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BALANCING SUPPLY AND DEMAND: A CASE STUDY OF RATTAN IN THE DANAU SENTARUM NATIONAL PARK, WEST KALIMANTAN, INDONESIA

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The Danau Sentarum Wildlife Reserve (DSNP) contains 30,000 ha of lake and 81,000 ha of lowland, seasonally flooded forest. It is the largest network of inland lakes on the island of Borneo. The reserve is inhabited by over 5,5000 Melayu fishermen who live in permanent or mobile settlements along the major watercourses. Most of the fishing implements used by the local population are made from rattan, and large quantities of rattan are also harvested and sold to timber companies for lashing together rafts of logs. The three most commonly used species at DSNP are *duri antu* (*Calamus schistoacanthus* Bl.), *duri tapah* (*Calamus tapa* Becc.), and *duri pelanduk* (*Ceratolobus hallierianus* Dransfield). Inventory results indicate that the three rattans differ greatly in terms of the number of harvestable clumps/ha (>4.0 m tall). The most abundant species, duri antu, forms populations with over 900 clumps/ha., duri pelanduk grows at densities of 400-500 clumps/ha, and duri tapah averages only 50 clumps/ha. Based on the observed relationship between clump height and number of canes/clump, it is estimated that there are over 34,000 duri antu canes/ha growing in the flooded forest of DSNP. Although these densities seem impressive, an analyses of local demand, productivity, and current harvest intensities reveal that local rattan resources are being gradually over-exploited. In response to this situation, several fishing communities have started to manage their rattan resources by controlling harvests and rehabilitating and enriching natural stands.

INTRODUCTION

Ethnobotanical studies have traditionally been concerned with documenting the relationships between people and plants at one moment in time. It is clear, however, that these relationships are extremely dynamic and that both the people and the plants are in a constant state of flux. The plants, through their local abundance, growth habits, and physical or chemical properties, influence the pattern of use by human populations. The people, through activities such as planting, resource management, destructive harvesting, and over-exploitation, continually impact the structure and dynamics of local plant populations. Simple species lists alone are insufficient to document the complex feedback loops that occur between a plant resource and its user group. To really examine the use, mis-use, and/or conservation of plant resources by indigenous populations, ethnobotanists need to broaden the focus of the questions they are asking (e.g. Peters, 1996).

The three basic parameters that determine the long-term impact of plant use are resource stock, growth, and offtake. Stock refers to the number of individuals of a particular species that are available in the forest at a given point in time. Growth represents the total amount of harvestable resource that is produced by these individuals in a year. Offtake refers to the quantity of material that is actually harvested each year. The relationship between stock, growth, and offtake is relatively straightforward. Abundant species of large stock produce the largest amount of resource in a year, while sparse, low-density resources exhibit a production rate that is much smaller. To exploit these resources on a sustained-yield basis year after year, it is important that the annual offtake be no larger than the annual growth. If harvest levels exceed the growth, the current stock of the resource is reduced, subsequent growth is also reduced, and, over time, the resource is gradually depleted. In excessive cases of over-exploitation, the species may be complete eliminated from the forest.

The collection of data on resource stock, growth, and offtake can provide a new dimension to ethnobotanical studies. To illustrate the utility of such an approach, the results from a long-term study of rattan in western Borneo are presented. The research documents the interplay between supply (stock) and demand (offtake) that characterizes the exploitation of a valuable forest resource, and demonstrates the key role that resource yield (growth) plays in determining the ultimate sustainability, or unsustainability, of this activity. The results presented herein also show that some indigenous communities are very aware of the dynamic nature of the interactions between people and plants—and that they frequently take concrete steps to maintain the balance between the supply and the demand of the resources upon which they depend.

Study Site

The research was conducted at the Danau Sentarum National Park (DSNP) in the Kapuas Hulu district of West Kalimantan, Indonesia. The reserve covers an area of 132,000 ha in the floodplain of the upper Kapuas River about 700 km upstream from the estuary at Pontianak. About 30,000 ha of DSNP is occupied by seasonal lakes and watercourses, the remainder of the area is covered by seasonally flooded swamp forest, riparian forest, scattered patches of peat forest, and dipterocarp hill forest (Giesen, 2000). The reserve contains a rich fauna including over 250 species of fish, more than 250 species of birds, crocodiles, pythons, gibbons, proboscis monkeys, and the occasional sun bear and orangutan (Jeanes and Meyaard, 2000). The annual rainfall in the region averages 3500 mm/yr with water levels in the lakes and rivers fluctuating 8 to 12 m during the flood cycle.

The DSNP is inhabited by over 5,500 Melayu fishermen who live in permanent or mobile settlements along the major lakes and watercourses. The houses, sidewalks, and docks of the permanent villages are built on stilts 3 to 4 m in the air; mobile settlements are made of house boats and floating docks that have been lashed together. Given the lack of unflooded terrain suitable for cultivation, fishing, rather than agriculture, is the primary subsistence activity and it has been estimated that from 80 to 90% of the local population is involved in this pursuit (Giesen, 1987; Colfer et al., 2000).

RATTAN SPECIES

The flooded forests of Danau Sentarum contain three species of rattan that are used by local communities. *Duri antu* (*Calamus schistoacanthus* Bl.) and *duri pelanduk* (*Ceratolobus hallerieranus* Dransfield) are slender, clustering rattans with stem diameters ranging from 3.0 to 6.0 mm. Duri antu cane is strong, flexible and extremely resistant to flooding, while duri pelanduk produces a cane that breaks rather easily and will rot after a year in the water. *Duri tapah* (*Calamus tapa* Becc.), in contrast, is a large diameter (10.0 to 12.0mm), solitary rattan. Although stiff and somewhat hard to work with, duri tapah canes are relatively resistant to flooding. The fruits of all three species are edible.

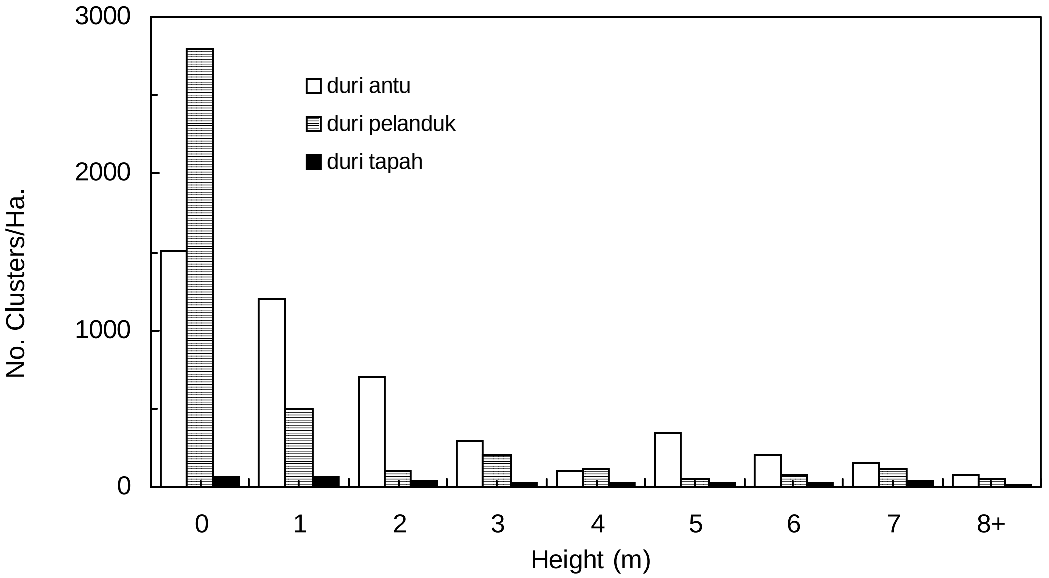

Figure 1. Density and size-class distribution of duri antu, duri pelanduk, and duri tapah populations within the DSWR. Histograms are divided into eight 1.0 m height classes with a zero class for seedlings and small saplings (0 – 100 cm tall). Data collected using replicate 10 m wide transects of variable length; see text for exact sample area at each site.

DISTRIBUTION AND ABUNDANCE OF LOCAL RATTANS

To quantify the available supply of rattan cane at Danau Sentarum, replicate strip transects were sampled at four different localities within the reserve: Sungai Berbaju, Sungai Leboyang, Sungai Insiluk, and Nanga Sauk. Exact sample sizes varied from site to site. A 10 X 200 m transect (2,000 m^2) was sampled at Sungai Berbaju and Sungai Leboyang, Sungai Insiluk was sampled using a 10 X 1,000 m transect (10,000 m^2), and a 10 X 100 m transect was sampled at Nanga Sauk. All of the rattan clumps encountered in each transect were counted, identified to species, and the height of the tallest cane in each clump estimated visually. All transects were oriented at right angles to the topography and slope corrections were applied as necessary to maintain a constant horizontal sample.

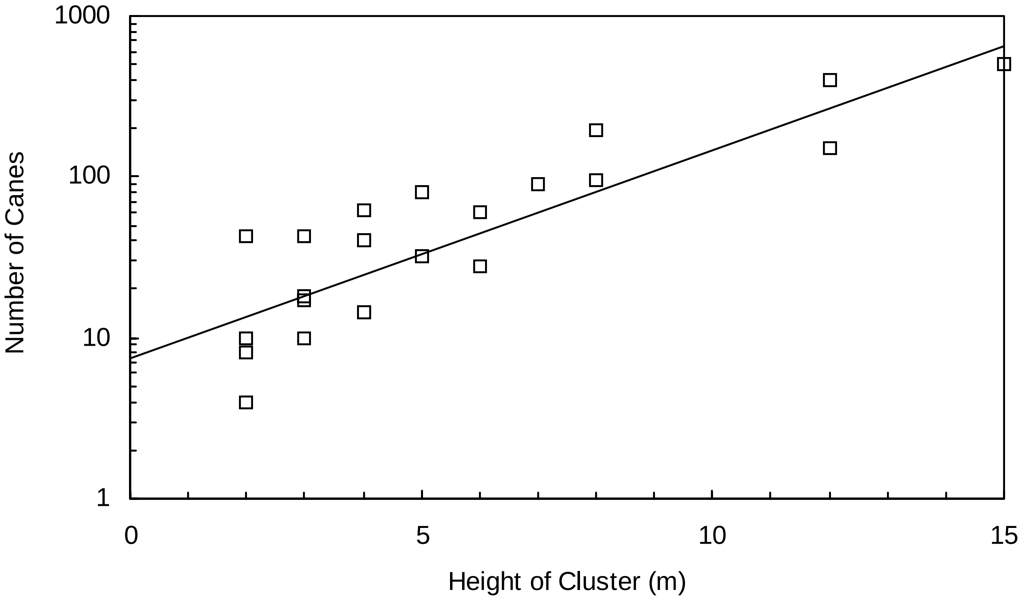

Figure 2. Number of duri antu canes as related to the height of a cluster. Cane density data are shown on a $\log_{10}$ scale; regression lines based on general linear model, i.e. $\log_{10}$ Number of Canes = a + b (Cluster Height). Parameter values and coefficient of determination are as follows: a = 0.927, b = 0.121, r^2=0.82.

The results from the inventory are presented in Figure 1. Separate histograms have been constructed for each rattan species using the average values from all transects. As is shown in the figure, the three rattan species differ greatly in terms of the total number of harvestable clumps/ha (³4.0m tall). The most abundant species, duri antu, can form populations containing over 900 clumps/ha, duri pelanduk was recorded at densities of 400 - 500 clumps/ha, and duri tapah was never observed in densities greater than 50 clumps/ha. An additional point of interest concerns the size-class distribution of the rattan populations recorded in the transects. Although the shape of the histogram is different for each species, all of them reflect a greater number of small individuals than large individuals. This results suggests that the rattan populations at DSNP are regenerating themselves, and that the harvest of large canes is being replaced to some degree by the recruitment of new individuals into the population.

It is important to note that the data shown in Figure 1 are for the number of clusters of each rattan species encountered in the transects. One cluster of a multi-stemmed rattan (e.g. duri antu or duri pelanduk), however, can be composed of numerous single canes. The more relevant question is “how many individual rattan canes of merchantable length occur in the forests of DSNP?” Data collected from a subsample of duri antu clumps provides a useful estimate of the magnitude of this number. As is shown in Figure 2, there is a strong exponential relationship (r^2=0.82) between the height of a duri antu clump and the total number of canes that it contains. Small, 2.0 m tall clusters may contain only five to ten canes; a single 15 m tall cluster may contain over 500 canes. Multiplying the number of clusters in each class by the estimated number of canes per cluster for that size class, it is calculated that there are over 34,000 duri antu canes/ha (³4.0 m tall) in the lowland forests of DSNP.

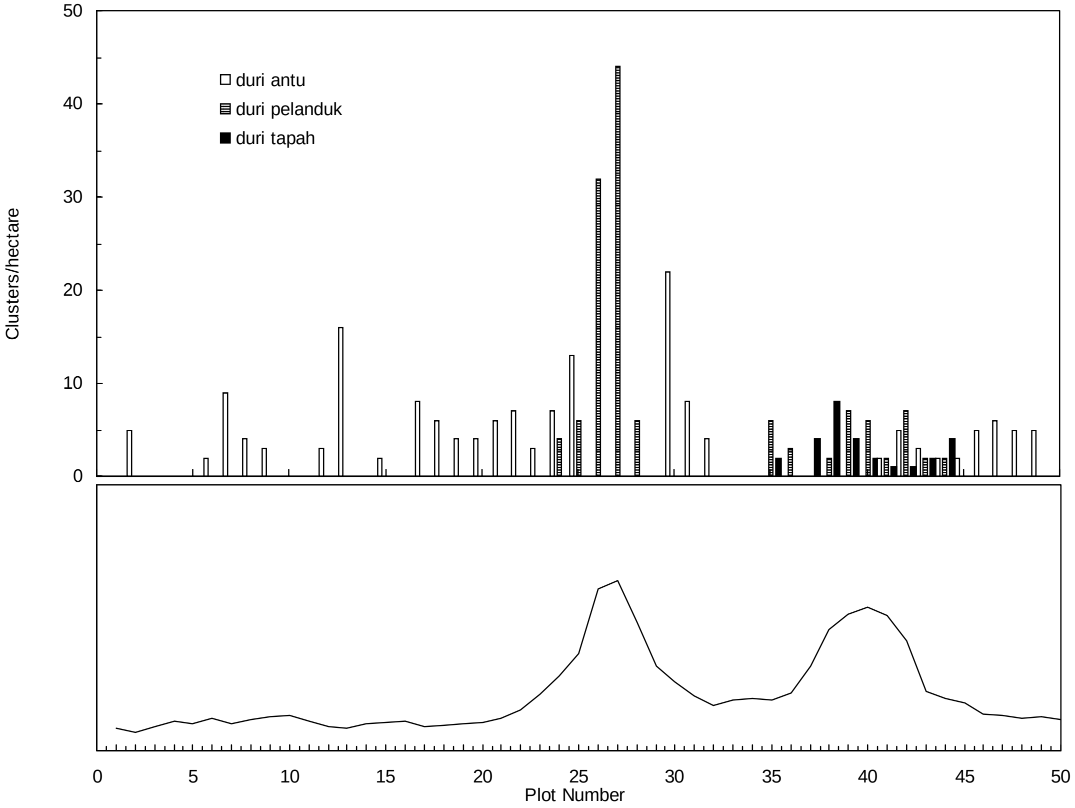

Figure 3. Density of duri antu, duri pelanduk, and duri tapah ckusters recorded in 50 contiguous 10 X 20 m plots along a 1.0 km transect at Sungai Insiluk. Bottom of graph shows general topography traversed by the transect; the two peaks shown are 2 –3 m above the rest of the floodplain.

A final aspect of the distribution and abundance of rattans at DSNP that can be examined using the inventory data concerns the habitat requirement of each species. This is illustrated in Figure 3, which divides the results from the kilometer-long Sungai Insiluk transect into fifty contiguous 10 X 20m plots and shows the density of duri antu, duri pelanduk, and duri tapah clusters recorded in each plot. The transect topography shown in the lower half of the figure was estimated visually based on the height of the flood line on the trees in each plot.

As can be appreciated in the histogram, all three rattan species were recorded in the Sungai Insiluk transect, but there is a definite pattern in the way that the species are associated. The first 22 plots (440 m) in the transect were in very low-lying terrain and duri antu was the only rattan species recorded. After this the transect climbed up a small levee and duri pelanduk started to appear in the plots with duri antu. The elevation of the transect continued to gradually increase and by plot 26 the forest was completely dominated by duri pelanduk. Further along the transect, duri tapah plants started to appear in association with duri pelanduk. The plots sampled toward the end of the transect (e.g. plots 46 - 50) were in progressively lower terrain and these sites were dominated exclusively by duri antu. Based on these results, it appears that duri antu does best on the low sites, duri tapah occupies the high sites, and duri pelanduk can share the middle ground with either of the other two rattan species.

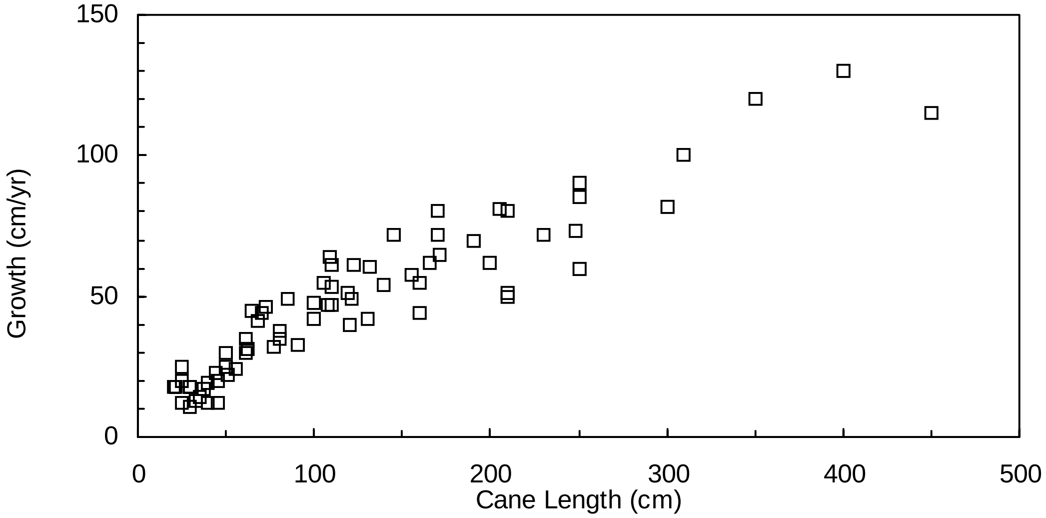

Figure 4. Annual extension growth as related to cane length for duri antu (*Calamus schistoacanthus*) in the flooded forests of DSWR. Regression line based on general linear model, i.e. growth = a + b (cane length); parameter values and coefficient of determination are: a = 13.458, b = 0.191, r^2 = 0.75.

RATTAN GROWTH

Collecting growth and yield data for rattan is usually an extremely tedious and time consuming task involving tree climbing and the periodic re-measurement of marked shoots. The annual rise and fall of the lakes at DSNP, however, provides a useful short cut for making preliminary estimates of productivity. As a result of the flood cycle, much of the vegetation in the reserve is under water for several months of the year. The sites examined in this study flood to a depth of 2.0 to 5.0 m and may be completely out of the water for a period of only three to four months each year. All but the tallest rattan canes are submerged during the flood cycle. When the water level subsides, these canes exhibit a rapid growth response and growth continues until the site begins to flood again. The new leaves and stem tissue produced during the low water period are glossy and green, while older leaves produced the previous year are covered with sediment from the long period of submersion. A reasonable estimate of annual growth can be obtained by measuring the length of the new stem tissue produced by a rattan immediately prior to flooding. Although these measurements are clearly under-estimates as the plants do not cease to grow immediately at the onset of flooding, they provide a useful, albeit conservative, approximation of rattan productivity.

Growth data collected for duri antu using this procedure are presented in Figure 4. A total of 78 individuals representing a range of different height classes were measured. For this species, there is a linear relationship between plant size and extension growth for canes up to 5 m long, and the relationship is strong enough from a statistical standpoint that stem growth can be meaningfully predicted from cane length. The fact that tall plants grow faster than short plants is not surprising given that the leaves of the larger canes stay out of the water longer than those of shorter plants, i.e. they have a longer "growing season". Of further interest in Figure 4 is that duri antu canes, especially the larger ones, exhibit a very fast rate of growth. Most of the canes produced about 50 cm of stem tissue/year and a few sample plants grew more than 1.0 m. These growth rates are comparable to those reported for other *Calamus* species in upland habitats (e.g. Dransfield and Manokaran, 1994, Bogh, 1995). Multiplying the size-specific growth estimates shown in Figure 4 by the number of canes/hectare in different size classes (from data in Figure 1 and Figure 2) provides a rough estimate of the total annual yield/hectare of duri antu cane. Based on these calculations, the forests at DSNP are producing about 4,500 m of duri antu cane per hectare each year. Given the existence of approximately 40,000 ha of forest containing duri antu at DSNP (Giesen, 2000), these yield estimates scale up to a total annual cane production of 180,000 km.

The high density and productivity of duri antu and other rattans at DSNP would suggest that there is more than enough rattan cane to supply the needs of the local fishing communities. From the supply side, the available stock of forest resources would seem inexhaustible. Before accepting this conclusion, however, it is important to examine the demand side of the equation in greater detail. Under high levels of exploitation and little management, history has shown that abundant forest resources frequently do not stay abundant for very long.

Local Use and Demand for Rattan

Rattan stems are extremely strong and flexible, and the canes from many species can tolerate long periods of submersion in water without rotting. Not surprisingly, rattans are a highly valued source of cordage and weaving material at DSNP and large quantities are harvested every year for both subsistence use and sale. No other non-timber forest resource in the reserve is exploited with this intensity.

Rattan is usually collected as an alternative activity during periods when fishing opportunities are limited in the lakes region (Aglionby, 1997). The exact timing of cane collection depends on the particular species being exploited. Duri antu, for example, is extremely tolerant of flooding and, as was shown earlier, natural populations of this species occur in habitats that are much lower than those occupied by duri pelanduk or duri tapah. The exploitation of duri antu, therefore, is limited to the early part of the flood cycle before its habitat becomes completely inundated, while duri pelanduk and duri tapah can be exploited for a much longer period.

Harvesting rattan is a relatively straightforward, yet strenuous task. After first locating a suitable specimen in the forest, the collector repeatedly tugs on the stem until the entire cane is dislodged and falls from the canopy. Care must be taken not to break the stem. Once on the ground, the spiny leaves and sheath around the stem are removed with a knife (*parang*) and the cane is bundled for transport out of the forest. Collectors preferentially harvest canes that are 4 m or longer; shorter or broken canes are used for making fishing implements. Local collectors report that one person can harvest up to one hundred and fifty 4 m canes on a good day. The rattan is usually sold in bundles of 50 canes. Women and children are frequently the most important rattan collectors in the community.

The great majority of the rattan harvested at DSNP is used on a subsistence basis for making fish traps, or sold to timber companies for lashing log rafts together. Both of these uses consume a very large quantity of rattan. Fish traps are an essential component of the livelihood of Melayu fishermen at DSNP, and almost every household is equipped with an assortment of different fishing tools, e.g. *bubu*, *pengilar*, *bubu keli*, and *seruak* (Giesen, 1987; Dudley, 2000). The *bubu*, or cylindrical fish trap, is an especially ubiquitous implement. The rattan used to make these traps (almost always duri antu) is first cured with smoke to make it more durable and water resistant. Depending on the frequency with which it is used, a cured and well-made bubu can last from 5 to 10 years. The construction of one bubu requires about 500 duri antu canes; pengilar, seruak, and bubu keli require 40 to 50 canes.

As an example of how much rattan this subsistence use requires, Dudley (2000) reports a total of 2,550 bubu, 7,550 *pengilar*, 3,950 *bubu keli*, and 16,500 *seruak* in use at DSNP. The construction of these fishing implements represent a total harvest of more than 2.5 million duri antu canes, i.e. 15,300 km of rattan. Assuming that these traps must be replaced every five years on average, this represents an annual harvest of 510,000 six meter long duri antu canes, or 3,060 km of rattan. As noted earlier, the forest is producing about 4500 m of rattan or 750 merchantable canes/ha each year.

The sale of rattan for lashing logs together also consumes a significant quantity of cane. Timber companies need some way to tie logs together so that they can be floated downriver to sawmills, and rattan cane is apparently the strongest and most cost-effective material for this purpose. The buyers are reportedly not very demanding about the quality of the material they receive as long as the canes are 5.0 to 6.0 m long. Given the difficulty of distinguishing duri antu from duri pelanduk once the stem sheath has been stripped away, commercial collectors supply the latter species whenever they can.

To float the timber downriver, the logs are grouped together in lots of 20 logs, the “sinker” logs being mixed strategically together with the “floaters”. Three bundles of rattan (approximately 150 canes) are needed to lash together one lot of logs. These lots are then lashed together into large rafts that may contain from 20 to 30 lots. During the course of this study, four large rafts of logs were sampled to determine the quantity of rattan required. The average size of a log raft was found to be 400 logs (i.e. 20 lots), with each raft containing approximately 18 km of rattan (i.e. 20 lots X 150 canes/lot X 6 m/cane). During periods of peak logging in the concessions around the reserve, as many as 12 to 15 log rafts a month can be observed floating through the reserve. Lashing these raft together adds another 30,000 to 40,000 rattan canes to the monthly demand for rattan at DSNP.

Taken together, rattan harvesting for making fish traps and for selling to timber companies consumes about 550,000 six meter long canes/year. More than 730 ha of lowland forest, or 22 ha for each of the 32 fishing villages in DSNP , are required to produce this quantity of material each year. Given that it takes about 12 years to produce a merchantable duri antu cane (average growth=50 cm/yr), each village needs a minimum of 260 ha of forest to supply its subsistence and commercial rattan needs. It should be noted that this calculation assumes that both demand and supply remain constant over time.

The current collection of rattan at DSNP exhibits two characteristics that suggest that the local demand for the resource is exceeding the productive capacity of the forest. First, villagers complain that they must go further and further into the forest each year to find sufficient quantities of long cane to harvest. This is especially the case with duri antu . Second, rattan theft is becoming an increasingly common problem in the reserve. In most cases, it is the larger villages, many of whom have already overexploited their rattan stocks, who are accused of stealing rattan from the forests surrounding the smaller villages. The great majority of the stolen rattan is sold to timber companies. In spite of the apparent abundance of rattan at DSNP, these patterns describe a classic scenario of resource over-exploitation (Peluso, 1983; Siebert and Belsky, 1985).

Balancing Supply and Demand

Perhaps the most interesting aspect of the relationship between the fisherman and the rattan at DSNP is that the people, in this case, are aware that the plants they depend on are running out and they have started to do something about it. The response of local fishing communities to an impending rattan shortage has taken two different forms: (1) stricter control of access to the resource, and (2) rehabilitation and enrichment of natural stands.

Rattan is such an important component of human subsistence that it has always been one of the most openly accessible forest resources at DSNP. Traditionally, communities have allowed the residents of other villages to enter their forest area and to harvest as much rattan as they need as long as verbal permission from the village head (*ketua nelayan*) was secured. This open policy, however, appears to be gradually changing. The results from informal surveys conducted at DSNP revealed that five villages have recently implemented sanctions against the commercial harvest of rattan. Each of these villages also complained of dwindling rattan stocks or illegal harvesting. Although there are still a large number of villages that reported rattan scarcity (N=11) or theft (N=5) and have yet to do anything about it, and although it is clearly too early to assess the effectiveness of these community resource controls, the behavior of these five villages provides an interesting case of where access to an valuable forest resource is being restricted in response to resource scarcity. This is quite a bit different from the “tragedy of the commons” scenario (*sensu* Hardin, 1968) that one might expect in such a situation.

Shortly after drafting a new set of regulations controlling the harvest of rattan by outsiders, the residents of the village of Sumpak approached the scientific staff at the field station in DSNP and requested technical assistance to grow rattan. It should be remember that these people are fisherman, not farmers, and that they have little experience with plant propagation and tending. It was clear to them that they needed more rattan, but they didn’t know exactly how to go about it. They had, however, put a lot of thought into the idea and were very clear on which species they wanted to plant and where they wanted to plant them. On the higher terrain across the river in front of the village they wanted to plant duri tapah, while on a lower site located to the north they wanted to plant duri antu. Clearly, the fisherman at Sumpak know the habitat requirements of their local rattan species.

A total of 48 duri tapah seedlings were planted on the higher site and 82 duri antu seedlings were planted on the lower site. Almost everyone in the village-men, women, and children-turned out to assist with the planting. All of the seedlings used in the operation were transplants that had been dug up in the forest. Two weeks after planting, the two sites were re-visited to assess seedling mortality.

Approximately 25% of the duri tapah seedlings were showing signs of yellowing and necrosis, and a slightly higher percentage of dying seedlings were encountered among the duri antu transplants. Much of this mortality was the result of careless and hasty transplanting. Although a common response to finding a dead seedlings was “that must have been one of those planted by the children”, the importance of careful transplanting was embarrassingly clear to everyone involved. Additional enrichment plantings were planned for the following year.

It is important to realize that the rattan plantings at Sumpak are about more than simply increasing the supply of a scarce resource. To put things in perspective, each of the 60 duri antu seedlings that survived may grow, branch, and produce a harvestable rattan cluster with about 10 to 15 canes. This is enough rattan to produce about one bubu. The real significance of the rattan planting at Sumpak has to do with village initiative. It has to do with not ignoring the resource depletion that is going on all around you. It has to do with taking a first concrete step, albeit a small one, towards forest management and sustainable resource use.

The enrichment planting by the Sumpak community did not go unnoticed by other villages in the park. Soon after the Sumpak experience, representatives from several villages expressed an interest in rehabilitating their own rattan stocks, and plans were developed to establish a rattan nursery at the UK-Indonesia Tropical Forest Management Project (UK-ITFMP) field station at Bukit Tekenang. The nursery was created with the help of four villages, and more than 10,000 duri tapah seeds were germinated, planted in trays in trays, and transplanted to polybags. By the end of the year, 700-800 seedlings were ready for outplanting, and plans were made for establishing three additional nurseries to supply the growing local demand for rattan seedlings. Although these activities have experienced some problems, e.g. low germination rates due to excessive shade in the nursery and disruption of transplanting work by the lack of a dry season in 1996 and 1996, local interest in the rehabilitation of rattan stocks persists.

As further indication of village initiative, a small, rattan handicraft industry was also established at DSNP (Geisen and Aglionby, 2000). The rattan cane was locally processed into baskets and sold to selected, up-scale markets in Pontianak, Jakarta, and Singapore with the assistance of the UK-ITFMP. Almost 5,000 baskets were sold during the first 1.5 years of the project and the total annual income derived from rattan was increased by 15%. Interestingly, the total volume of rattan harvested from the forests of DSNP during this period did not increase (Wickham, 1997).

CONCLUSION

A static analysis of the rattan situation at Danau Sentarum could provide a variety of different impressions. It could show that the fisherman in the reserve depend solely on three species of rattan, and that one species in particular, duri antu, is favored for making their fish traps. Or it could describe the abundance with which these three species occur in the forest. Or it could document that almost 4,000 km of rattan are harvested each year from the reserve. However, it is only through the integration of time-specific parameters like growth and yield that we glimpse the real dynamic between people and plants that is occurring at DSNP, i.e. the local populations are harvesting more than the forest can produce. The outcome of a chronic imbalance between supply and demand is relatively easy to extrapolate. If the demand functions do not change, or if nothing is done to increase the available supply of the resource, natural populations of the species will become severely degraded over time.

The salient feature of the research reported here is that local populations appear to be manipulating the supply side of the equation to ensure that this type of resource depletion does not happen. In the "doom-and-gloom" world of tropical forest destruction and biodiversity loss, the management initiative demonstrated by the fishermen at DSNP is a small success story. Similar responses to resource shortages are undoubtedly occurring in other tropical forest communities. By detecting and carefully documenting the dynamics of this process, ethnobotanists can make a major contribution to the conservation and sustainable use of tropical forest resources.

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