Harvest, trade, and conservation of the endemic multi-use cycad, *Cycas circinalis* L., in the Nilgiri Biosphere Reserve, South India

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Summary

Cycas circinalis L. is a multiuse cycad endemic to South India. Although reported to be in decline across its limited habitat, no information was available on the extent and nature of harvest and trade of this species or its ecological impacts. The aim of this study was to identify patterns of use, harvest and trade of *C. circinalis* in the Niligiri Biosphere Reserve (NBR) in the Western Ghats, and to assess their impacts on *C. circinalis* populations. We carried out focus group interviews with male and female harvesters in 14 indigenous communities on the Kerala and Tamil Nadu sides of the NBR, as well as semi-structured interviews with three *C. circinalis* traders in a large regional medicinal plant market. We also assessed the structure of populations subject to different types of harvest in 15, 20x 20 m plots located across nine regions in the NBR. *C. circinalis* fruits and young leaves are harvested by indigenous communities in the NBR for food, and in Kerala the fruits are heavily harvested and sold locally as medicine. The stems (pith) and male cones are extracted by outside harvesters and traded as medicines in regional and national markets. In Tamil Nadu the mature leaves are also harvested by outsiders for the floriculture industry. High rates of exploitation by outside harvesters are facilitated by the lack of tenure associated with these trees. Population structure analyses suggest that fruit harvest does not negatively affect recruitment. However, leaf-harvested populations showed low levels of recruitment and high adult mortality. In these populations, 92% of all individuals > 20 cm high were harvested for their leaves, and 91.3 ± 15 % of all leaves per tree were harvested. Stem-harvested populations showed clear signs of overexploitation, being devoid of all individuals > 50 cm high. Significant correlations between leaf scars and height allowed for estimates of cycad age, and indicate that these cycads reproduce after about 17 years and are harvested for their pith once they are 50 years old. The high demand for *C. circinalis* pith, cones and leaves, combined with the slow-growing nature of this species, suggest that conservation will require the combined efforts of cultivation inside and outside of forests, pressure on the floriculture industry to use leaves of substitute species, and better protection of the remaining wild populations.

1.0 Introduction

Non timber forest products (NTFP) represent important resources for hundreds of millions of people across the world (e.g. Iqbal 1993, Walter 2001). Those NTFP that have medicinal value hold particular social, cultural and economic importance, as they make significant contributions to local healthcare needs and local livelihoods. About 80% of populations in developing nations rely on traditional medicines (Hamilton 2004). In addition, many local and indigenous communities earn an important portion of their livelihoods from the harvest and sale of medicinal plants (Iqbal 1993). According to the WHO, the global market for medicinal plants exceeds $60 billion USD per year (Economist 2006). Most medicinal plants, however, are wild-harvested (Lange & Schippman 1997, Uniyal et al. 2000), and a growing number of them have been reported to be overexploited (e.g. Nault et al. 1996, Botha et al. 2004, Ghirmire 2005). In addition, many wild-harvested medicinal plants are also exploited for other uses as well, such as for timber, crafts, fodder etc (Shanley & Luz 2003). They are therefore subject to additional harvesting pressures and may be at particular risk of over harvest.

Cycas circinalis L. is a cycad endemic to South India. It is also an important multiuse NTFP for indigenous communities throughout India's Western Ghats, a biodiversity hotspot (Meyers et al. 2000). The pith and male cone of this species are collected for their medicinal value, the young leaves and fruits are used as food and medicine by indigenous and local communities, and the mature leaves are sold in the floriculture industry. *C. circinalis* is one of various important NTFP that are collected throughout the Western Ghats, but for which there is currently no or very little information available on the extent or of nature of harvest and trade or their ecological impacts. *C. circinalis*' endemic status combined with the fact that it is listed as 'Data Deficient' on the IUCN Red List (Hill 2003), and listed as critically endangered by FLHRT in the states of Karnataka and Tamil Nadu and vulnerable in Kerala (Ravikumar and Ved 2000), make it of special conservation concern and high priority for study. In addition, although cycads are harvested across the world and represent one of the world's most threatened groups of plants (IUCN 2006), there are few studies anywhere on the impacts of their harvest (but see Raimondo and Donaldson 2003).

1.1 Objectives

The aim of this study was to identify patterns of use, harvest and trade of *C. circinalis* in the Niligiri Biosphere Reserve in the Western Ghats, and to assess their impacts on *C. circinalis* populations. Specifically, our objectives were to:

1) Identify patterns of use and harvest and associated traditional knowledge and perceptions of *C. circinalis* by communities of the Niligiri Biosphere Reserve on both the Tamil Nadu and Kerala state sides of the Reserve.

2) Identify if and how *C. circinalis* is traded in local and regional markets.

3) Assess the impacts of harvest on *C. circinalis* populations by comparing the size and age structure of populations subject to different types of harvest

4) Based on the above information, assess the conservation status of *C. circinalis* in the Nilgiris Biosphere Reserve.

2.0. Study Species

C. circinalis is endemic to South India, where is it restricted to the Western Ghats and hilly regions of the southern peninsula, in the states of Kerala, Karnataka, Tamil Nadu, and the south of Maharashtra (Hill 1995). It is arborescent, growing up to 5 m tall, with bipinnate leaves that are about 150-200 cm long. The male individuals produce orange pollen cones, about 45 cm long. Seeds are yellow or red globose up to 4 cm long. *C. circinalis* is usually found fairly dense, seasonally dry scrubby woodlands in hilly areas.

2.1. Study Site

The Nilgiri Biosphere Reserve (NBR) is part of the Western Ghats chain of mountains of the Indian peninsula, and was the first Biosphere established India, declared in September 1986 by the Man and Biosphere program of the UNESCO. It lies between 10^0 45'N to 12^0 N and 76^0 E to 77^0 15' E with a total area of 5520 sq. kms spread across the three southern states of Karnataka, Kerala and Tamil Nadu. There are six protected areas within the reserve, the Wayanad Wildlife Sanctuary, Nagarhole, Bandipur and Mudumalai Tiger Reserves and the Mukurti and Silent Valley National Parks. Still larger tracts of forests lie outside as reserve forests. Altitude varies from 250m to 2650m , and at least four of the major rivers of South India originate in this region - the Bhavani, Moyar, Kabini and Chaliyar rivers.

The NBR's monsoon climate regime is characterized by an alteration of northeasterly surface winds in the winter and southwesterly winds in the summer, and its proximity of the mountains to the western coast further enhances the climatic impact of the monsoonal winds (Prabhakar 1994). The monsoons play a special role in enhancing the vegetation diversity so that it ranges from tropical evergreen to thorny scrub. The western ranges of the NBR receive higher precipitation (upto 4600 mm) while the eastern parts are part of the rain shadow, receiving less than 800mm rainfall annually. Most of the precipitation is during the SW monsoons. The east and northern parts often suffer from drought conditions, though they receive some showers during the northeast winter monsoon (Keystone Foundation 2005).

The NBR has been partitioned into six biophysical zones based on topography and climate (Prakbhakar 1994). The Nilambur plains and the Nilgiri plateau were the sites for the present study (Fig 1). The Nilambur area lies on the western side of the reserve, with an elevation of about 80m rising to 2000m. The area receives an annual rainfall of 2500 mm to 5000 mm. The natural vegetation is moist deciduous to dense evergreen. The teak plantations of this region are famous and a big source of revenue for

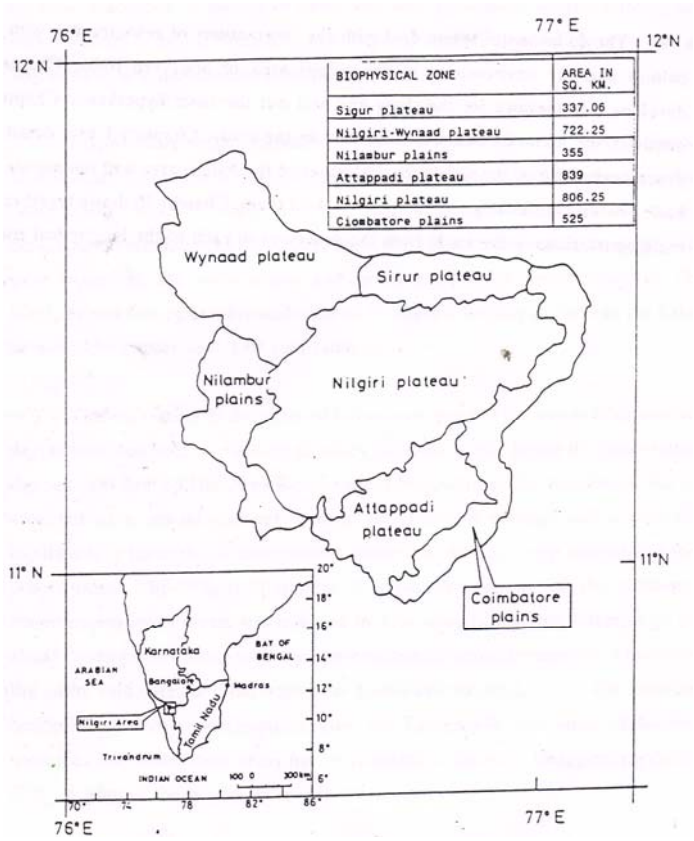
the Forest Department. The Nilgiri slopes rise suddenly to about 1800m to form the Nilgiri plateau. The Eastern slopes of the Nilgiris are in the rain shadow area and harbor dry deciduous and riparian forests of high diversity and vast stretches. The average rainfall is 1000mm for this region. It is in these forests that the indigenous people are allowed to collect NTFPs.

2.2 Populations in the NBR

The NBR is home to a large number of indigenous or adivasi communities, most of them forest dwellers and hunter gatherers. These distinct ethnic groups have small populations and live in geographical concentrations. The indigenous communities in the NBR include the only surviving hunter-gatherers of the Indian Sub-continent, the Cholanaikans in the New Amarambalam of Nilgiris, and various other groups such as the Todas, Paniyas, Irulas, Kurumbas, Kurichiyans, Mullukurumbans, Adiyans, and Alyars among others. The population of indigenous communities in the NBR is estimated to be 2,00,000.

One of the main activities within the forests of the NBR is the collection of NTFPs, including medicinal plants. Always treated as a minor activity by the Forest Department, this activity has increased in the region over the past few years. The rules of collection vary from state to state, making it convenient to have cross border transactions, and the markets for these products are often informal and traditional. Despite several measures undertaken by the Government under Joint Forest Management, NTFPs are controlled by traders and middlemen. The system is largely exploitative for the adivasi collector.

Fig. 1. Biophysical zones of the Nilgiri Biosphere Reserve. This study was carried out in the Niligiri Plateau and Nilambur Plains regions.



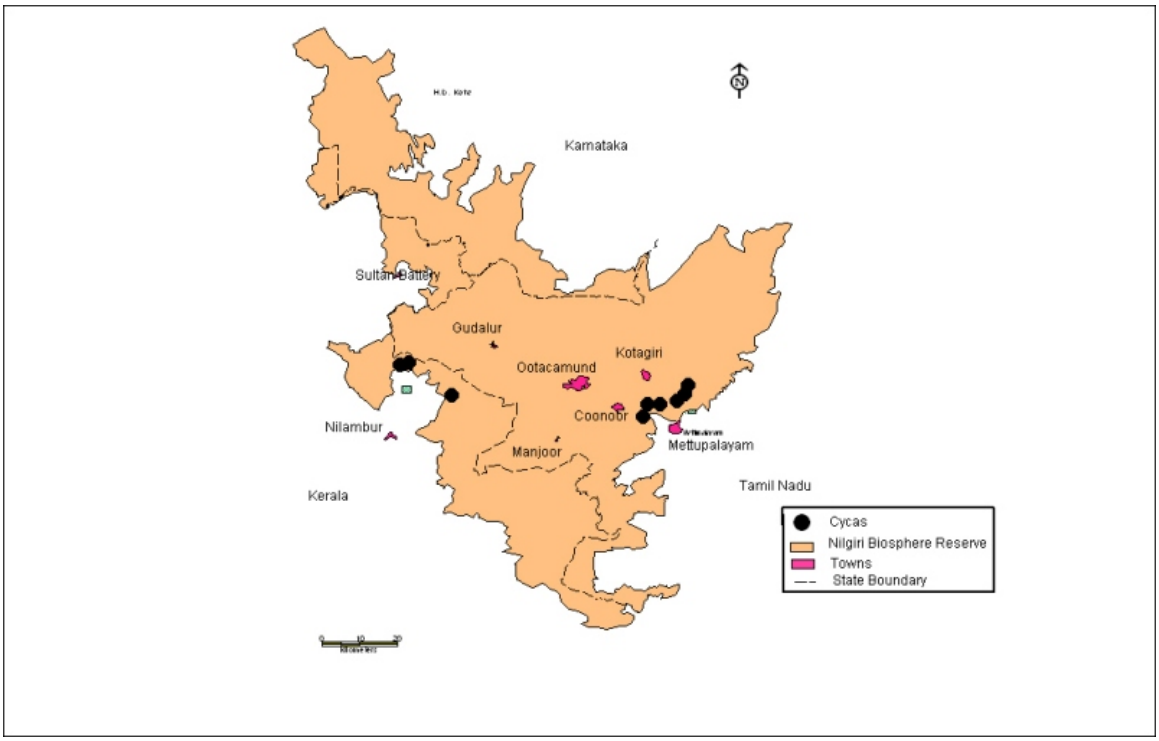
3. 0 Methods

To select communities for study in the NBR, participatory resource mapping exercises were used to map the areas where indigenous people go for collection of forest produce. Community members were asked to mark out the areas of collection of both commercial and non commercial forest produce. Subsequent reconnaissance surveys helped to ground truth the information. Based on this information, the sites where *C. circinalis* was present, and the surrounding communities were chosen for this study. These included 15 communities in nine sites in the states of Tamil Nadu and Kerala (Table 1, Fig. 2).

Table 1. *C. circinalis* study sites.

State	Name of site	Latitude (N)	Longitude (E)	Altitude (m)	Villages close to site	Indigenous group	Proximity of site to village (km)
Tamil Nadu	Velleri Combei	76.897626	11.356348	1012	Velleri Combei	Kurumba	4.5
Tamil Nadu	Marikode	76.868540	11.356530	876	Marikode	Kurumba	3.5
Tamil Nadu	Kudukamedu	76.959075	11.380503	505	Semenarai, Dhalamukh, Gandavayal	Irula	8
Tamil Nadu	Thatekadu	76.940049	11.362946	442	Semenarai, Dhalamukh	Irula	2.5
Tamil Nadu	Kallar	76.858440	11.327200	642	Pudurcombei	Kurumba	4.5
Tamil Nadu	Gudagur	76.967240	11.404070	571	Gudagur	Irula	2
Kerala	Appankaapu	76.288020	11.454910	585	Appankaapu, Thankdankallu	Katunaikans	0.5
Kerala	Vaniampuzha	76.264977	11.450070	300	Vaniampuzha	Paniyas+ Katunaikans	1
Kerala	Punchakolli	76.391566	11.377879	585	Alakal, Punchakolli, Maancheery	Katunaikans	0

Fig 2. Location of *C. circinalis* study sites in the Nilgiri Biosphere Reserve.



3.1. Interviews on use, traditional knowledge and perceptions

To document use and knowledge of *C. circinalis*, we carried out focus groups interviews in the 14 communities listed above. These involved villagers who were willing to participate and included the participation of both women and men. A series of 14 questions (Appendix IA) were asked. These questions addressed traditional knowledge related to *C. circinalis* harvesting practices (e.g. How do you select individuals to harvest? When is the best time to harvest? What are the best ways to harvest and why? Do other animals also use *C. circinalis*?) as well as perceptions on trends in *C. circinalis* trade and abundance (e.g. Have *C. circinalis* populations fluctuated over time and why? How much do prices fluctuate? Who else harvests this resource?). The series of questions was also designed to identify indicators that currently are, and could continue to be, used by local communities for local monitoring of *C. circinalis* conservation.

We also spoke informally with many members in communities across the NBR about their use and knowledge of *C. circinalis*.

3.2. Documenting *C. circinalis* trade

We located three Cycas dealers who were interviewed in the district of Virudhanagar(Tamil Nadu), one of the main markets for medicinal plants in South India to document trade in *C. circinalis*. Semi-structured interviews were used to ask dealers 10 questions in (Appendix IB). These referred to the volume of *C. circinalis* traded, place of origin of products, product quality, and buyers and size (national or international) of the market.

3.3 Assessing impact of harvest on *C. circinalis* populations:

To assess the impacts of harvest on *C. circinalis* population structure and vital rates, in each of the nine study sites all *C. circinalis* populations or patches were located. This ranged form one to three populations/patches per community. One 20 x 20 m permanent plot was then randomly established within each population. In total, 15 plots were established.

In each plot, all *C. circinalis* plants were counted and tagged, including adults, saplings and seedlings. For each individual, the following variables were measured: girth at breast height (GBH), height, number of cut leaves, number of whole leaves, number of leaf scars, number of branches, and fruiting status. Any observations of frugivores were also recorded. Vegetation type and dominant species were also recorded at each plot, canopy cover was ranked as partially open, open or closed, and presence of absence of fire and grazing. All plots were marked using a GPS.

3.4 Analyses of harvest rates and impacts

For each population, the types of and history of harvest (e.g which parts are harvested if any) were documented from the focus group discussions. Rates of leaf harvest were calculated at the individual and population levels. The proportion of leaves harvested per individual was calculated by dividing the number of cut leaves observed over the total number of leaves. The proportion of individuals harvested was also calculated for each size class. To assess how leaf production varies according to size, a regression analysis of the number of leaves produced versus height was also carried out.

To assess the impacts of harvest on population size structure, individuals in populations subject to the same type of harvest were summed and the height-class structure of each was calculated and compared using log-linear analyses. Populations of the same harvest type were summed as opposed to averaged given the low density of *C. circinalis* individuals per patch. A test of whether the ratio of reproductive adults: seedlings was independent of harvest type was carried out using log-linear analyses.

C. circinalis age structure was estimated by carrying out a regression analysis of the number of leaf scars versus height. Age was then estimated from height based on the the number of leaf scars produced per year.

Given that fruit harvest occurs every second year, we were unable to obtain information on rates of fruit harvest. However, this is an on-going study and we are currently collecting information on the following variables: rates of fruit harvest and stem

harvest , ratio of female: male individuals in each population, leaf size, number of leaves produced and number of fruits produced in harvested and non-harvested populations, and resprouting rates of harvested stems.

4.0 Results

4.1 Patterns of use and harvest of *C. circinalis* in NBR

Patterns of use and harvest of *C. circinalis* in the NBR varied across communities and between Tamil Nadu and Kerala states (Table 3).

4.1.1 Leaf and fruit harvest

The focus groups discussions and informal interviews revealed that in Kerala and Tamil Nadu the indigenous communities harvest mainly the fruit and the young leaves of *C. circinalis* (Table 3). These are considered delicacies and are highly valued. In Tamil Nadu, the villagers of Velleri Combei and Semenarai relish the young leaves and steamed fruit. However, the people of Dhalamukh and Gandavayal do not. These preferences seem related to the distance of the village from the resource (Table 2). In Kerala, the Kattu naickans of the villages of Appankaapu and Thandankallu in Nilambur are keen harvesters of *C. circinalis* fruit and the young leaf, but the Cholanaikans of Alakal and Maancheery showed less interest in these. The focus group discussion also revealed reports harvest by non-indigenous people (see below).

The young leaves are collected around October to November and in mid April, when flushing occurs and all new leaves from an individual are harvested. These are brought only for home use. Except for one harvester from Semenarai, most of the harvesters talked about making only one trip to the forests for the leaves. The harvesters also mentioned that as soon as they pinch out the young leaves, within a month a new set of flush is observed. All of them mentioned this as being the most delicious part of the plant. The outer skin of the leaf is removed and the cut leaf is then boiled and the water drained off before the leaf is cooked. The leaves are also cooked with lentils.

The harvesters reported that the fruits are not available for harvest every year. The fruit is collected during the months of July and August in the Nilambur area and between February and March in the Nilgiris area. While speaking to the women of the lower elevation in Nilgiris (Gandavayal), they repeatedly emphasized how actually it was the women in the hills who were experts at cleaning and processing the fruit of *C. circinalis*.

Although in Tamil Nadu *C. circinalis* fruit is harvested for home consumption, in Kerala there is also local demand for the dried fruit for medicine. The harvest is heavy here as the harvesters harvest the fruit and sell it after some processing and drying to the market. The ripe fruit is picked (about 25 kg per day) and smoked on a bamboo mat and then dehusked and dried. Harvesters reports that 25 kgs of fruit would yield only up to two kg of dried fruit. Some of the harvesters talked about washing the fruit in running water before drying it. In Thandankallu, the people reported leaving the outer shell of the fruit to rot in a dark corner of the house, then dehusking. Apparently the fungus on the

Table 3. Use, harvest patterns and demand for *C. circinalis* products in Tamils Nadu and Kerala portions of the NBR.

Part harvested	Harvest Status		Use	Harvest patterns		Demand	
	Tamil Nadu	**Kerala**		**Tamil Nadu**	**Kerala**	**Tamil Nadu**	**Kerala**
Young leaves	Yes	Yes	Food	Men and women involved, but mostly older people. Harvest once per year oct/nov or mid April. Hill communities	Men and women involved, young and old people. Harvest once per year.	Indigenous villages	Indigenous villages
Mature leaves	Yes	Yes	Floriculture, Thatching	For cultural events and small traders who pay up to 2 rupees per leaf. Mostly men involved.Heavy harvest for market.	For religious and cultural events. Men go for collection. Not sold.	Indigenous villages and local markets within the district	Indigenous villages
Fruit	Yes	Yes	Food and medicine	Men and women involved, collection rates of about 80% per individual	Men and women involved, collection rates of about 80% per individual. Observed in August.	Indigenous villages	Indigenous villages and markets within the district due to local demand for the dried kernel to be used in medicinal preparations.

Table 3 Cont'd.

Pith	Yes	Yes	Medicine	Traders bring their own set of harvesters. Clandestine operations with no local people involved. High harvest rates. Exhaustion of populations in Tamil Nadu resulted in move to harvest from homesteads in Kerala.	Traders from Tamil nadu come to collect the whole plant form the homesteads where it grows abundantly	South Tamil Nadu	South Tamil Nadu
Male cone	No	Yes	Medicine, Insect repellent		Local farmers come in to harvest this for use in their paddy fields	None	Local farmers within the district

outer coat breaks down the toxins and then there is no more need to leach the fruit. Boiling the fruit four times and draining the water each time was also one of the techniques reported to leach the fruit. Local residents of Kerala also cook the flour and eat it for its medicinal qualities.

4.1.2. Harvest of mature leaves and stems

Harvesters in Tamil Nadu and Kerala harvest the mature leaves of *C. circinalis* yearly for making the *pandhals* for special rituals (Table 3). According to the people of Thandankallu in Kerala no other leaf can be used.

In the past, the Irula and Kurumba of the Eastern slopes of the Nilgiris were also hired as labor to harvest the mature leaves and the pith when they were permitted for collection. The mature leaves are harvested for the floriculture industry and the pith is sold in medicinal markets (Table 3). They report that heavy harvest of mature leaf and pith collection continues today in the mid elevation forests of the Eastern slopes of the Nilgiris (Fig 3), but since the activity is illegal, it is bands of harvesters from elsewhere who come to do this. Occasionally the indigenous peoples are paid a per leaf rate and harvest the mature leaves for the floriculture industry.

There was no record of harvest for the pith from the Kerala sites. Only in the Appankaapu village area in Kerala were they aware of removal of the pith.

4.1.3. Harvest of male cones

In Kerala, the harvesters discussed that there is demand for the male cones by the local farmers (Table 3). Most paddy farmers place the cone in the middle of their paddy fields to drive away a particular insect which attacks the young paddy. The insect is drawn to the cone because of the smell and leaves the paddy alone.

The harvesters in Tamil Nadu were not aware of the male cone. Only one elderly lady of Velleri combei recognized the cone from our photographs, she called it the *Mudi kai* in Kurumba. Although the harvesters did not discuss the harvest of male cones for medicinal purposes, these are sold as medicine in markets (see below).

4.2 Local knowledge and perceptions

The focus group discussion revealed that there appears to be no tenure associated with *C. circinalis*. The only occasion in which *C. circinalis* was spoken about with special significance was with respect to the harvest of leaves for special rituals. Otherwise the discucsions indicated that it did not feature in lore or other rituals and is treated like a 'poor relative'

In addition, although this species is red listed, there seemed to be no perception of any threat to the species amongst the people who live closest to it. One of the harvesters we spoke to in Kerala mentioned that when he was a child he would take a knife and playfully hack the Cycas trees because they had soft stems and were easy to cut.

When asked if there were any disturbances to the plant, the people of Appankaapu, Thandankallu in Kerala spoke of fire being a threat to the species. The

Fig. 3. ***Cycas Circinalis*** **L**. a) adult with fruit b) pith harvest; male cone beside stump c) harvest of leaves d) seedling.

harvesters of Vellericombei also reported that indiscriminate harvest of the stem causes much damage. This stem harvest was reported from the slopes of Kotagiri.

Almost all the people interviewed mentioned that they have seen the fruits being eaten by small bats and they must be the dispersal agents. People of Kerala told us that they have seen porcupines chewing on the bark of the *C. circinalis*. One individual of Semenarai mentioned that he has seen elephants eating the young leaves.

4.3 *C. circinalis* trade

Cycas circinalis is included in the negative list of exports notified by the GOI Notification 2 (RE-98) dt. 13-04-1998, 1997-2002 (Ravikumar and Ved 2000). Nonetheless, the *C. circinalis* traders interviewed spoke openly about the sale of this species. The four traders interviewed coincided that the price per kg of dried pith is 20 rupees per kg, if it is milky white. One of the traditional traders at Virudhanagar estimated that from Tamil Nadu itself about 200-300 tons of the pith is being traded annually. He reported that the bulk of it was coming from Kerala. The pith is sent to traders in North India to supply to the herbal medicine industry. An extract of the pith is used to increase milk production in lactating mothers. He also reported that the male cone is very important for the production of a male aphrodisiac and much in demand but hard to get.

The vendor emphasized that *C. circinalis* trees were very abundant about 10 years ago and even found in gardens, but now they are gone so that pith is now brought from homesteads in Kerala, where the whole tree is purchased for Rs. 50 -60. The demand is for young trees of around 5 ft. tall as it is the pith found at the lower end of the trunk that is used. Bigger trees have more fibrous piths and are not favorable.

One trader mentioned that the traders and gatherers are in a hurry always and continue to harvest in the monsoons, when it is difficult to dry the produce properly making it brown in color. When the color is brown the price also drops and the traders are not able to sell the produce then.

There are also many small time contractors operating from the base of the forested slopes of the Nilgiris. One forest contractor we interviewed, who has his home in the mid elevation slopes, reported that he contracts harvesters to extract *C. circinalis* leaves and pith. One rupee is paid per mature leaf. Leaf is in most demand around January-February and October to November. He confirmed that pith harvesters look for the younger trees as the pith of these is less powdery and they harvest the pith which is attached to the bark.

4.4. Population monitoring

Fifteen patches of *C. circinalis* were located in nine communities in the NBR. Based on interviews in the local communities and on evidence of harvest in the plots, it was determined that four of these patches were subject only to fruit harvest, four to fruit and leaf harvest, and seven to fruit, leaf and stem and male cone harvest (Table 4).

In total, 150 *Cycas circinalis* individuals, including 179 stems were monitored across the 15 plots.

Table 4. Number of *C. circinalis* study plots established per location and types of harvest to which they are subjected

State	Location	No. of populations monitored	Harvest Type
Tamil Nadu	Gudagur	1	Fruit & leaf
Tamil Nadu	Kallar	1	Fruit, leaf & stem
Tamil Nadu	Kudkmedu	2	Fruit, leaf & stem
Tamil Nadu	Marikode	1	Fruit, leaf & stem
Tamil Nadu	Thattekaru	3	Fruit, leaf & stem
Tamil Nadu	Vellericombei	3	Fruit & leaf
Kerala	Appankapu	1	Fruit only
Kerala	Punjakoli	1	Fruit only
Kerala	Vaniampuzha	2	Fruit only

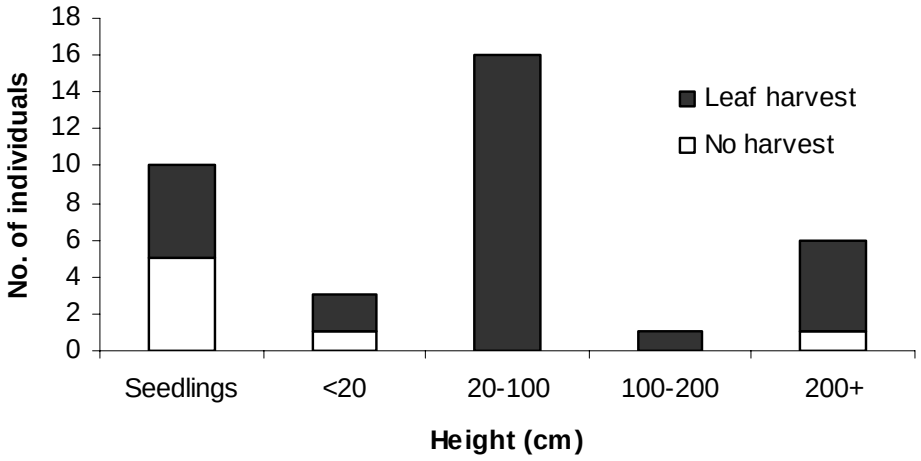
4.4.1 Rates of harvest

The surveys illustrated very high levels of leaf-harvest at the individual level (proportion of leaves harvested per individual) and at the population level (proportion of individuals harvested per populations). At the time of the surveys, two of the regions sampled (Marikode and Vellericombei) had been harvested for their most recent whorl of leaves, and therefore rates and patterns of leaf removal were calculated for these regions only. The other areas sampled are also harvested for their leaves consistently but did not have the most recent whorl harvested.

Ninety-two percent of all *C. circinalis* individuals > 20 cm height (those that have a visible stem) were harvested for their leaves. Only the smallest and the very largest individuals appear to have escaped harvest (Fig 4). All individuals in the 20-200 cm range were harvested. Some of the very largest individuals likely escape harvest as it is very difficult to access their high leaves.

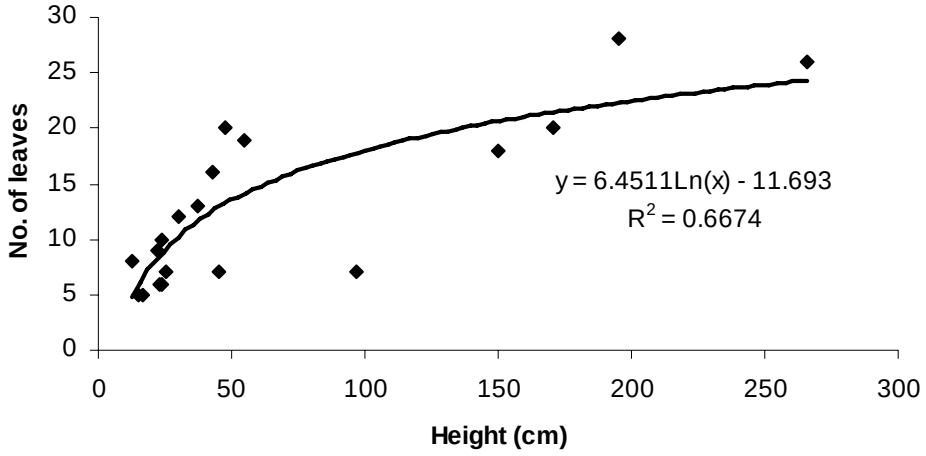
For those individuals that were harvested, an average of 91.3 ± 15 % of all leaves were removed. Only those leaves damaged by insects were left. The consistent harvest of such a high proportion of leaves per individual may be expected to decrease the photosynthetic capacity of the harvested individuals. This in turn could result in decreased number of leaves produced per whorl; and/or decreased leaf size; and/or decreased rates of reproduction. Our data did not yield conclusive results with respect to the number of leaves produced per whorl in harvested versus non harvested plants, because the data collected did not distinguish the presence of dead leaves versus leaves from previous whorls. Therefore this as well as leaf length and reproductive output will be assessed with the next set of monitoring data.

Fig. 4. Proportion of *C. circinalis* individuals harvested for their leaves according to size-classes.



There was no relationship between *C. circinalis* height and the proportion of leaves cut per individual. However, taller cycads produce more leaves and are therefore more desirable targets for harvesters (Fig 5). The number of leaves produced per whorl ranged from 5 in the smallest individuals, to 26 in the largest ones.

Fig. 5. Relationship between *C. circinalis* height and number of leaves produced per whorl. Data obtained from fruit-harvested only populations. N=18, $p < 0.001$



Stem harvest and fruit harvest patterns were not observed. Fruiting occurs every second year in this species, and did not occur the year of this monitoring. This information will be obtained in the upcoming fruiting season.

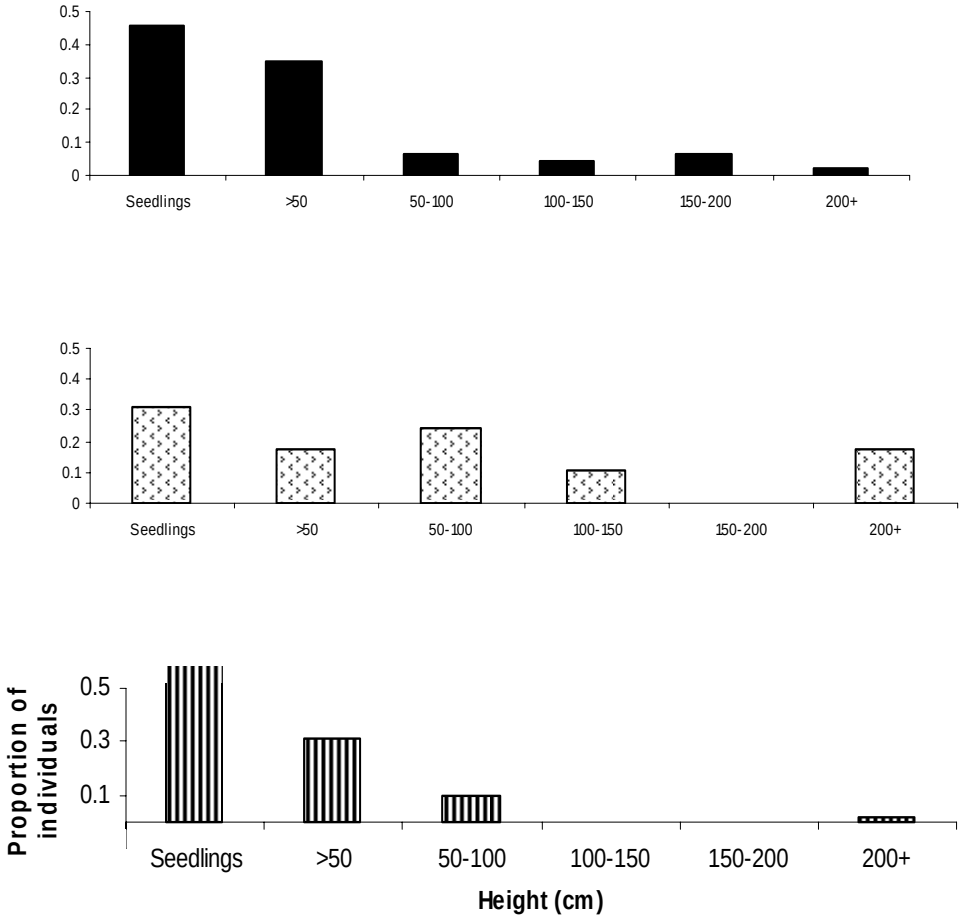
4.4.2 Effects of harvest on *C. circinalis* population size and age structure

The population structure varied among the plots subject to the different harvest types (Fig. 6) and loglinear analyses revealed that structure was dependent on harvest type ($\chi^2 = 25.02$ $p < 0.001$). Populations that were harvested only for fruits showed a reverse J curve, with many individuals in the smaller size classes. This suggests that good levels of regeneration despite fruit harvest.

Populations subject to fruit and leaf harvest showed a much lower proportion of seedlings and saplings. This may indicate lower rates of regeneration as compared to those populations that are not harvested for their leaves. In addition there were no individuals in the 150-200 cm height size class. The very high rates of leaf harvest reported above suggest that the lack of individuals in this size-class could be a result of repeated overharvest of leaves.

The structure of the populations subject to fruit, leaf, stem and male cone harvest consisted almost entirely of individuals in the smallest size classes. There were no individuals larger than 100 cm in height. The one exception was one very large individual (> 200 cm height), but this was found among rocks and highly inaccessible. The lack of adult individuals points to high levels of stem harvest and depletion of the adult population.

Fig. 6. Population structure of *C. circinalis* subject to different types of harvest. a) Fruit harvest only, N= 63; b) Fruit and leaf harvest, N=33; c) Fruit, leaf and stem harvest, N=69. Population structure is dependent on harvest type ($\chi^2 = 25.02$ $p < 0.001$)



There was a very strong positive correlation between number of leaf scars and *C. circinalis* height (Fig. 7). This allowed us to estimate cycad age based on their height. Given that each individual produces two whorls of leaves per year, the height class categories in Fig. 4 can be converted to approximate ages, illustrated in Table 5.

Fig. 7. Relationship between height and number of leaf scars for *C. circinalis*. N=34, $p < 0.001$

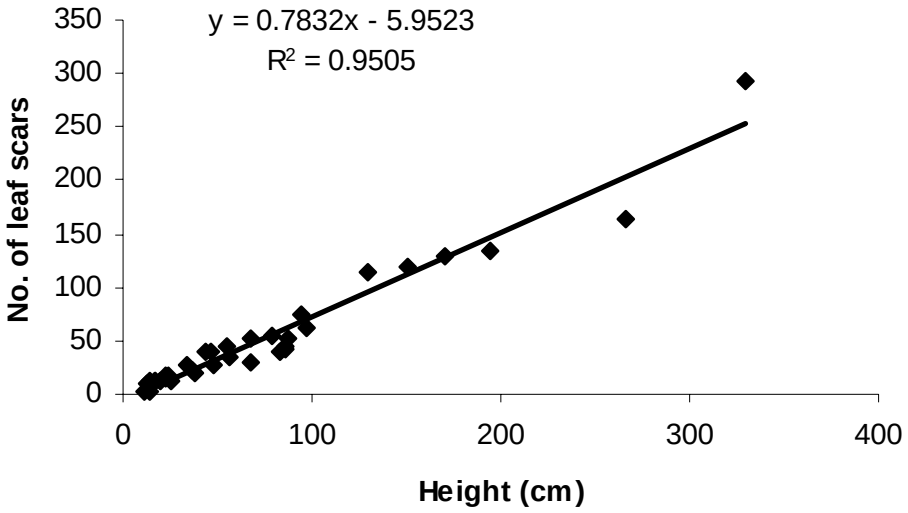


Table 5. Conversion of height classes to age classes based on estimates from number of leaf scars.

Height class category (cm)	Estimated Age Class (years)
Seedlings (no stem)	
< 50 (non reproductive)	<17
50-100	17 – 36
100-150	36-56
150-200	56-75
200 +	> 75

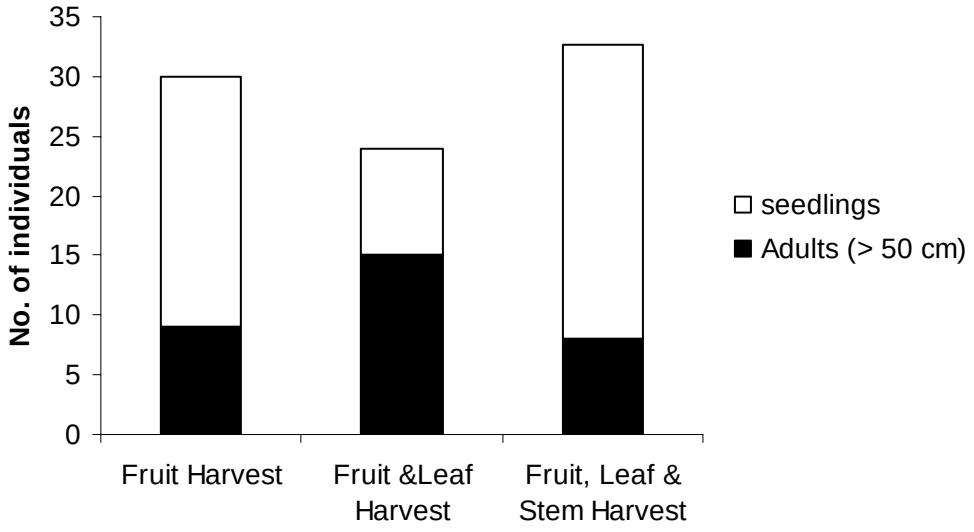
These results suggest that cycads of about 15 years old and more are heavily harvested for their leaves. The data also indicate that *C. circinalis* individuals begin to reproduce at approximately 17 years of age. The biggest individual found measured 330 cm high, and is estimated to be 146 years old.

4. 4.3. Effects of harvest on *C. circinalis* density

The density of individuals was similar between fruit harvested and leaf and stem harvested populations, and was 46 and 43 individuals /1.6 km^2 respectively. The density of adults was lower in the leaf harvested populations (29 individuals/1.6 km^2), but this may also be an artifact of the sampling strategy, as two plots were in patches made up of only young individuals.

The ratio of seedlings: adults was significantly lower in the leaf harvested populations than in the non-harvested populations (p =0.16; loglinear analyses) and than in the leaf & stem harvested populations (p = 0.004) (Fig 8). This is likely due to lower levels of reproduction in the leaf-harvested populations. The low proportion of adults in the leaf &stem harvested populations probably reflects high adult mortality. Individuals are reported to begin flowering at about 50 cm in height and therefore are considered adults in this analysis

Fig 8. Density of *C. circinalis* individuals in plots subject to different types of harvest.



Branching appears to be a response to heavy leaf harvest. None of the *C. circinalis* individuals in the fruit-harvested populations (Kerala) showed any branching. However, 21.3 % of the individuals in leaf harvested populations were branched, with the main apical meristem not producing leaves anymore.

5. Discussion

5.1 Traditional fruit harvest of *C. circinalis*

The steamed fruit of *C. circinalis* continues to be a traditional food for many indigenous communities in the NBR, particularly those who still have close access to wild populations. The fruits of other *Cycas* species elsewhere are also reported to be eaten after steaming, boiling or fermentation (Thieret 1962; Whiting 1962). These processes remove the toxins. The NBR communities we interviewed were aware of the importance of removing the toxins before consumption, commenting that failure to do so would make one lose consciousness.

The population structure and density analyses of fruit-harvested populations suggest that fruit harvest, even at the levels harvested for local medicinal commercial trade in Kerala, appears to have little negative impact on rates of regeneration. Heavy seed harvest has also been shown to have little impact on population growth of other cycads (Raimondo and Donaldson 2003), and other tropical tree species (e.g. Ratsirarson et al. 1996; Zuidema and Boot 2002). However, humans are not the only consumers of *C. circinalis* seeds, and very heavy fruit harvest could have an impact on the bats who are reported to disperse the seeds.

5.2. Leaf harvest of *C. circinalis*

The steamed young leaves of *C. circinalis* also continue to be a traditional food in NBR communities. The young leaves of other *Cycas* species are reported to be consumed in South and South East Asia as well (Whiting 1962). The intensity of this harvest appears to be much less, however, than that of the commercial harvesting of mature leaves for the floriculture market. The harvest of mature leaves from Tamil Nadu for the market appears to be quite prevalent as all populations encountered in Tamil Nadu were harvested for mature leaves. In addition, harvest levels were extremely high in terms of both the percent of individuals harvested per population and of the percent of leaves harvested per tree. The lack of tenure associated with *C. ciricinalis* in NBR communities likely facilitates the harvest of mature leaves and pith by groups of outside harvesters. The trade channel for NTFP in Tamil Nadu can be broadly classified as gatherer-contractor-big contractor- wholesaler-retailer (Samraj 2002). The fact that these harvesters have not moved in to Kerala suggests that currently the availability of *C. circinalis* leaves in Tamil Nadu can still meet the market demands.

This heavy leaf harvest appears to be negatively impacting *C. circinalis* populations. Our ecological results indicate that fruit and leaf harvested populations appear to have reduced rates of regeneration and, likely, elevated mortality of older individuals as a result of consistent leaf-harvest over time. This is consistent with research on leaf harvest of other species such as palms, where heavy leaf harvest leads to decreased reproductive output (Ratsirason, Silander & Richard 1996; Flores & Ashton 2000; Endress, Gorchov & Noble 2004). As with other species (Whitham et al. 1991), *C. circinalis* may be able to allocate the stored resources it holds in its stems to growth and reproduction after defoliation. This could allow for sustained rates of growth and

reproduction (hence the harvesters' observation that a new set of leaves emerge soon after they harvest a set of flushing leaves), but not necessarily over high harvest intensities nor over the long-term. While in some species partial leaf harvest may allow for sustained growth and reproduction due to increased rates of photosynthesis in remaining leaves (Anten et al. 2003), the practice of harvesting almost all of the leaves on *Cycas* would make this impossible in this species.

One critical factor that can greatly alter the impacts of leaf harvest is the timing of harvest. Since *Cycas* produce two flushes of leaves per year, harvest soon before the leaves are shed could have little impact as compared to harvest soon after the flush is produced. The report that one of the favored times for mature leaf harvest is November suggests that this may be soon after flushing and thus likely more damaging.

5.3. Pith and cone harvest

Pith harvest involves cutting the entire plant and results in mortality. The populations we monitored that were harvested for their pith (as well as fruit and stems) were depleted almost entirely of adult cycads, strongly indicating overexploitation. Our results suggest that plants of about five ft tall, which the traders confirmed are preferred for harvest, are approximately 50 years old. This is consistent with our population structure analysis, which indicated that pith-harvested populations consist of individuals less than about 30 years old. However, these populations are devoid of the larger adults as well even though they are apparently not favored for pith. This lack of large adult individuals suggests that either pith harvesters cut down adults of all sizes of trees even though the smaller ones are preferred, or that, potentially, pith harvest has been going on for a long period.

Our results are also consistent with reports from traders and harvesters that many populations have disappeared, and with calculations by FRLHT, who estimated a reduction in *C. circinalis* populations of > 80% and >50% in Karnataka and Tamil Nadu respectively. Other cycads have been found to be able to tolerate annual harvest of less than 5 % of adults (Raimondo & Donaldson 2003), which appears to be much less than current rates of *C. circinalis* populations in Tamil Nadu.

The depletion of wild populations in Tamil Nadu due to stem harvesting can be expected to lead to a lower availability of mature leaves for floriculture collectors. This could lead to increasing penetration of currently unharvested populations in Kerala.

The demand for male cones both for local farmers in Kerala and for the medicinal plant industry could also have a strong impact on regeneration of this dioecious species. The fact that few harveters recognized photos of male cones suggest that the number of male individuals in these populations may be low. We are currently collecting data on this.

5.4 Potential conservation strategies

Our results indicate that *C. circinalis* populations are currently overexploited in Tamil Nadu due to harvest of mature leaves and pith. Given that this harvest is illegal and very difficult to patrol, an obvious but challenging strategy to decrease pressure on wild

populations would be to push for a shift in market demand towards substitutes. For instance, indigenous communities in the NBR who harvest mature leaves for ritual purposes could be encouraged to use substitute species. However, the major impacts of leaf harvest appear to come from external collectors for the floriculture industry and the main strategy would therefore be to encourage this industry to use substitutes such as leaves from cultivated palms that are faster growing.

The biggest impacts on *C. circinalis* populations, however, come from the harvest of pith and male cone for the medicinal plant industry. Here substitutes are not likely an option, and the only potential effective strategy may to increase populations through propagation. The latter can be encouraged by cultivation and enrichment plantings both inside and outside of forests, especially since landless harvesters will likely continue to harvest from wild populations. *C. circinalis* germinates readily and Keystone has been working with communities in the NBR to grow *C. circinalis* in nurseries. For now the plants are planted in the homesteads but need to be planted in the forest areas where their populations are declining.

However, our results indicate that it would take about 50 years for individuals to reach harvest size, so that even if cultivation were to begin now, there would be a long lag in production time. Therefore in the shorter term it will be imperative to somehow protect at least some of the remaining populations. This will be a challenge given the lack of tenure associated with these trees, the fact that they hold low relatively importance in terms of local lore and rituals, and the lack of awareness in general on the importance or endangered status of the species. Nonetheless, community-based monitoring in combination with propagation and value addition that could bring recognition to local villages as 'cycad conservation areas' may be a strategy. Given the heavy demand for this endemic species, and its small range of habitat that is also subject to destruction for other purposes, a combination of all of the above strategies will likely be necessary over the long-term to preserve this species.

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Appendix I.

A. Questions asked to focus groups to document traditional knowledge, management and local perceptions of *C. circinalis*. The questions were also designed to illustrate indicators that harvesters use, and could therefore be possibly used to monitor *C. circinalis* conservation status at the community level.

Question asked	**Perceptions and indicators towards which the question is intended**
What are the tenural considerations with respect to the species/ life forms that you harvest?	*Type of tenure is key factor in sustainability of any harvest system and needs to be identified from the start*
Has the harvested resource fluctuated over time, and if so, why?	*Is there a perception that fluctuation is linked to harvests, prices, scarcity etc?*
How do you tell if it is the right individual to harvest? Are there substitutes to the product in focus and what is the status of the substitutant? (adulturants)	*Might lead to indicators that that harvesters use to identify what is a good or healthy plant to harvest, and could therefore be used for monitoring; harvest/trade of subsistituents may serve as indicator*
When (and why) is it the best time to harvest?	*Perceptions of when plants should be harvested (and can be compared to when they actually are harvested)*
Who are the kinds of harvesters? (Perrenial, Oppurtunistic, Hired etc…..) Are their impacts different?	*Perceptions of what kinds of harvest methods/patterns are best or not*
What is the best way to harvest?	*Adds on to the above question, but more explicit; useful monitoring indicators can involve both ecological indicators on what a good or healthy plant is or needs, as well as the rates of 'bad' or destructive harvest*
How far do you live from the resource? Is there awareness about the disturbance to the resource?	*Perceptions and indicators at the landscape level*
How could we improve the harvests / how could we get more yield?	*Perceptions of what causes overharvest, if there is overharvest, and indicators or protocols for better management*
What are the biggest threats to maintaining or conserving the resource? How could we best save the resource base?	*Relates to the above question, but aimed to identify/include more socioeconomic and landscape level issues*

Can you predict productivity and what are your indicators?	*Indicators for what conditions are needed for good harvests*
What are the links of the species in question to other species?	*Perceptions on potential effects of harvest on plant-plant or plant-animal interactions*
What could happen within the ecosystem if the species in question was to become extinct?	*Perceptions of an ecological role the species could play, impacts at the ecosystem level*
How often do the prices fluctuate and to what extent?	*Perceptions of resource and market fluctuations over time*
Percentage of wasted produce – unripe, harvested in the wrong way, shelf life, transport… what is the reason for this wastage?	*Indicators that could be used to detect overharvest*

B. Interview questions for *C. circinalis* dealers at the state markets.

1. What volume have you traded over the past three years?
2. Place of origin. Any preferred places. If so why are they preferred?
3. What is a quality product?
4. Where is it going to from here?
5. When is the peak availability time?
6. Any primary processing involved?
7. National or export demand?
8. Are there storage facilities?
9. Is it coming from agricultural lands?