless and Gullison (2003) found that outcrossing rates declined from 100% to 85% when the forest around a stand was logged. Given that genetic variation buffers species against environmental change, this is assumed to be deleterious to the species, although it is not known to what extent.

### **Conclusion**

The effects of unmanaged logging are severe on populations of mahogany. Logging greatly decreases the population size of adults. It can reduce the genetic diversity of mahogany regeneration. Mahogany seedlings may germinate and survive initially in logged forests, but it is unlikely that regeneration is typically sufficient to



replace the harvested adults. Certainly the pattern of trade based on local depletion of mahogany, thus necessitating a shift in the source of supply (Robbins 2000), suggests that past mahogany logging was neither biologically nor commercially sustainable. Although it is possible that logging can be nondetrimental, less than 1% of mahogany range is harvested according to the standards of the Forest Stewardship Council, and all these forests are in Central America (Blundell and Gullison 2003). Unless existing regulations that require sustainable management are enforced, it is precautionary to assume that logged forests will not contribute greatly to the conservation of mahogany.

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