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Growth of wild rattans in Cambodia and Laos: Implications for management

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ABSTRACT

We studied the annual stem growth of six species of wild rattans over a 4-year period in permanent plots located in Prek Thnot, Cambodia and Ban Sopphouane, Laos. The rattan species studied in Cambodia included *Calamus palustris*, *C. tetradactylus*, *C. viminalis*, *Myrialepis paradoxa*, and *Plectocomia pierreana*; *C. solitarius* was studied in Laos. We collected a total of 1206 growth measurements over the 4-year period. There were significant differences in growth between species, with the *M. paradoxa* and *P. pierreana* exhibiting the fastest growth (229.7 ± 29.8 cm year^{-1} and 221.5 ± 17.9 cm year^{-1}, respectively) and *C. tetradactylus* exhibiting the slowest growth (78.3 ± 4.3 cm year^{-1}). Stem height and measurement year also had a significant effect on growth. Growth projections revealed that the time required to produce a commercial cane varied from 2 to 8 years. Analyses of sample size requirements using group means and variances showed that a reasonable estimate of wild rattan growth can be obtained by marking and measuring 50–60 sample plants, over half of which are of pre-commercial size. Using growth rates to guide the annual harvest of rattan in Southeast Asia would be a major step forward to insure a continual supply of this valuable non-timber resource.

1. Introduction

The sustainable exploitation of non-timber forest resources, especially those with commercial value, requires baseline information about the density and yield of the harvest species. This information can be collected quantitatively through forest inventories and growth studies or approximated based on long-term, qualitative observations of the species and the forest within which it grows. An understanding of species abundance and growth can be used to define sustainable harvest levels, predict yields, estimate changes in population structure over time, and calculate the economic returns from forest use (Peters, 1994; Stockdale, 2005). Alternatively, harvesting a resource without a basic understanding of the ecology of the species that has produced it precludes any type of planning and frequently leads to over-exploitation, resource depletion, and a loss of revenues. The current situation with rattan in South East Asia provides a useful example of the importance of diagnostic data to sustainable resource use.

Rattans, which have been described as "the world's most important and widely used non-timber forest product" (Siebert, 2012), are spiny, climbing palms in the subfamily Calamoideae. There are over 550 different species of rattan belonging to 12 genera distributed throughout the Old World tropics (Dransfield et al., 2008). Rattan palms are used for a variety of different subsistence purposes, e.g. basketry, cordage, food, medicine, and thatch, and the flexible stem fibers, or canes, form the basis of a multi-billion dollar year^{-1} furniture industry. The great majority of this material is harvested from wild populations. It is estimated that over 700 million people use, collect, and sell rattan, or are involved in some way in the international rattan trade (Dransfield and Manokaran, 1994).

In spite of the great value and utility of this resource, several recent studies have reported that supplies of wild rattan are declining rapidly in Southeast Asia, especially of valuable commercial species and large-diameter canes used for furniture (e.g. Binh, 2009; Siebert, 2004; Evans, 2002; De Beer et al., 2000) The two main reasons given for the dwindling supplies are forest loss and over-exploitation – forests are being converted to alternative

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land-uses and collectors are harvesting more than they should each year. Although some of this rattan is harvested illegally, a large percentage of the material is collected by villagers with permits. Unfortunately, in the absence of information about the actual volume and growth of local rattan species, harvest quotas in many countries are based more on the existing demand from the rattan industry than on the actual supply of the resource in the forest (Hirschberger, 2011; pers. obs.).

In 2006, the WWF Great Mekong Program initiated a long-term project focused on the sustainable production of rattan in Cambodia, Laos, and Vietnam and enhancing linkages to regional and international markets. The project, done in collaboration with selected communities in each country, conducted taxonomic surveys of local rattan species, initiated participatory inventories to quantify the distribution and abundance of rattans, and established a network of permanent plots to assess rattan growth, mortality, and the production of new stems through seedling establishment or sprouting. In this paper, we report 4 years of growth data from six rattan species growing in permanent plots in Laos and Cambodia. We examine the effect of species, height, and measurement year on rattan growth and use size-specific growth rates to estimate the time required to produce a harvestable cane at each site. To facilitate further growth studies of wild rattan, we apply the observed variability of our growth measurements to calculate the minimum sample size needed for each species.

2. Methods

2.1. Study sites

In Cambodia, we measured the growth of wild rattans in sample plots located within the Prek Thnot Community Protected Area (CPA), Kampot District, Kampot Province. The Prek Thnot CPA forms part of the Bokor National Park, a 140,000 ha protected area containing extensive tracts of moist evergreen forest with pockets of mixed deciduous forest to the north (IUCN, 1997). In Laos, our growth measurements are from sample plots in a 45 ha tract of semi-evergreen forest belonging to the community of Ban Sopphouane, Khamkeud District, Bolikhamxay Province. Although the climate at both sites is monsoonal, monthly fluctuations in temperature and precipitation are more pronounced at Ban Sopphouane, and annual rainfall at this site is almost twice that of Prek Thnot (Fig. 1).

2.2. Plot measurements

We laid out nine 10 × 50 m permanent plots in each of the two study sites in January (Laos) and February (Cambodia) of 2007. The plots varied in terms of degree of disturbance, canopy closure, and land-use history, and three of the plots in Cambodia were in active rattan harvesting areas. In each of the plots, we counted and identified all of the rattan seedlings (⩽70.0 cm tall) and measured the height of taller individuals, gave each a unique number, and labeled it with a plastic tag. We used a fiberglass meter tape to measure heights, attaching the tape to a bamboo pole to measure the height of taller canes. In the case of extremely tall and looped canes, we used the meter tape as a reference and visually estimated stem height (Stockdale and Power, 1994).

On as many individuals size class^{-1} as we could access without pulling down the cane or damaging it, we marked a point on the stem between the terminal bud and the last leaf sheath using colored tape or paint. We used this mark as a baseline to measure extension growth. Every 3 months for 4 years, i.e. until January–February 2011, we re-located the sample plants and measured the distance from the tape or paint mark to the tip of the shoot. The number of canes measured at each sampling period varied. Some of the canes died, or were harvested, or the tag was lost, and we periodically added new individuals to the sample as rattan seedlings grew to a measurable size (⩾70 cm tall).

2.3. Rattan species

We collected growth measurements from six of the most abundant rattan species in the sample plots. The species include important commercial taxa, marginal-quality subsistence canes, clustering growth forms, and solitary stems. All of the rattans are exploited to some extent. The following species descriptions are based on Evans et al. (2001), NAFRI (2007), Eang Hourt (2008), Henderson (2009), and personal observations.

Calamus palustris Griff. is a clustering, climbing rattan that is widely distributed in the semi-evergreen and evergreen forests of Cambodia and Laos. The stems are up to 30 m long with cane diameters of 0.3–1.5 cm. The species is generally classified as good quality for handicrafts and furniture; the shoots are edible.

Calamus solitarius T. Evans, K. Sengdala, O. Viengkham, B. Thammavong & J. Dransf. is a climbing, solitary rattan. The stems are up to 50 m long and 0.5–1.0 cm in diameter. The species is one of the most common and valuable small-diameter canes in Laos; it was identified as a new species in 2000 (Evans et al., 2000). Although abundant in evergreen forests from 200 to 600 m, its solitary habit and inability to sprout make the species extremely susceptible to over-exploitation. *C. solitarius* was the only species measured for growth in Laos.

Calamus tetradactylus Hance is clustering, climbing rattan widespread throughout lowland areas in Cambodia and Laos. The stems are 6–10 m long and 0.3–1.0 cm in diameter. The slender, high-quality cane is a preferred material for basketry and cordage; it is frequently planted in Vietnam and China.

Calamus viminalis Willd. is a clustering, climbing rattan that often forms thickets in semi-evergreen, mixed deciduous, and evergreen forests. The stems are up to 35 m long and 0.5–1.5 cm in diameter. The cane is of moderate quality for furniture and basketry and is harvested extensively for domestic and international markets; the young shoots and fruit are edible.

Myrialepis paradoxa (Kurz) J. Dransf. is a clustering, climbing rattan common along forest margins and in disturbed semi-evergreen and evergreen forests in Cambodia and Laos; the species frequently forms thickets. The stems are up to 30 m long and 1.0–3.0 cm in diameter. The cane has a soft core and is difficult to bend; it is used to frame low-quality furniture and for handicrafts. The young shoots are edible.

Plectocomia pierreana Becc. is a clustering, high climbing rattan with stems up to 50 m long. The species is found in disturbed semi-evergreen and evergreen forests in Cambodia and Laos from sea level up to 1000 m. The canes are large diameter, 0.5–4.0 cm, with limited flexibility and strength. The species is used for handicrafts and low-quality furniture; the shoots are edible.

2.4. Data analysis

We compiled the quarterly growth measurements for each species to produce an estimate of total extension growth year^{-1} and grouped the results into six 1.0 m height classes. At the end of each sample year, we added the recorded growth of each individual to its initial height and, if necessary, moved the plant to the next 1.0 m height class for subsequent calculations. Sample sizes height class^{-1} varied from year to year, with the smaller classes exhibiting the most pronounced depletion over the 4-year period as outgrowth was consistently greater than the addition of new sample plants.

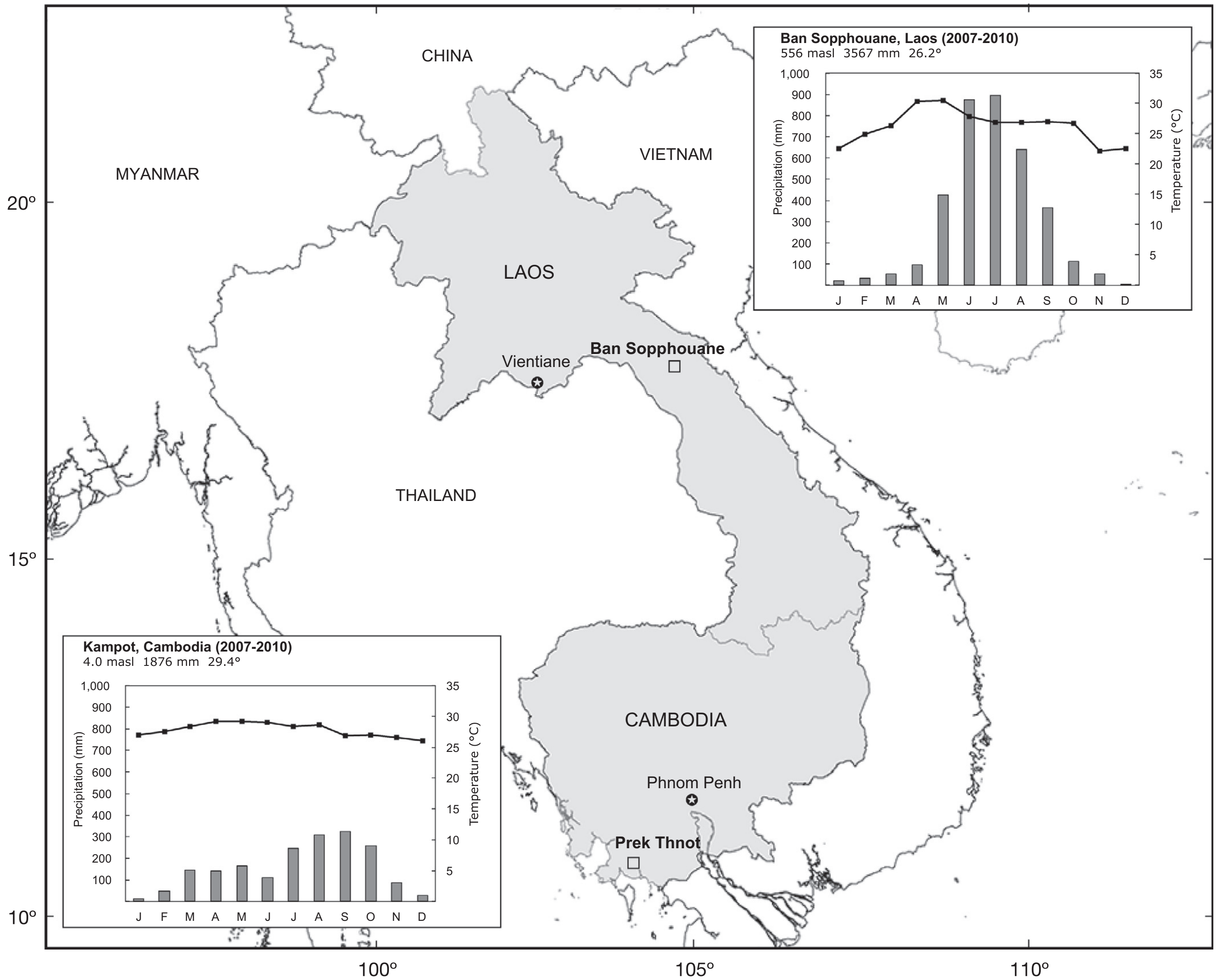

Fig. 1. Location of study sites at Prek Thnot, Cambodia and Ban Sopphouane, Laos with climate diagrams for each location showing average monthly temperature (°C) and precipitation (mm) from 2007 to 2010. Climate records for Prek Thnot (Kampot station) and Ban Sopphouane are from MWRM (2007–2010) and DAFO (2011), respectively.

We used frequency histograms to visually assess the normality of the data sets for each species and Bartlett's test to assess the homogeneity of within-group variances. We performed square root transformations to meet the homogeneity assumptions for the *C. solitarius*, *C. viminalis*, and *P. pierreana* data sets. We analyzed for significant differences between rattan species, size class, and measurement year using model I analysis of variance, and conducted unplanned comparisons of the means of selected data sets using the Tukey–Kramer method ($P = 0.05$).

To assess the time required by each species to produce a commercial rattan cane ($\geqslant$5.0 m tall), we used size-specific growth rates, pooled growth rates from commercial ($\geqslant$5.0 m tall) canes, pooled growth rates from pre-commercial (<5.0 m tall) canes, and an initial seedling size of 0.50 m to estimate cane length over time. Based on the assumption that an estimate of rattan growth with a standard error to mean ratio of 0.1 would be suitable for management planning, we used the results from the growth study (group means, coefficients of variation) to calculate the number of measurements required for each species to provide an estimate of annual growth at this level of precision (Philip, 1994; Husch et al., 2003).

3. Results

3.1. Growth by species

A total of 1206 measurements of rattan growth year^{-1} were collected over the 4-year period. ANOVA results showed that there are significant differences in the annual stem growth of different rattan species (Table 1), both in terms of all canes species^{-1} ($F_{5,1206} = 80.18$, $P < 0.001$) and commercial length canes species^{-1} ($F_{5,265} = 31.52$, $P < 0.001$). The fastest growing species in both data sets are *M. paradoxa* and *P. pierreana*, both large diameter canes, while *C. tetradactylus* exhibits the slowest growth and produces the most slender cane. Although the commercial canes of each species consistently grow faster than the average calculated for all individuals of that species, growth difference between taxa are more distinct when all canes are included, i.e. the mean growth rates of commercial canes reflect two distinct groups of species based on the Tukey–Kramer tests ($P = 0.05$), while the data set including all canes reflects three groups.

Table 1
Average annual growth (cm year^{-1}) ± standard error of six rattan study species. Data are presented for all canes and for only commercial canes (⩾5 m tall). Means followed by the same letter are not significantly different from each other (Tukey–Kramer test, $P = 0.05$). The range in height (m) of the individuals measured for growth is shown for each rattan species.

	All canes			Commercial canes (⩾5.0 m tall)	
	N^{A}	Height (m)	Growth (cm year^{-1})	N^{A}	Growth (cm year^{-1})
Calamus palustris	122	0.4–19.4	78.7 ± 4.8^{a}	14	140.8 ± 15.0^{a}
Calamus solitarius	352	0.7–8.7	80.3 ± 2.1^{a}	97	109.2 ± 4.3^{a}
Calamus tetradactylus	437	0.4–8.9	65.0 ± 1.2^{a}	35	78.3 ± 4.6^{a}
Calamus viminalis	173	0.4–16.1	138.7 ± 6.5^{b}	73	184.5 ± 8.1^{ab}
Myrialepis paradoxa	60	0.6–15.3	129.0 ± 14.2^{b}	20	229.7 ± 29.8^{b}
Plectocomia pierreana	62	0.4–16.8	169.2 ± 12.2	26	221.5 ± 17.9^{b}

[A] Number of annual growth measurements over 4-year sample period.

3.2. Size-specific growth

All of the rattan species showed a significant ($P < 0.01$) effect of height on extension growth year^{-1}, commercial-length canes (classes 5 and 6), as a general rule, growing faster than smaller, pre-commercial canes (Fig. 2). Examination of the group means and Tukey–Kramer results reveal several different patterns in the expression of size-specific growth. The class 1 canes (⩽1.0 m) of *C. palustris* and *C. viminalis* grow significantly slower than all of the larger size classes, while the growth differences between the rattans in classes 2–6 are insignificant. A contrasting pattern is exhibited by *M. paradoxa* and *P. pierreana*, the two large diameter canes. For these species, the growth of the tallest canes (⩾6.0 m) is significantly faster than all of the smaller size classes (classes 1–5), which exhibit insignificant differences in growth rate. *C. solitarius* and *C. tetradactylus*, the rattans with the largest sample sizes, show continual increases in average growth rate from one size class to the next, and we found significant differences in the growth rates of several classes.

3.3. Effect of measurement year

There were notable differences in annual rainfall at the Cambodia and Laos sites from 2007 to 2010, and these differences were reflected in the growth rates of some of the rattan species. *C. solitarius* ($F_{3,352} = 16.32$, $P < 0.001$) and *C. tetradactylus* ($F_{3,437} = 6.33$, $P < 0.001$) exhibited significant differences in growth rate between measurement years (Fig. 3), while the ANOVA results for *C. palustris*, *C. viminalis*, *M. paradoxa*, and *P. pierreana* were not significant.

The significant effect of measurement year on the growth of two species of *Calamus*, one growing in Cambodia and the other in Laos, highlights a contrasting growth response. For commercial-length canes of *C. solitarius* in Laos, the average growth rate in 2010 was the highest recorded during the measurement period and was significantly different ($P = 0.05$) from the growth in 2007–2009. The rainfall in Ban Sopphouane during 2010 (4028 mm) was also higher than in the other 3 years. The rainfall in Cambodia displayed a completely different pattern. Precipitation at Prek Thnot in 2010 (1357 mm) was the lowest of all 4 years; the only significant ($P = 0.05$) difference we found in the annual growth *C. tetradactylus* was for pre-commercial (<5.0 m) canes in 2008.

3.4. Growth projections

The results from the growth projections are shown in Table 2. The time required to produce a 5.0 m long cane varies from 2 years

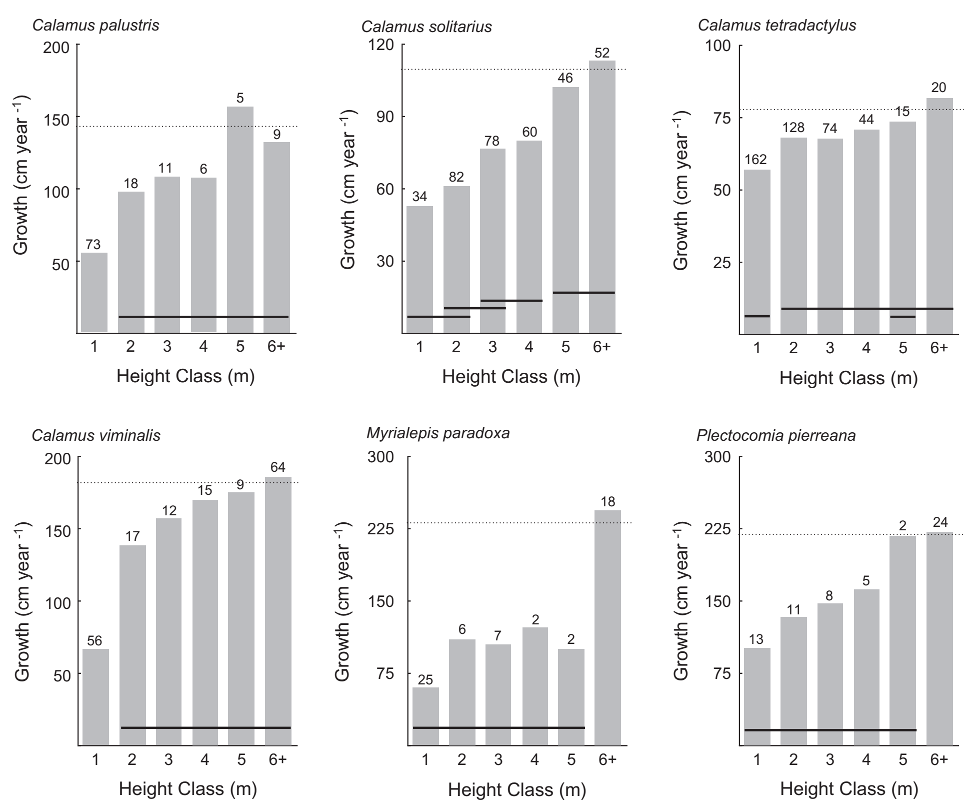

Fig. 2. Average size-specific height growth (cm year^{-1}) of six rattan study species. Number of measurements is shown above the bars in each histogram; dotted horizontal line indicates mean growth of commercial canes (⩾5.0 m tall). Means grouped by a horizontal line are not significantly different (Tukey–Kramer, $P > 0.05$).

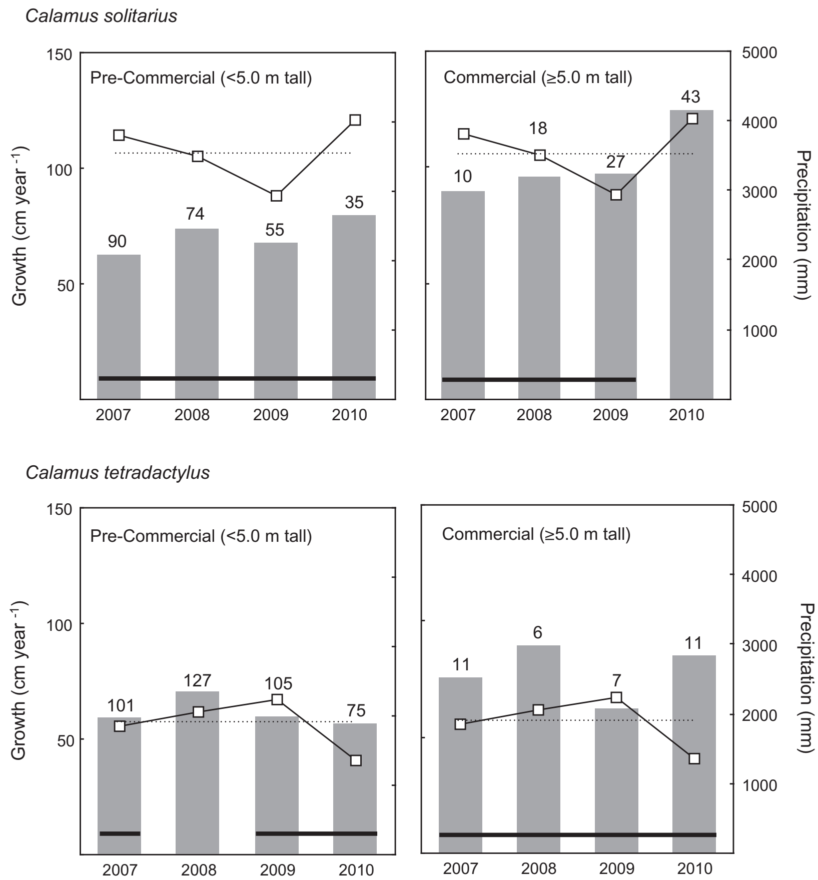

Fig. 3. Mean annual growth (cm year^{-1}) of pre-commercial and commercial ($\geqslant$5.0 m tall) canes of *Calamus solitarius* and *Calamus tetradactylus* from 2007 to 2010. Number of measurements is shown above the bars in each histogram; means grouped by a horizontal line are not significantly different (Tukey–Kramer, $P > 0.05$). Annual precipitation (mm) is shown as line plot; dotted horizontal line represents average annual precipitation during the study period.

for *M. paradoxa* using the growth rates of commercial (C) plants to 8 years for *C. tetradactylus* using the growth rates of pre-commercial (PC) plants. The use of pooled growth estimates from pre-commercial plants produced a 5.0 m long cane in the same number of years as the size-specific (SS) growth rate projection for *C. solitarius* and *P. pierreana*, added 1 year for *C. tetradactylus*, *C. viminalis*, and *M. paradoxa*, and added 2 years *C. palustris*. Projections based on growth estimates obtained exclusively from commercial-length plants always produced a 5.0 m cane in the shortest period of time.

3.5. Number of samples required to estimate rattan growth

The sample size and standard error to mean ratio for pre-commercial and commercial canes of the six rattan species are presented in Table 3, together with an estimate of the number of sample plants that need to be measured as a result to produce a standard error to mean ratio of 0.1. With the exception of the pre-commercial canes of *P. pierreana* and the commercial canes of *C. palustris* and *M. paradoxa*, the standard errors from our study data were consistently less than 10% of the mean. The recommended number of sample plants is, as result, in most cases considerably less than what we measured, especially for smaller, pre-commercial canes. Recommended sample sizes of combined pre-commercial and commercial plants range from 71.8 for *C. viminalis* to 26.0 for *C. tetradactylus*.

4. Discussion

While things have certainly improved since the report that "there is no published information on the growth of rattans growing in the wild" (Dransfield and Manokaran, 1994), only a few species of wild rattan have been studied to date and comparisons are difficult because of the different methodologies used. Bogh (1996) measured the growth of three species of *Calamus* in southern Thailand, but the species were different from those included in our study and growth rates were calculated by multiplying the rate of leaf production by the average internode length of different stages. Van Valkenburg (1997) studied the growth of wild rattans in logged and unlogged forest plots in East Kalimantan over a 2-year period. The results from this research, however, are presented as changes in the number of canes in different growth stages, i.e. sucker, juvenile, immature, and mature, over time, rather than species-specific stem growth (m year^{-1}). Several authors have used stem analysis, e.g. measurement of internode and/or inflorescence scar distances, to provide an indirect estimate of the annual growth of wild rattan (Shim, 1989; Stockdale, 1994).

The detailed research of Evans (2001) on the rattans of Lao includes two growth studies of *C. solitarius*. In the first, detailed stem analyses were conducted to obtain growth information, but no significant variation in internode distances along the stem was detected and no growth estimates were reported. The second study monitored the growth of marked plants of varying size in a permanent plot for 1 year and annual growth estimates were reported in a scattergram and with quadratic ($r^2 = 0.284$, $P = 0.025$) and linear ($r^2 = 0.164$, $P = 0.02$) equations. Although basic descriptive statistics are not presented for the data set, visual inspection of the graph and estimates calculated using the quadratic equation suggest that the growth of pre-commercial *C. solitarius* canes was similar to the averages recorded in this study (Table 1), while the growth of commercial canes appears to have been greater.

Table 2
Growth projections for six rattan study species showing the number of years required to produce a cane of commercial size (⩾5.0 m). Projections based on three growth estimates (cm year^{-1}): SS = size-specific, C = commercial (⩾5.0 m tall) canes only, and PC = pre-commercial (<5.0 m tall) canes only.

Species	Growth estimate	Rattan height (cm)							
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Calamus palustris	SS	105.4	203.0	311.1	418.4	574.9			
	C	190.8	331.6	472.4	613.2				
	PC	120.7	191.4	262.1	332.8	403.5	474.2	544.9	
Calamus solitarius	SS	109.1	170.3	231.4	307.9	388.1	468.2	570.5	
	C	159.2	268.4	377.6	486.8	596.0			
	PC	119.2	188.4	257.6	326.8	396.0	465.2	534.4	
Calamus tetradactylus	SS	107.1	175.3	243.4	311.1	382.1	453.1	526.7	
	C	128.3	206.6	284.9	363.2	441.5	519.8		
	PC	112.5	175.0	237.5	300.0	362.5	425.0	487.5	550.0
Calamus viminalis	SS	116.7	255.1	412.0	587.0				
	C	234.5	419.0	603.5					
	PC	155.2	260.4	365.6	470.8	576.0			
Myrialepis paradoxa	SS	110.2	220.3	325.2	447.7	548.2			
	C	279.7	509.4						
	PC	128.6	207.2	285.8	364.4	443.0	521.6		
Plectocomia pierreana	SS	151.4	284.7	432.0	649.5				
	C	271.5	493.0	714.5					
	PC	179.0	308.0	437.0	566.0				

Table 3
Number of samples required to obtain an estimate of the growth (cm year^{-1}) of pre-commercial (<5.0 m tall) and commercial (⩾5.0 m tall) canes with a standard error/mean ratio of 0.1 for six rattan study species. Estimates based on group means and coefficients of variation of the original data set. *N* indicates the number of measurements included in the original survey.

Species	Pre-commercial canes (<5.0 m tall)			Commercial canes (⩾5.0 m tall)		
	N	SE/mean ratio	No. samples required (SE/mean = 0.1)	*N*	SE/mean ratio	No. samples required (SE/mean = 0.1)
Calamus palustris	108	0.063	43.5	14	0.107	15.9
Calamus solitarius	254	0.028	21.2	97	0.041	16.2
Calamus						

tetradactylus
4020.01914.1350.05811.9*Calamus viminalis*
1000.07657.7730.04414.1*Myrialepis paradoxa*
400.08931.5200.12933.6*Plectocomia pierreana*
360.10440.2260.08117.1

The growth estimates for wild rattans most comparable to our results are those provided by Binh (2009) in her study of *C. platyacanthoides*, *C. rhabdocladus*, and *Daemonorops poilanei* in Vietnam. All of the species are climbing, clustering rattans, and the growth of marked canes was measured for 3 years in permanent plots. The average growth rates reported for large canes of *C. platyacanthoides* (2.4 m year^{-1}) and *D. poilanei* (2.8 m year^{-1}) are similar to those we observed for *M. paradoxa* and *P. pierreana*, while the growth of large *C. rhabdocladus* canes (1.5 m year^{-1}) approximates our results for *C. solitarius*, *C. palustris*, and *C. viminalis*. Growth rates reported by Siebert (2004) for *C. zollingeri* (1.4 m year^{-1}) growing in central Sulawesi forests are also comparable to our findings. The slowest growing rattan in our study, *C. tetradactylus*, exhibits a rate of extension growth that is considerably less than that reported by Dransfield and Manokaran (1994) for the species growing in plantations (2.3 m year^{-1}). That said, the large sample size and the small standard error associated with our growth estimate for *C. tetradactylus* (Table 1) would suggest that this slender rattan just does not grow very fast in the wild.

Several studies have found a positive correlation between rattan height and growth, both in plantations (e.g. Noor and Mohd, 1987; Sulaiman and Phillipps, 1987; Bacilieri and Appanah, 1999) and from wild populations (e.g. Peters and Giesen, 2000; Evans, 2001). In most cases, light level and canopy opening play an important role in this relationship. As canes grow taller, they move up into the canopy where irradiance levels and rates of stem elongation increase. Smaller rattans inhabit a darker, more heterogeneous light environment, and the slower growth rates and greater variability observed for all species in the pre-commercial size classes (Table 1 and Fig. 2) reflect this.

A useful finding from the Vietnam study (Binh, 2009) is that the relationship between rattan size and growth will eventually reach an asymptote where further increases in height no longer produce a measurable growth increase. This occurred at cane lengths of 10 m for *C. platyacanthoides*, *C. rhabdocladus*, and *D. poilanei*. For these species, there is little to be gained in terms of growth information by trying to mark and re-measure taller canes (⩾10 m) as the maximum growth increments have already been recorded from the smaller size-classes. The decrease in growth exhibited by long rattan stems is thought to be the result of decreasing intermodal distances (Putz, 1990); the investment in height growth may no longer be advantageous once a rattan has reached the canopy.

In the absence of quantitative growth data for commercial rattan species in Laos and Cambodia, the WWF Sustainable Rattan Project initially based community management prescriptions on a general 20% harvest limit, i.e. no more than 20% of the commercial canes within a management area could be harvested each year. The basic assumption is that it takes 5 years to produce a commercial cane. Our results (Table 2) suggest that this assumption is essentially correct for most of the species studied, yet largely depends on the type of growth estimate used. Using size-specific growth rates, presumably the most realistic projection, four of the rattan species produce a commercial length cane in 5 years; *C. viminalis* and *P. pierreana* will produce a commercial cane in 4 years. Applying the growth rates of only commercial canes, all species except *C. tetradactylus* produce a 5.0 m long cane in 5 years, and rotation lengths go down to 3 years (33.3% harvest limit) for *C. viminalis* and *P. pierreana* and 2 years (50% harvest limit) for *M. paradoxa*. The salient difference is that the establishment and early growth of pre-commercial canes have been eliminated from the projections. Smaller canes grow slower than taller ones, and the growth rates of these plants must necessarily be included in the definition of harvest limits and/or rotation times.

Taken together, the limitations of a blanket harvest prescription, the slower growth and variability of the smaller size classes, and the growth asymptote exhibited by larger canes provide both a foundation and a rationale for developing more parsimonious and economical growth studies for rattan. It is not necessary to collect growth data from every size class, especially the extremely tall and operationally difficult ones, nor is it advisable to eliminate growth measurements from the pre-commercial classes on the assumption that many of these individuals will die anyway and their inclusion incorrectly reduces growth estimates. Our results suggest that a reasonable estimate of the growth of wild rattans can be obtained by dividing a population into pre-commercial canes (<5.0 m) and commercial canes (⩾5.0 m), marking 50–60 sample plants (over half of which are of pre-commercial size), and carefully measuring extension growth from the baseline mark after a year.

Two caveats are necessary. First, a certain percentage of the sample plants will invariably be damaged or harvested. We lost about 10–15% of the sample individuals over the 4-year period, mostly from the commercial size classes. Initial sample sizes should be expanded to account for this mortality. Second, rattan growth varies from site to site and there are obvious limits to how far the growth data from a local species can be applied. Using the growth estimates collected in one forest to define a sustainable harvest of rattan in a neighboring forest of similar composition would seem appropriate; using growth estimates for *C. tetradactylus* in Cambodia to define harvest limits for wild populations of this species in Laos is clearly not advisable. Ideally, separate growth studies should be conducted in each production area from which rattan is harvested.

5. Conclusions

The importance of growth data for defining a sustainable harvest of wild rattan has been emphasized repeatedly over the past 20 years (Stockdale, 1994; Peters, 1996; Evans, 2001; Siebert, 2002). Yet, in spite of the management importance and potential conservation value of this biometric parameter, quantitative studies of wild rattan growth are still extremely rare. As was pointed out by Evans (2001), this is at least partly the result of the low demand for such information "since sustainability is rarely a target in the harvesting of wild rattan". Other reasons for the lack of the data include the operational difficulty of marking tall rattan canes, the perception of great variability in the measurement parameter, and the time and economic investment required to conduct such a study. In essence, there is one group of stakeholders that does not really need or want these data, and another group that appreciates the benefits of sustainable resource use but thinks that growth studies are too expensive, complicated, or tedious.

The fact that long-term growth studies of rattan were even conducted in Cambodia and Laos suggests that impending resource shortages may have enhanced the political and economic relevance of sustainable resource management. Furthermore, the results from our research provide some indication that the quantitative study of wild rattan growth need not always be something prohibitively expensive or time-consuming. Given existing trends of uncontrolled harvesting, forest conversion, and resource depletion in the rattan sectors of South East Asia, the incorporation of growth studies into basic management activities would be a major step forward to insure a continual supply of rattan canes and to promote the conservation and sustainable use of the forests that produce them.

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