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DEVELOPMENT OF CONSERVATION STRATEGIES FOR SELECTED, ENDANGERED RATTAN SPECIES OF THE WESTERN GHATS

(Final report of the project KFRI 404/03 April 2003-March 2007)

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(Forest Ecology & Biodiversity Conservation)

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PROJECT PROPOSAL

Project No.	: KFRI 404/03
Title	Development of conservation strategies for selected, endangered rattan species of the Western Ghats
Investigators	Dr. C. Renuka Mrs. P. Rugmini
Objectives	1. To study the population demography of *Calamus travancoricus* and *C. brandisii*, two endangered rattan species of the Western Ghats. 2. To study their reproductive biology 3. To develop suitable conservation strategies
Duration	April 2003-March 2007
Funding Agency	KFRI Plan Grants

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Abstract

Rattan resources in Kerala are getting reduced drastically and hence there is an urgent need for evolving conservation and management strategies for this valuable resource. Knowledge of the performance of the existing population is essential for this. A demographic study of population changes across the different life stages will help to understand exactly at what stage the population is affected adversely and the reason for the decreasing population size.

Two endangered rattan species of the Western Ghats, *Calamus travancoricus* Bedd. and *C. brandisii* Becc. were selected for the study. *C. travancoricus,* even though distributed throughout the Western Ghats at 200-500 m above msl, populations of considerable size are seen towards the southern parts of the Western Ghats. *C. brandisii* is restricted to the southern part of the Western Ghats at 1000-1500 m above msl. For both species the population size is very small ranging from one plant to 100 at a locality.

The finite rate of population increase, λ, is an estimator of the population growth rate. When λ equals one, the population size is constant, when it is greater than one, the population is increasing and when it is less than one, the population is decreasing. The studies showed that there was an annual decrease of nine per cent in the population of *C. travancoricus* at Arienkavu and 61 per cent decrease in the population of *C. brandisii* at Agasthyamala.

In *C. brandisii* the annual recruitment was decreasing. At the same time there was not much decrease in the annual death rate. The number of flowering plants in the population was very low which affected the seed production. The adult survival rate also was low. This along with long adult stage duration is detrimental to the population with low annual reproductive success. All these resulted in a decreasing population. Sensitivity and elasticity analyses revealed that juveniles and sub adults in *C. travancoricus* and sub adult stage in *C. brandisii* are very important from conservation point of view.

The calculated stable life stage distribution of the two species shows that in a climax population a greater proportion will be constituted by the juveniles. But the observed life stage distribution does not match with this indicating that the population structure is changing rapidly and it has not reached its climax stage. But the finite rate of population increase (λ) is 1.06 in the case of *C. travancoricus* in Achencoil, which shows that this population as a whole is in demographic equilibrium even though some stages of the life cycle are increasing and some decreasing.

The life stage duration of adults is longer in both cases. Hence harvesting only the longest cane would reduce the effect of harvest on population. In the juvenile stage, competition from other undergrowth species, herbivore and human interferences are probably the important causes of death. A reduction of these factors would also cause increased growth rate of juveniles.

In both species the number of fruits produced is lesser when compared to other species of the Western Ghats. In *C. brandisii* natural regeneration seems very poor and only 4.6 per cent of the population belong to seedlings. Hence mature fruits should be collected, germinated and transplanted in the forest areas.

Both species are good quality rattans and are extracted in large quantities for furniture and handicraft industries. In Kerala large populations of *C. brandisii* are seen only at Agasthyamala region. This area is important from the ecotourism point of view, and hence special care should be taken for the protection of this species. For this species all the life stages of the population need protection during conservation efforts, while in the case of *C. travancoricus*, juveniles and sub adults need more protection.

The present study has clearly shown that population dynamics and population structure vary across the range of habitats available. This implies that the conservation strategy developed for one location need not be effective for another location. In problematic species, therefore, population modeling and different conservation strategies for different locations would be needed.

Acknowledgements

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INTRODUCTION

Rattans, the climbing palms, are heavily extracted for furniture and handicraft industries. As a result, many species have become vulnerable or rare in their conservation status. In Kerala, rattans are represented by 15 species belonging to the genus *Calamus* (Renuka, 2000). During the last 25 years, the exploitation of rattans from the Kerala part of the Western Ghats was very extensive and this along with other biotic factors lead to the disappearance of rattans from all accessible areas. Large scale destruction and fragmentation of forests have further aggravated the situation. At present the rattan resources are restricted mostly to remote areas in Kerala; hence better resource management is urgently needed. For effective resource management or conservation programmes to be developed, thorough knowledge of the performance of the existing population is essential. A demographic study of population changes across the different life stages will help to understand exactly at what stage the population is affected adversely and the reason for the decreasing population size.

Demography is the study of population changes and their causes throughout the life cycle. Demographic studies of rare species can provide a logical basis for the planning of conservation management, the design of monitoring programmes and the interpretation of fluctuations in population size. Majority of the plant demographic studies deal with arborescent species (Bannister,1970; Hartshorn, 1975; Van Valen,1975; Ernright and Ogden.1979;Sharukhan, 1980; Bullock and Bawa, 1981). Certain palms also were subjected to demographic studies (Bannister, 1972; Bullock, 1980; Pinero *et al*., 1984; Oyama, 1984; Padmakumar, 2003). Recently Bøgh (1995) and Anto (2005) carried out such studies in rattans. What is needed for such studies is a transition matrix including data on transition probabilities, survival and reproduction for different age classes.

Population growth rate quantifies the changes in the numbers of individuals in a population through time. Vital rates such as survival and reproduction are responsible for these changes and determine the demographic parameters that describe the development of individuals through the life cycle (Caswell, 1989). Demographic parameters are a function of the individual's age, size, developmental state or a combination of any of them. The use of matrix models to address issues of species conservation has increased dramatically in recent years. The surge of interest in matrix models stems from the directness with which matrix models are connected to field data and the clarity with which matrix models link life history traits to population characteristics. Consequently, matrix population models are a primary means of assessing population viability for many species of concern (Burgman *et al*., 1993; Mills *et al.,* 1996; Heppel *et al*., 2000). Sensitivity and elasticity analysis are popular, because they provide a clear, straight forward ranking of the importance of the different demographic rates using sensitivity and elasticity values (de Kroon *et al*., 1986, 2000; van Groenendael *et al*., 1988; Caswell, 1989). Many recent studies have used elasticities to infer which life stages are most important for species conservation (Crouse *et al*., 1987; Wootton and Bell, 1992; Olmsted and Alvarez-Buyllam, 1995; Silvertown *et al*., 1996). Knowledge about the contributions of different stages of the life cycle to population growth rate enhances our understanding of the life histories of species.

Calamus travancoricus Bedd. and *C. brandisii* Becc. are two endangered rattan species of the Western Ghats (Renuka, 2001). These rattans are extracted in large quantities for furniture as well as handicraft industries and conservation efforts are very urgently required for these species. Hence this project was initiated with the following objectives,

- to study the population demography of *Calamus travancoricus* and *C. brandisii*, two endangered rattan species of the Western Ghats.
- to study their reproductive biology and
- to develop suitable conservation strategies.

REVIEW OF LITERATURE

DEMOGRAPHY

A number of demographic studies on palms have been published during the last three decades. Most of the studies have sought a general understanding of populaton and community dynamics (Bullock, 1980; Pinero *et al*., 1984; Pinard, 1993; Olmsted and Alvarez-Buylla, 1995; Svenning and Balslev, 1997; Bernal, 1998; Pena-Claros and Zuidema, 1999; Silva Matos *et al*., 1999; Padmakumar, 2003). However, the population studies on rattans are very few (Bǿgh, 1995; Anto, 2005). Demography of *Astrocaryum sciophilum*, an understory palm, was studied by Sist (1989), where the dynamics and seed dispersal of three populations of tropical forest were explained. Growth and survival of seedlings of *Welfia georgii* were noted by Vandermeer (1990). Vandermeer (1993) studied the successional pattern of understory palm in Costa Rica. The population structure of different palms were studied by Hnatiuk (1997) and Savage and Ashton (1983).

The effective population size was used for the estimation of relative importance of genetic drift in tropical palm *Astrocaryum mexicanum* in Mexico (Sarukhan and Pinero, 1993). Zakaria *et al*. (1999) conducted a demographic study of *Arenga westerhoutii* and *A. obtusifolia.* For both species the highest mortality occurred during the seedling phase. The demography of natural population of *Euterpe edulis* was analyzed by Reis *et al*. (2000). According to them, the natural populations showed a pyramid-shaped demographic structure with a large base of juvenile plants and a small number of reproductive individuals. This suggested a strong dependence of a large population on a proportionally small number of genetically effective individuals.

Bruna (2003) studied the effect of limited recruitment on plant population on fragmented habitat. This study reveals that the decreased recruitment to be a primary mechanism driving the local extinction of a plant species from fragmented landscapes. Genet and ramet demography of *Oenocarpus mapora*, a palm of Barro Colorado island, was studied by De Steven (1989). He proved that a static population structure in the climax forest type was evident in its low genet population density, high dominance of adult clones and poor seedling recruitment. Population dynamics of *Rhopalostylis sapida* was studied by Enright and Watson (1992).

The study by Ratsirarson *et al*. (1996) on *Neodypsis decaryi*, a threatened palm species in Madascar, showed a high mortality rate in early stage of life cycle. Demographic studies indicated that the population was either stable or increasing. Sensitivity and elasticity analysis indicated that adult population is the most sensitive to the changes in population growth rate.

REPRODUCTIVE BIOLOGY

Studies on reproductive biology of rattans are very few. Bøgh (1996) investigated the phenology of four Thailand rattans. Mohd. Zaki and Othman (1998); Banik and Nabi (1981); Alloysius (1994) and Raja Barizan (1992) conducted studies on the initiation of flowering in rattans. Renuka (2003) and Sulekha (2004) reported the reproductive biology of certain Western Ghat rattan species.

At present our knowledge on pollination mechanism in rattans is very limited. Both anemophily and entomophily have been recorded in rattans (Dransfield, 1979; Lee and Jong, 1995; Renuka *et al*., 1998; Sulekha, 2004). Fruiting phenology of three rattan species was reported by Renuka (1995).

Generalao (1977) reported that viability of rattan seeds was related to moisture content and dry storage methods were not effective. Sulekha (2004) conducted detailed embryological studies on *Calamus thwaitesii* and *C. hookerianus* and reported that the seeds are recalcitrant. She also reported the development of a haustorium by the enlargement of the basal part of the embryo.

The germination percentage and time taken for germination vary widely between and within the species (Generalao, 1997; Manokaran, 1978; Agmato,1984). Removal of hilar cover and stratification of the seeds were suggested by Agmato (1984) and Bagalayos (1987) for reducing the time required for germination..

MATERIALS AND METHODS

MATERIALS

The species selected were *Clamus brandisii* Becc. ex Becc. & Hook. f. and *Calamus travancoricus* Bedd. ex Becc. & Hook. f. Both species are seen in the evergreen forests. *C. travancoricus,* even though has an extended distribution along the Western Ghats between 200-500 m msl, populations of considerable size are located towards the southern part of the Western Ghats. *C. brandisii* is restricted to the southern end of the Western Ghats at an altitude of 1000-1500 m msl. The populations of both species are very much scattered and the population size is very small ranging from a single plant to a hundred.

Calamus brandisii Becc. ex Becc. & Hook. f.

A cluster forming, slender rattan. Stem with sheaths 1.5 cm in diameter, without sheaths up to 0.8 cm. Leaves about 1m long; leaf sheath green, with minute bristle like spines; mouth of the sheath with larger spines to 4 cm long; knee present; leaflets grouped. Male and female inflorescences long and slender; partial inflorescence 55 cm long. Fruits ovate, 1.8 x 0.8 cm, scales arranged in 17 vertical rows, slightly channeled in the middle, brown with dark brown border (Fig. 1).

Figure 1. ***Calamus brandisii* . A) Habit B) Fruits**

Calamus travancoricus Bedd. ex Becc. & Hook. f.

A very slender, cluster forming rattan. Stem with sheaths to 0.8 cm in diameter and without sheaths to 0.4 cm. Leaf to 45 cm long; leaf sheath green, armed with small spines of 0.5 cm length, mouth of the sheath with slightly longer spines; leaflets grouped. Inflorescence to 1 m long, partial inflorescence 10-12 cm long. Fruit 1 cm across, globose, scales in 24 rows, straw yellow with dark brown border (Fig. 2).

Figure 2. ***Calamus travancoricus.*** **A) Habit B) Fruits**

Study area

The study plots for *C. travancoricus* were selected at Achencoil and Arienkavu Forest ranges while that for *C. brandisii* were selected in Agasthyamalai at Kuranchadikadavu. All the plots suffer moderate disturbances from human population. Four plots of 25 m x 25 m were selected in each area.

METHODOLOGY

Four life stages such as seedlings, juveniles, sub-adults and adults were defined on the basis of the changes in growth mode and reproductive status, which occur during the life of an individual (Table 1).

Table 1. Life stage and size of individuals recorded

Life stages	Seedling (acaulescent, < 4 leaves)	Juvenile (acaulescent, ≥ 4 leaves)	Sub adult (Stem length till flowering)	Adult (Stem length after flowering)
Size units	Number of leaves	Number of leaves	Length of stem (cm)	Length of stem (cm)
C. travancoricus (Achencoil)	1 - 4	4-25	< 630	≥ 630
C. travancoricus (Aryankavu)	1 – 4	4-25	< 770	≥ 770
C.brandisii (Agastyamala)	1 – 4	4-10	< 500	≥ 500

The number of individuals coming under each life stage was observed periodically, at three months interval, for two years.

Data collection

All rattans rooted in the plot were marked with numbered plastic tags. Height and diameter of the stem were recorded. On each stem one leaf was marked by removing a few pinnae near the leaf base. The position of the marked leaf relative to the apical leaf was carefully recorded. Production of new leaf was noted from the position of the marked leaf in later surveys. Number of new leaves and suckers were noted. Internodal length was measured as the distance of the stem between two adjacent leaves.

Data analysis

Population matrix

The data analysis was based on the method formulated by Bǿgh (1995). For each life stage yearly transition probabilities, G_i, and yearly probabilities of surviving and remaining in the same stage, P_i, were calculated. Average yearly fecundities, F_{ij}, were calculated for the reproductive stages. All estimates of growth and survival rates were calculated assuming that the rates were equal for all individuals in each stage.

Yearly transition probabilities, G_i, was calculated as:

$$G_i = \sigma_i / \bar{\tau}_i; \; i = 1, 2, 3$$

where σ_i is the survival probability and $\bar{\tau}_i$ is the average stage duration. For the seedling and juvenile stages $\bar{\tau}_i$ was calculated from the proportion of individuals that survived through the study period. Among sub-adults and adults deaths were rare. In these stages the defining size ranges were divided into halves. The survival probabilities were calculated from the decrease in number of individuals from the first half to the second half of the stage. The calculations of $\bar{\tau}_i$ and the survival probability, σ_i; of the sub-adult and adult stages were based on the assumption that the size distribution within the stages was stable. Stage durations, $\bar{\tau}_i$, were calculated as the average time required for surviving individuals to pass through a given stage at the observed growth rates. Seedling and juvenile growth rates were calculated as the increase in number of leaves. The growth rates of sub-adults and adults were calculated by multiplying the number of new leaves produced per year by the average internodal lengths. Then age was obtained by dividing total height by the product of number of new leaves produced and average internodal length.

Probability of survival, P_i, was calculated as:

$$P_i = \sigma_i - G_i; \quad i = 1, 2, 3, 4$$

Estimates of sexual fecundities, F_{14} were calculated as the ratio between the number of new seedlings and the total number of adults.

The vegetative fecundities of the sub-adult and adult stages, F_{23} and F_{24}, were calculated as the average production of new suckers per individual in each stage.

The above mentioned parameters were used to construct transition matrices as shown below. From these matrices the finite rates of population increase, λ, were calculated as the dominant eigen values, whereas the stable life stage distributions, w, were given by the corresponding right eigen vectors. Finally, elasticity values for the matrix coefficients were calculated (Table 2).

Table 2. Matrix Elements

	Seedling	Juvenile	Sub-adult	Adult
Seedling	P_1	0	0	F_{14}
Juvenile	G_1	P_2	F_{23}	F_{24}
Sub-adult	0	G_2	P_3	0
Adult	0	0	G_3	P_4

Sensitivity and elasticity

Sensitivities are the sensitivity of λ, the asymptotic population growth rate, to an absolute change in each element in the projection matrix. The sensitivities allow one to see what would happen to the population growth rate if we could improve survival and fecundity values in the projection matrix one at a time of particular value.

Elasticity analysis estimates the proportional change in the population growth rate for a proportional change in a vital rate ie., survival, growth or reproduction. It can be used to point out the stage of an organism's life history that should be the focus of management effort, or those that contribute most to fitness.

The asymptotic rate of population growth is given by the dominant eigen value, λ, of the above projection matrix. The stable stage structure and reproductive values are given by the corresponding right and left eigen vectors W and V. The sensitivity, $S_{ij,}$ of λ to change in the matrix element $a_{ij,}$ of projection matrix is given by the partial differential, ∂.

$$s_{ij} = \frac{\partial\lambda}{\partial a_{ij}} = \frac{(\boldsymbol{VW})}{<\boldsymbol{VW}>}$$

where < > represents the scalar product of vectors. Sensitivity measures how λ changes with an absolute change in a_{ij}. The effect of proportional changes in a_{ij} can be explained by scaling the sensitivities and calculating elasticities (e_{ij}) using formula,

$$e_{ij} = \frac{(a_{ij}\partial\lambda)}{(\lambda\partial a_{ij})} = \frac{\lambda\log\lambda}{\lambda\log a_{ij}}$$

Elasticity also has the useful properties that they sum to 1.0, and thus also represents the proportional contribution of each element to λ. Even though, both sensitivity and elasticity are used in management programmes, generally, elasticities are considered more useful for management consideration.

Sensitivity only gives a proportional clue to the change of a_{ij} to λ. In this proportional change, it does not give equal weightage to fecundity and survival. It gives more importance to sensitivity changes of fecundity than survival. Moreover, s_{ij} is very large even though $a_{ij} = 0$. When we are comparing the plants which show similar life history parameters with growth rate differences in field condition, an analytical measure of proportional sensitivity i.e. elasticity is used. Here proportional change in a_{ij} gives proportional change in λ (de Kroon, *et al*., 1986).

Population dynamics

The data analysis was based on the method formulated by Zar (1974). To study how the life stages vary in the consecutive observations, regression was formulated with number of each life stage of plants as dependent variable and period as independent variable Different functional forms were tried and the best fitted models were selected based on adjusted R^2 values.

Seasonal variation in recruitment and death rates

The transition from one life stage to another is termed as recruitment. Recruitment may occur from seeds or by producing suckers. Rate of new recruitment was found out as follows:

Rate of new recruitment = (n/N) 100, where 'n' is the number of new recruitment and 'N' is the total number of plant at the time of initial observation.

Rate of death was calculated with the formula

Rate of death = (d/N) 100 where 'd' is the number of deaths noted in a particular period and 'N' is the total number of plants observed in that particular plot at the time of initial observation.

Population flux

Summarization of the population dynamics for each species is the population flux. It was calculated for an annual basis for the whole period. From the population flux the variations in the annual recruitment and death of the study period were calculated. It gives the changing pattern of population in the consecutive years.

The rate of increase was calculated as a / b, where 'b' is the total number of plants in the final measurement and 'a' is the number of plants in the initial measurement. The total arrival and total mortality in the total period or year- wise are included in the population flux. From the data, the total plants recorded during the period was calculated as 'a + e' where 'a' is the initial number of plants and 'e' the number of new arrivals or recruitments during the period.

The percentage of death was calculated as (f/g) 100, where 'f' is the total mortality during the period and 'g' is the number of total plants recorded. The percentage of annual recruitment was calculated as (e / g)100, where ‘e’ is the total arrival between the period and ‘g’ is the number of total plants recorded.

Reproductive biology

Frequent visits were made to the study plots to monitor the flowering season. Once the flowering started, regular observations were carried out from the period of initiation of inflorescence to the period of fruit maturation. During anthesis the inflorescences were observed continuously for 10 - 20 minutes, at an hourly interval. The observations were continued for 48 hours. The sequence of flower opening was studied by marking the individual rachillae. Pollen viability and stigma receptivity were studied through artificial pollination and through in vitro germination. Observations were made on the presence and behaviour of visiting insects. The insects were tested for pollen loads under microscope. A strip of transparent adhesive tape was suspended for about 24 hrs near the pistillate inflorescences. The strip was observed under microscope for the presence of pollen.

Seeds were stored in air-tight plastic bags at room temperature, at 10 ^{0}C and at 5 ^{0}C and their viability was assessed periodically.

RESULTS

DEMOGRAPHIC STUDIES

Number of plants under each life stage

At Achencoil, number of seedlings ranged from 11-51, juveniles varied from 13-43 and sub adults from 17-47. The number of adults were very low, only one or two adult plants were seen in the population. At Arienkavu the number of seedlings ranged from 26-76, juveniles from 7-49 and sub adults from 52-84. Here there were more adult plants in the population and it varied from 12-18. Total number of plants increased during the study period in both locations.

Table 3. Number of individuals of *C. travancoricus* in each stage at Achencoil

Measurement time	Seedlings	Juveniles	Sub adult	Adult	Total
Dec 04	35	13	18	1	67
March 05	32	20	17	1	70
June 05	29	28	16	2	75
Sept 05	19	37	16	2	74
Dec 05	13	43	17	2	75
March 06	11	39	25	2	77
Sept 06	51	21	47	2	121

Table 4. Number of individuals of *C. travancoricus* in each stage at Arienkavu

Measurement time	Seedlings	Juveniles	Sub adult	Adult	Total
Dec 04	51	7	63	14	135
March 05	42	20	60	13	135
June 05	34	33	63	12	142
Sept 05	30	47	52	17	146
Dec 05	26	48	55	17	146
March 06	26	49	61	18	153
Sept 06	76	18	84	18	196

Table 5. Number of individuals of *C. brandisii*

Measurement time	Seedlings	Juveniles	Sub adult	Adult	Total
Dec 04	2	4	31	6	43
March 05	3	2	32	8	45
June 05	19	2	29	8	58
Sept 05	21	21	28	7	77
Dec 05	23	20	33	7	83
March 06	30	17	45	7	99
Sept 06	22	37	43	8	110

In case of *C. brandisii* the number of seedlings varied from 2-30, juveniles from 2-21, sub adults from 28-45 and adults from 6-8. Here also the number of total plants increased during the study period.

Growth characteristics

The Growth characteristics measured during the study period are shown in table 6.

Table 6. Growth characteristics

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Average internodal length (cm)</th><th colspan="2">Average No. of leaves</th><th colspan="3">Average No. of suckers</th><th colspan="2">Average height (m)</th><th colspan="2">Average sucker height (m)</th></tr>
<tr><th>SA</th><th>A</th><th>J</th><th>SA</th><th>A</th><th>SA</th><th>A</th><th>SA</th><th>A</th></tr>
<tr><td>C. travancoricus (Achencoil)</td><td>9.2</td><td>18</td><td>18</td><td>1</td><td>2</td><td>3</td><td>2.6</td><td>6.8</td><td>1.2</td><td>2.1</td></tr>
<tr><td>C. travancoricus (Arienkavu)</td><td>11.6</td><td>17</td><td>22</td><td>2</td><td>2</td><td>4</td><td>3</td><td>1.1</td><td>1.9</td><td>5.7</td></tr>
<tr><td>C. brandisii</td><td>11.5</td><td>14</td><td>28</td><td>1</td><td>3</td><td>4</td><td>1.8</td><td>6.9</td><td>2.4</td><td>2.6</td></tr>
</table>

The average internodal length, average number of leaves, average number of suckers average height of the main stem and that of the suckers are given in table 6. There were significant differences on the annual rate of leaf production in case of seedlings and juveniles while sub adults did not show significant differences (Tables 7, 8).

Table 7. ANOVA on mean number of leaves produced in each stage

Species	source	df	Sum of Squares	Mean Square	F
C. travancoricus	Between stage	3	126.885	42.295	36.938**
	Within Groups	11	12.595	1.145	
	Total	14	139.480		
C. brandisii	Between stage	3	107.023	35.674	18.674**
	Within Groups	12	22.924	1.910	

Table 8. Mean number of new leaves produced in each stage

Stage	*C. travancoricus*		*C. brandisii*	
	Mean	Std. Error	Mean	Std. Error
Seedling	5.813[c]	.1383	5.700[c]	.8554
Juveniles	9.165[b]	.6999	9.389[b]	.9635
Sub adults	13.076[a]	.5677	11.232[ab]	.3637
Adults	12.321[a]	.6608	12.583[a]	.3436

Life stage duration

The calculated life stage duration is given in table 9. For both species the seedling stage duration was one year. The duration of juvenile stage for *C. brandisii* (7.1 years) was slightly lesser than *C. travancoricus* (8.4-8.9 years). But the duration of the sub adult stage vary between species and within species in different localities.

C. travancoricus remained in the sub adult stage for 26.5 years at Achencoil while it was only 9.9 years at Arienkavu. The duration of sub adult stage in *C. brandisii* was only 1.5 years. Stage duration of adults in *C. travancoricus* varied from 43.6 at Achencoil to 66.9

Table 9. Calculated Stage duration in years

Species	Seedling	Juvenile	Sub adult	Adult	Total
C. travancoricus (Achencoil)	1	8.4	26.5	43.6	79.6
C. travancoricus (Arienkavu)	1	8.9	9.9	66.9	86.8
C. brandisii	1	7.1	1.5	69.8	79.4

at Arienkavu and that in *C. brandisii was* 69.8. The sum of the stage duration are estimates of the longevities of the species. At Achencoil it was 79.6 years and at Arienkavu it was 86.8 while for *C. brandsii* it was 79.4 years.

Population matrix

The transition matrices given in tables 10-12 are the calculated demographic rates. A visual representation of the rates is given in Figures 3-4. The probabilities of surviving and remaining in the same stage (P values) are listed on the matrix diagonals. P_1(Seedling) values were relatively small for both species. In case of *C. brandisii* P_1 and P_2 (Juveniles) values were zero. For *C. travancoricus* P_2 and P_4 (Adult) values at Achencoil were greater than that at Arienkavu while P_3 (Subadult) value was greater at Arienkavu. In *C. brandisii* P_3 value was greater than P_4.

Table 10. Projection matrix for *C. travancoricus* in Achencoil

λ = 1.06

	Seedling	Juvenile	Sub adult	Adult	w
Seedling	0.03	0	0.00	6.58	0.090
Juvenile	0.029	0.77	2.14	2.5	0.803
Sub adult	0	0.091	0.28	0	0.093
Adult	0	0	0.010	1	0.014

Table 11. Projection matrix for *C. travancoricus* in Arienkavu

λ = 0.91

	Seedling	Juvenile	Sub adult	Adult	w
Seedling	0.02	0	0	0.87	0.011
Juvenile	0.020	0.57	2.36	3.7	0.866
Sub adult	0	0.064	0.43	0	0.112
Adult	0	0	0.043	0.50	0.011

Table 12. Projection matrix for *C. brandisii*

λ = 0.39

	Seedling	Juvenile	Sub adult	Adult	w
Seedling	0	0	0	1.90	0.200
Juvenile	0	0	2.97	4.35	0.724
Sub adult	0	0	0.39	0	0.035
Adult	0	0	0.26	0.17	0.041

For *C. travancoricus* at Achencoil the yearly transition probabilities of seedling to juvenile (G_1) was less than that of juvenile to sub adult (G_2). Same trend was shown at Arienkavu also, but here G_3 (Sub adult to adult) value was greater than G_1. For *C. brandisii* G_3 value was greater than G_1 and G_2.

Sexual fecundity (F_{14}) was greater in *C. travancoricus* at Achencoil (6.58) when compared to that at Arienkavu (0.87). In *C. brandsii* it was 1.90. Vegetative fecundities of the sub-adult and adult stages, F_{23} and F_{24} of *C. travancoricus* at Achencoil were 2.14 and 2.5 and that of Arienkavu were 2.36 and 3.7. These values in case of *C. brandisii* were 2.97 and 4.35.

Achencoil

Arienkavu

Figure 3. Graphical representation of the stable stage duration and transition rates of *C. travancoricus*

Figure 4. Graphical representation of the stable stage duration and transition rates of *C. brandisii*

The stable life stage distribution (w) of adults (Tables 10-12) was low in both species. The finite rate of population increase λ was slightly greater than one in *C. travancoricus* at Achencoil while it was slightly lesser than one at Arienkavu. For *C. brandisii* the λ value was very low. A λ value greater than 1 indicates that the population is stable if the demographic rate remains constant. At Arienkavu the population of *C. travancoricus* is decreasing by nine per cent per year while at Arienkavu, the population is increasing by six per cent annually. The low value for *C. brandisii* indicates that the population is decreasing. It shows 61 per cent annual decrease.

Sensitivity

One percent change in the survival value of the juveniles of *C. travancoricus* will make a change of 0.477 per cent and 0.546 per cent in the λ value at Achencoil and Arienkavu respectively. In *C. brandisii* P value was prominent only for sub adults (Tables 13-15). Sexual fecundity values were very low or zero in all cases. One per cent change in the vegetative fecundity will make a change of 0.05 and 0.07 percentages in the λ value at Achencoil and Arienkavu (Tables 13,14) respectively. In *C. brandisii* vegetative fecundity was zero.

Elasticity

In *C. travancoricus* at Achencoil the highest elasticity value was for juveniles followed by adults. These two stages were critical in changing the λ value of this species at Achencoil.

At Arienkavu, the juvenile survival elasticity was higher followed by sub adults and hence these two stages had the major role in changing the λ value. In case of *C. brandisii* only sub adults had any role in changing the λ value (Tables 16-18).

Table 13. Sensitivity of *C. travancoricus* at Achencoil

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.002	0.020	0.002	0.000
Juvenile	0.054	0.477	0.055	0.008
Sub adult	0.174	1.551	0.179	0.027
Adult	2.229	19.824	2.290	0.341

Table 14. Sensitivity of *C. travancoricus* in Arienkavu

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.0001	0.0114	0.0015	0.0001
Juvenile	0.0072	0.5464	0.0705	0.0072
Sub adult	0.0397	3.0278	0.3907	0.0397
Adult	0.0628	4.7921	0.6183	0.0628

Table15. Sensitivity of *C. brandisii*

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.000	0.000	0.000	0.000
Juvenile	0.000	0.000	0.000	0.000
Sub adult	5.783	20.891	1.000	1.174
Adult	0.000	0.000	0.000	0.000

Table 16. Elasticity of *C. travancoricus* at Achencoil

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.000	0.000	0.000	0.002
Juvenile	0.002	0.363	0.117	0.020
Sub adult	0.000	0.140	0.049	0.000
Adult	0.000	0.000	0.024	0.338

Table 17. Elasticity of *C. travancoricus* in Arienkavu

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.000003	0.000000	0.000000	0.000128
Juvenile	0.000139	0.309119	0.164731	0.026230
Sub adult	0.000000	0.192969	0.165778	0.000000
Adult	0.000000	0.000000	0.026376	0.031089

Table 18. Elasticity of *C. brandisii*

	Seedling	Juvenile	Sub adult	Adult
Seedling	0.000	0.000	0.000	0.000
Juvenile	0.000	0.000	0.000	0.000
Sub adult	0.000	0.000	0.383	0.000
Adult	0.000	0.000	0.000	0.000

Observed stage distribution

The observed stage distribution (Table19) showed that in the existing population of *C. travancoricus* at Achencoil, 52.24 per cent were seedlings, 19.40 per cent were juveniles, 26.87 per cent were sub adults and 1.49 per cent were adults. At Arienkavu, 37.78 per cent were seedlings, 5.19 per cent were juveniles, 46.67 per cent were sub adults and 10.37 per cent were adults. For *C. brandisii* 4.654 per cent were seedlings, 9.30 percent were juveniles, 72.09 per cent were sub adults and 13.95 per cent were adults.

Table 19. The observed stage distribution (in %) of the three species studied

Species	Seedling	Juvenile	Sub adult	Adult	χ^2 test
C. travancoricus Achencoil	52.24	19.40	26.87	1.49	192.4 P<0.0001
C. travancoricus Aryankavu	37.78	5.19	46.67	10.37	2011.4 P<0.0001
C.brandisii	4.65	9.30	72.09	13.95	616.9 P<0.0001

The stable stage distribution (w) of the two species showed that juvenile stage constitutes a much grater proportion of the stable population for all three cases (Tables10-12). Whether the observed stage distribution follows the same pattern as stable stage distribution was tested by using χ^2. Chi-square was found significant in all the three cases indicating that the observed stage distribution was significantly different from the stable stage distribution.

Population dynamics

At Achencoil, seedlings and sub adults were the major components in the population. But in Arienkavu, sub adults were the major component followed by seedlings. The number of adults at Achencoil was very low, varying from one to nine. In both places the number of total plants increased during the study period. In *C. brandsii* sub adult stage was the major component in the population. The number of adults was low in the population. The total number of plants increased during the study period (Tables 3-5).

Recruitment and death rates

The recruitment and death rates of both the species are given in tables 20-22. In *C. travancoricus* recruitment rate increased considerably by the end of the study period. It increased up to 57.14 in Achencoil and 31.37 at Arienkavu. The maximum death rate at

Table 20. Death and recruitment rate of *C. travancoricus* at Achencoil

Month	No. death	No. recruitment	Death rate	Recruitment rate
1	0	0	0.00	0.00
4	2	5	2.99	7.46
7	2	7	2.86	10.00
10	4	3	5.33	4.00
13	8	9	10.81	12.16
16	4	6	5.33	8.00
22	0	44	0.00	57.14

Table 21. Death and recruitment rate of *C. travancoricus* at Arienkavu

Month	No. death	No. recruitment	Death rate	Recruitment rate
1	0	0	0	0
4	6	6	4.44	4.44
7	2	9	1.48	6.67
10	2	6	1.41	4.23
13	6	6	4.11	4.11
16	5	12	3.42	8.22
22	5	48	3.27	31.37

Achencoil was 10.81 and that at Arienkavu was 4.44. The death rate was found reduced to zero at Achencoil and to 3.27 at Arienkavu. In case of *C. brandisii*, the recruitment rate increased up to 33.33 while the death rate increased up to 7.79 during the study period but both decreased towards the end. There was no definite periodicity for maximum recruitment and death rates in both the species (Figs. 5-7).

Table 22. Death and recruitment rates of *C. brandisii*

Month	No. death	No. recruitment	Death rate	Recruitment rate
1	0	0	0	0
4	1	3	2.33	6.98
7	2	15	4.44	33.33
10	0	19	0.00	32.76
13	6	12	7.79	15.58
16	4	20	4.82	24.10
22	6	17	6.06	17.17

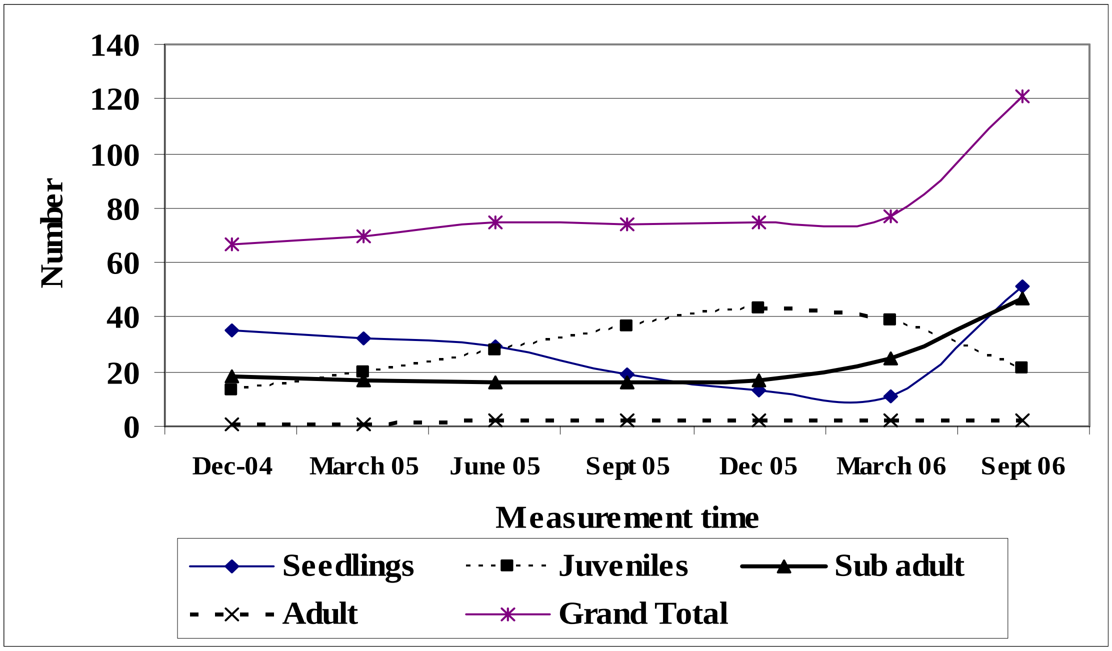

Figure 5. Seasonal variation in the number of individuals *of C. travancoricus* in each stage at Achencoil

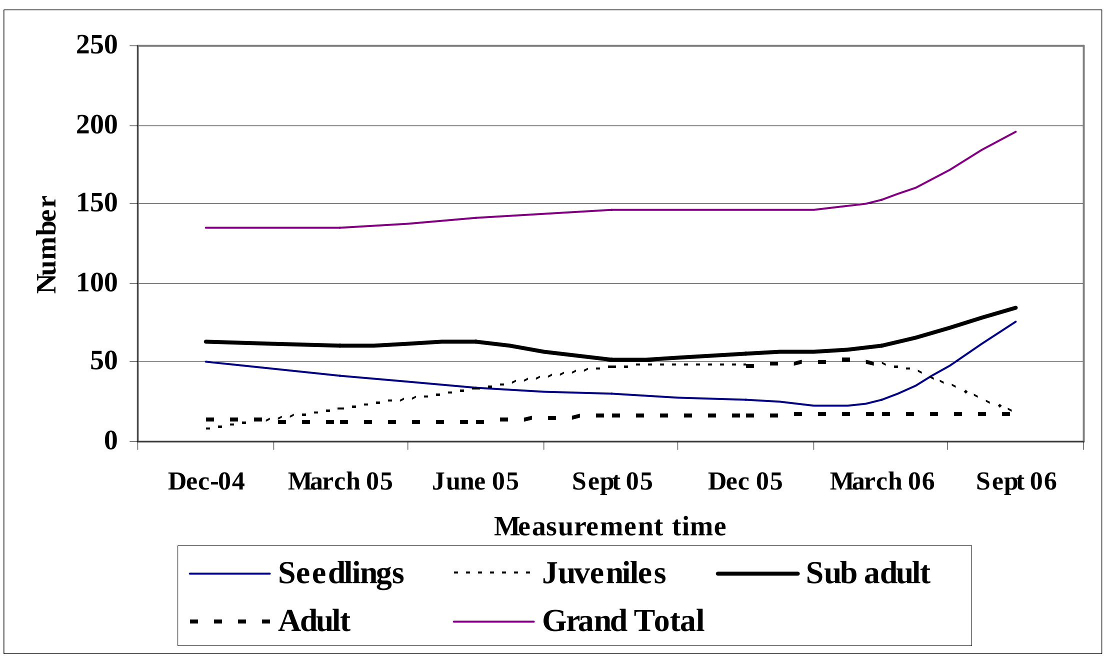

Figure 6 . Seasonal variation in the number of individuals *of C. travancoricus* in each stage at Arienkavu

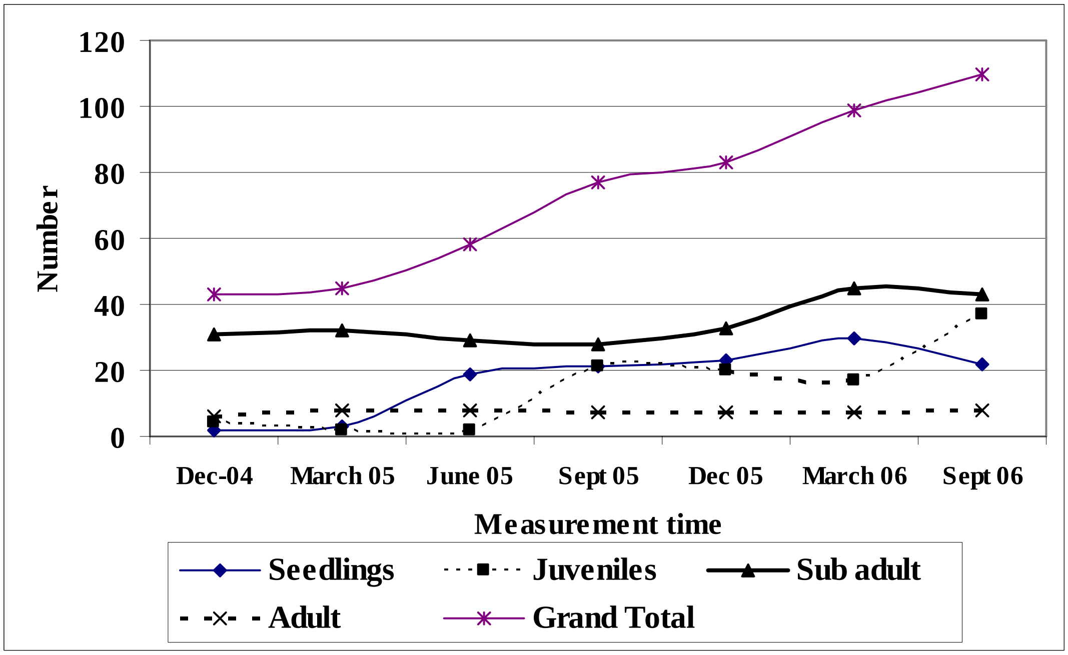

Figure 7. Seasonal variation in the number of individuals *of C. brandisii* in each stage

Regression

In order to find the trend in total number of plants from time to time, equations were developed with total number of plants in each stage as dependent variable and month as independent variable.

Table 23. Regression functions fitted to number of plants in *C. travancoricus* at Achencoil

Status	Regression function	R^2
Seedling	$Y = 47.1031 – 5.6679 X + 0.2549 X^2$	0.745
Juvenile	$Y = 4.5755 + 5.3452 X - 0.2058 X^2$	0.932
Sub adult	$Y = 21.555 – 2.0593 X + 0.1446 X^2$	0.982
Adult	$Y = 0.7488 + 0.1697 X - 0.0052 X^2$	0.820
Total	$Y = 73.9825 – 2.2123 X + 0.1885 X^2$	0.896

The adjusted R^2 was found to be highly significant in all the cases indicating that the fitted model was adequate one and the quadratic regression model estimated explained substantial amount of variation in the number of plants in each life stage of plants (Table 23).

The number of plants in seedling, sub adult and adult followed the same trend over time. The number was increasing over period. However for the juvenile stage it was in the reverse trend. The regression coefficient was negative in case of juveniles which implies that the number of juveniles showed a decreasing trend. Even though all other stages showed an increasing trend the rate of increase was very small.

Table 24 . Regression functions fitted to number of plants in *C. travancoricus* in Arienkavu

Status	Regression function	R^2
Seedling	$Y = 62.5950 -7.1797 X +0.3451 X^2$	0.899
Juvenile	$Y = -4.6622 +8.2677 X -3246 X^2$	0.926
Sub adult	$Y = 68.7630 – 3.0585 X + 0.1674 X^2$	0.870
Adult	$Y = 12.6366 + 0.2814 X$	0.659
Total	$Y = 139.246 -1.6718 X +0.1863 X^2$	0.951

Almost a similar trend was shown at Arienkavu also (Table 24). The adjusted R^2 was found to be highly significant in all cases except adult stage indicating that the fitted model was adequate one and the quadratic regression model estimated explained substantial amount of variation in the number of plants in each life stage of plants. But in the case of adult stage linear regression model fitted very well indicating that the number of adult plants was increasing over time linearly.

Table 25. Regression functions fitted tonumber of plants in *C. brandisii*

Status	Regression function	R^2
Seedling	$Y = -4.5325 +3.7359 X -0.1126 X^2$	0.900
Juvenile	$Y = -2.1680 +1.6189 X$	0.816
Sub adult	$Y = 26.9918 +0.7131 X$	0.579
Adult	No trend	
Total	$Y = 36.6298 +3.5423 X$	0.968

In case of *C. brandisii* the adjusted R^2 was found to be highly significant in the case of seedling stage indicating that the fitted quadratic regression model was adequate one and it explained substantial amount of variation in the number of plants in each life stage of plants (Table 25). Here the seedling population was decreasing after an initial increase. In the case of juvenile and sub adult stages linear model fitted very well showing that the number was increasing steadily. But for the adult stage, no specific pattern could be identified.

Population flux

At Achencoil total number of plants in the initial observation was 67. At the end of the year it increased to 75. In the second year it increased to 121. In the first year total new recruitments was 24 and in the second year it increased to 50. Total mortality in the first year was 16 and it got reduced to four in the second year. Total number of plants also increased from 91 in the first year to 125 in the second year. Percentage of annual death decreased from 17.58 to 3.20 and percentage of annual recruitment increased from 26.37 to 40. A similar trend was observed at Arienkavu also. In both areas there was a stable rate of population increase (Tables 26-27).

Table 26. Population flux of *C. travancoricus* at Achencoil

	First year	Second year
No. of plants in the initial measurement (a)	67	75
No. of plants in the final measurement (b)	75	121
Net change (c=b-a)	8	46
Rate of increase (d)	11.94	61.33
Total new arrivals (e)	24	50
Total mortality (f)	16	4
Total plants recorded (g)	91	125
Percentage annual death ($h = \frac{f}{g} \times 100$)	17.58	3.20
Percentage annual recruitment ($i = \frac{e}{g} \times 100$)	26.37	40.00

Table 27. Population flux of *C. travancoricus* at Arienkavu

	First year	Second year
No. of plants in the initial measurement (a)	135	146
No. of plants in the final measurement (b)	146	196
Net change (c=b-a)	11	50
Rate of increase (d)	8.15	34.25
Total new arrivals (e)	27	60
Total mortality (f)	16	10
Total plants recorded (g)	162	206
Percentage annual death ($h = \frac{f}{g} \times 100$)	9.88	4.85
Percentage annual recruitment $(i = \frac{e}{g} \times 100)$	16.67	29.13

In *C. brandisii* the number of plants increased from 43 to 83 in the first year and to 110 in the second year. The number of new arrivals in the first year was 49 while it reduced to 37 in the second year. Total mortality increased slightly during the study period. Percentage of annual death and annual recruitment decreased. Rate of increase got reduced from 93.02 to 32.53. This along with increase in mortality rate showed that the population size was decreasing (Table 28).

Table 28. Population flux of *C. brandisii*

	First year	Second year
No. of plants in the initial measurement (a)	43	83
No. of plants in the final measurement (b)	83	110
Net change (c=b-a)	40	27
Rate of increase (d)	93.02	32.53
Total new arrivals (e)	49	37
Total mortality (f)	9	10
Total plants recorded (g)	92	120
Percentage annual death ($h = \frac{f}{g} \times 100$)	9.78	8.33
Percentage annual recruitment $(i = \frac{e}{g} \times 100)$	53.26	30.83

REPRODUCTIVE BIOLOGY

Rattans are dioecious and flower annually. In general, male inflorescences are produced first flowed by females. Both male and female inflorescences are long and flagellate. In both species 2-3 inflorescences are produced in a single plant during one season.

C. brandisii

Inflorescence about 1 m long with 3-4 partial inflorescences; male partial inflorescence 55 cm long, rachilla 15 cm long bearing 8-10 flowers on each side; female partial inflorescence 15-20cm long, with 5-6 rachillae on each side, rachilla 3 cm long, 8-10 flowers on each side; flowers very crowded, distinctly 4 seriate when young due o the presence of neuter flowers. Fruits ovoid, 1.8 x 0.8 cm, scales arranged in 17 vertical rows, slightly channeled in the middle, brown with dark brown border.

C. travancoricus

Inflorescence slender, about 1m long including a terminal flagellum; male with 6-7 partial inflorescence; partial inflorescence small, rather dense, spreading, 7-8 cm long, with 3-4 rachillae on each side of the very slender and very sinuous axis, rachilla small, slightly arched, very spreading, delicate, with 4-5 distichous flowers on each side, the axis very slender, zig-zag sinuous; female partial inflorescence 7-10 cm long, shorter than subtending bracts, female rachilla simple, axis zig-zag, 12-15 mm long, with 3-4 distinct female flowers on each side, neuter flowers present during young stage. Fruits globose, 8-10 mm across, scales in 21 rows, straw yellow with a dark brown margin.

Flowering season

The time of initiation of flowering varied slightly with locality. In both species flowering started during September-October and the fruit matured during April-May.

Development of inflorescence

The development of inflorescence was of the same pattern in both species. The first indication of flowering was seen as slight inflation of the bracts which ensheath the basal part of the partial inflorescence. The development of the partial inflorescence and the rachilla on it were acropetal. It took about one month to complete the emergence of all partial inflorescences and rachillae. The time taken from the emergence of the inflorescence to fruit maturity was about eight months in both species.

Male inflorescence

In the male inflorescence the flowers were borne on second order of branching in both species. In *C. brandisii* the flowers were closely arranged on the rachilla whereas in *C. travancoricus* the flowers were not crowded.

Anthesis

No sequence of opening was evident as anthesis progressed. The flowers opened around 4 AM immediately followed by anthesis. A droplet of nectar is produced at the base of the flower. All the pollen was shed within three to four hours. The longevity of the flowers was about 12-18 hrs. Anthesis of the whole inflorescence lasted for about 3-4 days. Following anthesis the flowers shriveled and fell off.

Female inflorescence

In the female inflorescence also the flowers were borne on second order branching and the female flowers were subtended at their base with a sterile male flower.

Anthesis

Anthesis in the female flowers mostly occurred at 4AM. Anthesis of the female flowers resulted in the emergence of receptive stigma which were bright, hyaline and adaxially covered with a liquid film. The loss of the receptivity was characterised by the disappearance of the stigmatic liquid and by the colour change of the stigmas from white to brown. Female flowers did not produce nectar. Anthesis lasted for 12 –15 days in an inflorescence.

Sterile male flower

The behaviour of the sterile male flowers on the female inflorescence during anthesis was the same as that of the fertile males, except that no pollen was produced by the staminodes which bore empty anthers. Like male flowers, these flowers also produced nectar. There was no particular time for the opening of the sterile male flowers.

Gynoecium

The ovary comprised of three carpels in both species. During the course of development, two ovules degenerated and only a single ovule developed into seed. The style was solid and the stigma three lobed.

Method of pollination

In both species the male inflorescence during anthesis were visited by a species of *Drosophila*, honey bees and wasps. In the female inflorescence *Drosophila* and honey bees were observed but none of these were abundant. The body of the insect visitors sampled from the female inflorescence did not show any pollen grains. Pollen viability was lost after about 12 hrs from the time of anthesis.

Pollen collected from near the female plants with adhesive tape showed the presence of *Calamus* pollen grains. Both species showed several features of wind pollination namely production of large quantity of powdery pollen grains, a distinct exposure of anthers to the air, the three lobed stigma with a sticky surface, and lack of showy bright coloured floral parts.

Fruits and seeds

Each inflorescence produced only a very limited number of mature fruits and seeds. The fruit is covered with a scaly pericarp and the seed was covered with a fleshy layer of sarcotesta. The small cylindrical embryo was positioned basally on the dorsal side of the seed.

Seed viability

The seeds lose their viability soon and cannot be stored for long. The fruits stored in the plastic bags under room temperature were found to be viable for one month. Seeds kept in the refrigerator at 5^0C maintained viability for three months. Reduction of moisture content level of the seeds adversely affected their viability. Both species showed 80 per cent germination in fresh condition.

DISCUSSION

Calamus brandisii and *C. travancoricus* are distributed in the evergreen forests of the Western Ghats. *C. travancoricus* is seen between 200-500m asl while *C. brandisii* is seen only at higher elevations, at 1000-1500 m asl. When *C. travancoricus* is distributed through out the Western Ghats, *C. brandisii* is restricted to certain areas in the southern part of the Western Ghats. For both species the size of the population is very small, ranging from one plant to hundred, and the populations are very much scattered. Both species are heavily extracted for furniture and handicraft industries causing a drastic decrease in population size year after year.

POPULATION MATRIX

Life stage duration

The seedling stage lasted only an year in both species (Table 9). The duration of juvenile stage also was about 8-9 years in *C. travancoricus* and seven years in *C. brandisii*. Since these are small diameter rattans, the basal girth required for vertical growth is attained within the first 9-10 years and the plants will reach the sub adult stage within this period. Anto (2005) reported longer stage duration for juveniles, 12- 20 years, for medium and large diameter rattans of the Western Ghats. Bogh (199905) reported 13 years for small diameter rattan and 22-38 years for medium diameter rattans.

The sub adult stage lasts for about 26 years in *C. travancoricus* at Achencoil while it is only ten years at Arienkavu. *C. brandisii* is having a very short sub adult stage duration, 1.5 years. *C. travancoricus* started flowering at about 6 m height at Achencoil and at 7.7 m height at Arienkavu. It takes about 36 years at Achencoil and about 20 years at Arienkavu, to start flowering. The late flowering increased the duration of sub adult stage. The calculation of the duration of the sub adult and adult stages involves estimates of maximum stem lengths. Consequently, the longevity estimates may be strongly affected by the coincidental presence or absence of long stems in the plots. At Achencoil some of the stems were very long in the sub adult stage. The allocation of resources for production of suckers may also prolong the sub adult stage. *C. brandisii* starts flowering when it reaches about 5 m length which is attained within ten years. This shows that this species is fast growing. Bogh (1995) reported 8.7 years of sub adult stage for *Calamus peregrinus* 11 years for *C. rudentum* and 13.5 years for *Calamus* species. Anto (2003) reported 40 years of sub adult stage for *C. vattayila,* 25 years for *C. delessertianus*, 16.9 years for *C. thwaitesii* and 17 years for *C. hookerianus.*

The adult stage duration was long in *C. brandsii* and the vegetative fecundity of the adult stage was highest (Tables 10-12). A similar situation is seen in *C. travancoricus* at Arienkavu. Both species are suckering and hence the competition among the individuals will be very high in such cases which inversely affect the growth rate which is reflected in the stage duration. The sum of the stage durations are estimates of the longevities of the plant. *C. travancoricus* at Arienkavu is having the longest life duration.

The λ is an estimator of the population growth rate. Population size is constant when λ equals one, increases when λ is greater than one and declines when it is less than one. In this study the λ value is greater than one for *C. travancoricus* at Achencoil while it is less than one at Arienkavu which indicates that the population at Arienkavu is decreasing. Here the annual decrease is nine percent. The λ value for *C. brandisii* is very low, 0.39, indicating that the population is drastically decreasing. It shows 61 per cent annual decrease (Tables 10-12). Based on demographic studies Enright and Watson (1992), Pinard (1993), Pinero *et al.* (1984) and Bǿgh (1995) reported increasing population for four palm species and Svenning and Balslev (1999) reported a decreasing trend in the palm *Iriartea deltoidea*. Anto (2003) reported a steady population for *C. thwaitesii* and *C. hookerianus* (λ = 1.01 & 1.05), a decreasing population for *C. vattayila* (λ = 0.94) and an increasing population for *C. delessertianus* (λ = 1.21).

The longevity of sub adult stage in *C. travancoricus* at Achencoil resulted in few adult plants (Table 9). But sexual fecundity, the maximum potential rate of which the female plants are capable of reproduction, is higher here (6.58) while it is very low at Arienkavu (0.87), even though the number of adults are more here. The long stage duration of sub adult stage is reflected in the P_3 and G_3 values also. P_3 Value is very high and G_3 value is very low.

The adult survival rate is low in *C. brandisii*. This along with long stage duration is detrimental to the population with low annual reproductive success.

Sensitivity

A sensitivity analysis of different demographic parameters on the finite rate of increase has also been used to understand the population densities. The sensitivities allow one to see what would happen to the population growth rate if we could improve survival and fecundity values in the projection matrix one at a time of particular value. One percent change in the survival value of the juveniles of *C. travancoricus* will make a change of 0.477 and 0.546 in the λ value at Achencoil and Arienkavu respectively. In case of *C. brandisii* sub adult stage is very important in that one percent change in the survival value of this life stage can produce one percent change in the λ value (Tables 13-15). Finite rate of increase (λ value) is not at all affected by sexual fecundity. But probabilities of survival and transition in a given stage affects the λ value. Transition probabilities are more important in changing the λ value than survival probabilities in a given stage. In *C. travancoricus* survival and transition of juveniles and sub adults are important at Achencoil, while only juvenile is important at Arienkavu. In *C. brandisii* only transition of juveniles and recruitment and survival of sub adults are important in changing the finite rate of increase.

Elasticity

Elasticity analysis is a useful tool in conservation biology. Elasticity analysis can be a quantitative guide for research and management particularly for lesser known species and a useful first step in a larger modeling effort to determine population viability. An elasticity pattern is composed of the relative contribution of matrix entries to population growth that are grouped biologically meaningful ways for comparative analysis

Survival and transition of juveniles and survival of adults were critical in changing the λ value in *C. travancoricus* at Achencoil while those of juvenile and sub adult stages influenced the λ value at Arienkavu. For *C. brandisii* recruitment and survival of only sub adult stage was influencing the λ value. One percent change in the juvenile stage of *C. travancoricus* makes a change of 0.363 and 0.309 in the λ value at Achencoil and Arienkavu respectively. Hence in the conservation programmme for this species the juvenile stage is more important. In case of *C. brandisii* sub adult stage is more important (Tables 16-18). The low elasticity value in vegetative fecundity indicates that in spite of the clustering habit, the population is not growing rapidly.

Life stage distribution

The calculated stable stage distribution (w) of the two species shows that juvenile stage constitutes a much greater proportion of the stable population in all three cases (Tables 10-12). Whether the observed stage distribution follows the same pattern as stable stage distribution was tested using χ^2. Chi-square was found to be significant in all the three cases indicating that the observed stage distribution was significantly different from the stable stage distribution. Similar observations have been reported for the palm *Astrocaryum mexicanum* (Pinero *et al*., 1984), for certain Thailand rattan species (Bogh, 1995) and for some Western Ghat rattan species (Anto, 2003). In the stable stage distribution 72-86 per cent of the population will be juveniles (Tables 10-12). In the observed distribution in case of *C. travancoricus* seedlings and sub adults contribute to the majority of the population while in case of *C. brandisii* sub adults form 72 per cent of the population. This shows that the population structure is changing and it has not reached its climax stage.

But the finite rate of population increase (λ) is 1.06 in case of *C. travancoricus* in Achencoil, which shows that this population as a whole is in demographic equilibrium even though some stages of the life cycle are increasing and some decreasing. But, at Arienkavu, λ is 0.9 and for *C. brandisii* it is 0.39, which indicate that drastic changes are taking place in the population and the population is decreasing.

POPULATION DYNAMICS

Even though at Arienkavu the sub adult stage dominates, the stage duration is less when compared to that at Achencoil But here the plants started flowering only after they attained a height of about eight meters while at Achencoil flowering started at a height of about six meters. The late flowering increased the number of sub adult plants in the population. At Achencoil the stage duration of sub adult stage was longer here which was reflected in the number of adult plants in the population and this in turn caused the reduced number of seedlings.

In *C. brandisii* also sub adult stage dominates. Generally the suckers grow faster than seedlings and reach the sub adult stage earlier. Flowering was very less in this population and hence most of the plants remained in the sub adult stage. The vegetative fecundity of sub adults also is higher for *C. brandisii.* This also contributed to the higher number of sub adults.

Recruitment and death rates

The balancing of the birth and death rates determine increase or decrease of the population. In *C. travancoricus* the number of new recruitments increased and the mortality decreased during the study period which shows that the population is increasing in both places. In case of *C. brandisii*, the annual recruitment was decreasing. At the same time there was not much decrease in the annual death rate. The number of flowering plants in the population was very low which affected the seed production. All these resulted in a decreasing population.

There is no obvious seasonal variation in the recruitment and death rates. Delayed germination and slow growth during the early stages are common in the family Arecaceae. *Calamus* is dioecious and the number of female plants affects the next seedling generation.

For *C. travancoricus* regression coefficient is negative in case of juveniles which implies that the number of juveniles show a decreasing trend. All other stages show an increasing trend even though the rate of increase is small. In case of *C. brandisii* the adjusted R^2 was found to be highly significant in seedling stage. Here the population is decreasing. The number of juveniles and sub adults are increasing steadily.

POPULATION FLUX

In a stable population, a high rate of recruitment should be balanced by an almost equal number of deaths. The study shows that this did not occur in the study period. The total number of plants at the end was greater than the number of plants at the beginning for both species. This may be due to the increased number of recruitment occurred during this period and the study period was short. If this situation continues, there will be an overloading of individuals which will not usually happen. The rate of death especially during the seedling stage will increase to give a more constant final population.

In *C. brandisii*, even though there is an increase in the number of plants during the study period, the rate of increase is very low in the second year. In *C. travancoricus* at Arienkavu the rate of increase is lower when compared to that at Achencoil. This is reflected in the λ value also. The populations of *C. brandisii* and *C. travancoricus* at Arienkavu are diminishing. Hence management practices should be initiated for stabilizing the population.

REPRODUCTIVE BIOLOGY

Both species are dioecious and flower annually. The number of fruits produced is very low especially in *C. brandisii* when compared to other species of the Western Ghats (Renuka, 2003). The time of flowering varies slightly with locality. The inflorescence is long and flagellate. In total length and in the number of partial inflorescence, these two species are similar to the South East Asian species. Alloysius (1997) reported that *C. caesius* and *C. subinermis* developed two to three inflorescences with an average length of 1.3 m per plant.

Both species started flowering during September–October after the South West monsoon. Mohd. Zaki and Othman (1998) observed that rain had a predominant influence on flowering. Manokaran (1989) reported that a period of relative dryness and hence higher temperature followed by a period of high rainfall trigger flowering in rattans. The present study also proves this.

Anthesis occurs during the early morning hours and pollen is viable for about 12 hrs. Lee and Jong (1995) reported a similar timing for anthesis in four *Calamus* species in Thailand. Renuka (2003) and Sulekha (2004) reported anthesis in the early morning hours in certain *Calamus* species of the Western Ghats. Even though the sterile male flowers produce nectar and attract insects, it is not actually helping in pollination, since these flowers wither away before the opening of the female flower.

The pollination is anemophilous in both species even though they have some adaptations for entomophily. Wind pollination was reported in certain *Calamus* species of the Western Ghats (Renuka, 2003; Sulekha, 2004) and certain South East Asian species (Lee and Jong.1995).

The seeds cannot be stored for long duration under normal conditions since they lose the viability within a month.

The reduced number of mature fruits produced per inflorescence, especially in *C. brandisi*, affects the next generation. The number of flowering plants was very low for this species. The germination percentage of seeds under natural condition is very low. This contributes to the reduced natural regeneration.

CONSERVATION STRATEGIES

The widespread over-harvesting of the most valuable rattans calls for efficient management plans. Matrix, sensitivity and elasticity analyses are very useful in resource management planning.

Demographic studies conducted show that there is an annual decrease of 9 per cent in the population of *C. travancoricus* at Arienkavu and 61 per cent in the population of *C. brandisii*. Hence conservation measures should be initiated for these two populations.

Both elasticity and sensitivity analyses show that survival and transition of juveniles and sub adults at Achencoil and that of juveniles at Arienkavu are more critical in changing the finite rate of increase in *C. travancoricus* while survival and transition of juveniles and recruitment and survival of sub adults are the critical stages in *C. brandisii*. Hence in the conservation programme more importance should be given to juvenile and sub adult stages.

The stage duration of adults is longer in both cases. Harvesting only the longest cane would reduce the effect of harvest on population. In the juvenile stage, competition from other undergrowth species, herbivore and human interferences are probably the important causes of death. A reduction of these factors would also cause increased growth rate of juveniles.

Very small quantity of fruits and seeds are produced in *C. brandisii,* when compared to other species of the Western Ghats. Natural regeneration seems very poor, since seedlings contribute only 4.65 per cent of the population. The number of flowering plants in the population was very low. Hence, in the conservation strategies for this species importance should be given to seedlings and adult plants also. It is better to collect the fruits at maturity, germinate and transplant them in a protected area since natural regeneration is scanty.

Both species are good quality rattans and are extracted in large quantities for furniture and handicraft industries. In Kerala large populations of *C. brandisii* are seen only at Agasthyamala region. This area is important from the ecotourism point of view, and hence special care should be taken for the protection of this species. Here all the life stages of the population need protection during conservation programmes while for *C. travancoricus*, juveniles and sub adults require special protection.

The present study has clearly shown that the population dynamics and population structure vary across the range of habitats available. This implies that the conservation strategy developed for one location need not be effective for another location. In problematic species, therefore, population modeling and different conservation strategies for different locations would be needed.

REFERENCES CITED

Agmato, A. 1984. Rapid germination method for Palasan, Calamus merrillii Becc. Seed. Technical paper. 10th Annual FORI Research Symposium, Collge, Laguna. pp. 15-19.

Alloysius, D. 1994. Flowering and fruiting pattern of *Calamus caesius* PISP Report. Pp. 1-10.

Alloysius, D. 1997. Reproductive biology of rattans. *In*: A. N. Rao and V. R. Rao(eds.)Rattan: Taxonomy, ecology, silviculture, conservation, genetic improvement and biotechnology. Proceeding of training courses cum workshops. 14-26 April 1996, Sarawak, Sabah. IPGRI-APO, Serdang,Malaysia. pp. 137-145.

Anto, P.V. 2005. Demographic studies on selected species of the genus *Calamus* L. (Arecaceae). Ph.D thesis submitted to the University of Calicut, Kerala, India.

Bagalotos, A.P. 1987. rattan seed collection and storage. Rattan information Centre. Occasional paper, No. 5, Kuala Lumpur, Malaysia. pp 7-12.

Banik, R. L. and M. N. Nabi. 1981. An observation on the flowering time and seed germination in bara bet *Calamus viminalis* var. *fasciculatus* (Griff.) Becc. *In*: R.L. Banik and M. N. Nabi (eds.). Proceeding of the 4th and 5th Bangladesh Science Conference, Rajshastri, Bangladesh. 2-5 March, 1980. pp. 52-56.

Bannister, B.A. 1970.Ecological life cycle of Euterpe globosa Gaertn. *In*: H. T. Odum and R. F. Pigeon (eds.) a tropical rain forest. U. S. Atomic Energy Commission. Oak Ridge, Tenessee.pp. 79-89.

Bannister, B.A. 1972. Ecological life cycle of Euterpe globosa Gaert. *In*: H.T. Odum and R. F. Pigeon (eds.), A tropical rain forest. A study of irradiation and ecology at El verde Puerto Rico. Oak Ridge Tenn. U. S. Atomic Energy Commission. Pp. 229-314.

Bernal, R. 1998. Demography of the vegetable ivory palm *Phytelephas seemannii* in Colombia, and the impact of seed harvesting. J. Appl. Ecol. 35(1): 64-74.

Bǿgh, A. 1995. The demography and pollination biology of selected speces of rattans in Thailand. Ph. D dissertation submitted to the faculty of Natural Science, University of Aarhus, Denmark.

Bǿgh, A. 1996. The reproductive phenology and pollination biology of four *Calamus* (Arecaceae) species in Thailand. Principes, 0(1): 5-15.

Bruna, E.M. 2003. Are plant populations in fragmented habits recruitment limited? Tests with an Amazonian herb. Ecology 84(4): 932-947.

Bullock, S. H.1980. Demography of undergrowth palm in littoral Cameroon. Biotropica 12; 247-255.

Bullock, S. H. and K. S. Bawa. 1981. Sexual dimorphism and the annual flowering pattern in *Jacaratia dolichula* (D. Smith) Woodson (Cariceae) in a Costa Rican rain forest. Ecology 62: 1494-1504.

Burgman, M.A., S. Fersonand and H. R. Akcakaya. 1993. Risk assessment in conservation biology. Chapman and Hall, New York, USA.

Caswell, H. 1989. Matrix population models. Sinauer Associates Inc. Publishers. Sunderlands, Massachussets. USA Pp. 165.

Caswell, H. 2001. M. Matrix population models. 2nd edn. Sinauer Associates Inc. Publishers. Sunderlands, Massachussets, USA. Pp. 722.

Crouse, D. T., L. B. Crowder and H. Caswell. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. Ecology 86: 1412-1423.

De kroon, H., A. Plaisier, J. V. Groenendael and H. Caswell. 1986. Elasticity: the relative contribution of demographic parameters to population growth rate. Ecology 67(5): 1427-1431.De Steven, D. 1989. Comparative demography of a clonal palm (Oenocarpus mapora ssp. mapora) in Panama. Principes 30: 100-113.

Dransfield, J. 1979. A manual of the rattans of the Malay Peninsula. Forest Department, Ministry of Primary Industries. Malay. For. Rec., 29: 270 p.

Enright, N. and J. Ogden 1979. Application of transition matrix models in forest dynamics: *Araucaria* in Papua, New Guinea and *Nothofagus* in New Zealand. Australian journal of Ecology 4: 3-23.

Enright, N. J. and A. D. Watson. 1992. Population dynamics of the Nikau palm. Rhopalostylis sapida (Wendl. Et Drude) in temperate forest remnant near Auckland, New Zealand. N. Z. J. Bot. 30(1): 39-43.

Generalao, M. L. 1977. Effect of pre treatment media on the germination of Palasan(*Calamus maximus* Becc.) and Limuran (*C. ornatus* Blume) seeds at Pagbilao,quezon, Sylvatrop Philipp. For. Res. J., 2: 215-218.

Hartshorn, G. S. 1975.A matrix model of tree population dynamics. *In*: F. B. Golley and E. Medina (eds.) Tropical ecological systems. Springer, New york. Pp. 41-51.

Heppel, S.S., H. Caswell and I. B. Crowder. 2000. Life histories and elasticity patterns: perturbation analysis for species with minimal demographic data. Ecology 81(3): 654-665.

Hnatuik, R.T. 1977. Population structure of Livistona eastonii Gardn. Mitchell Plateae, Western Australia. Aust. J. Ecol. 2: 461-466.

Lee, Y. F. and K. Jong. 1995. Longivity of *Calamus subinermis* H. A. Wendl. And *Calamus caesius* Bl. Flowers. Sandakania No. 6: 1-14.

Manokaran, N. 1978. Germination of fresh seeds of Malaysian rattans. Malay For. 41(4): 319-324.

Manokaran, N. 1989. Flowering and fruiting patterns in *Calamus caesius* Bl. *In*: A. N. Rao (ed.) Recent research on rattans. Proceedings of the International rattan seminar. Nov. 12-14, 1987. Chiangmai, Thailand. Kasetsart University, Thailandand IDRC, Canada. Pp. 122-129.

Mills, L. S., S. G. Hayes, C. Baldwin, M. J. Wisdom, J. Citta, D. J. Mattson and K. Murphy. 1996. Factors leading to different viability predictions for a grizzly bear data set. Conservation Biology 10: 863-873.

Mohd. Zaki, H.A. and J. Othman. 1998. Phenological observations on *Calamus palustris* Griff., *C. scipionum* Mart. and *Cocos nucifera* L. in Peninsular Malaysia. *In*: R. Bacilieri and S. Appanah (eds.). Rattan cultivation: Achievements, problems and prospects. An International consultation of experts for the project conservation , genetic improvement and silviculture of rattans in South East Asia, Kuala Lumpur, Malaysia. 12-14 May 1998. pp. 61-71.

Olmsted, I. And E. R. Alvarez-Buylla. 1995. Sustainable harvesting of tropical trees: demography and matrix models of two palm species in Mexico. Ecol. Appl. 5(2): 484-500.

Oyama, K. 1991.Variation in growth and reproduction in the neotropical dioecious palm *Chaemodorea tepejilote*. J. Ecol. 78(3): 648-663.

Padmakumar, P. K. 2003. Developmental morphology in relation to conservation in the family palmae. (Arecaceae). Ph.D thesis submitted to the University of Calicut, Kerala, India.

Pena-Claros, M. and P. A. Zuidema. 1999. Demographic limitations to the sustainable extractive of palm heart from *Euterpe precatoria* in two forest types in Bolivia. Ecologia-en-bolivia. 33: 3-21.

Pinard, M. 1993. Impacts of stem harvesting on population of *Iriartia deltoidea* (Plmae) in an extractive reserve in Acre, Brazil. Biotropica 25(1): 2-14.

Pinero, D., M. Martinez Ramos and J. Sarukhan. 1984. A population model of *Astrocaryum mexicanum* and a sensitivity analysis of the finite rate of increase. J. Ecol. 72: 977-991.

Raja- Barizan, R.S. 1992. Phenology of rattans. *In*: Wan Razalli Wan Mohd. (ed.) A guide to the cultivation of rattans. Malay. For. Rec. No. 35. FRIM, Kepong, Kuala Lumpur. pp. 39-46.

Ratsirarson, J., J. A. Silander Jr. and A. F. Richard. 1996. Conservation and management of a threatened Madagascar palm species. *Neodypsis decaryi* Jumelle. Conserv. Biol. 10(1): 40-52.

Reis, M. S., A. C. Fantini, R. O. Nodari, A. Reis and A. Mantovani. 2000. Management and conservation of natural population in Atlantic rain forest: The case study of palm heart *Euterpe edulis* Mart. Biotropica 32(4b): 894-902.

Renuka, C. 1995. Reproductive biology of rattans. *In* J.T. Williams, I. V. R. Rao and A. N. Rao (eds.), Genetic enhancement of bamboo and rattan. INBAR. Technical Report No. 7, New Delhi. Pp. 135-141.

Renuka, C. 2000. A field identification key for rattans of Kerala. KFRI Research Report No. 188. Kerala Forest Research Institute, Peechi. Pp. 34.

Renuka,.C. 2001. Palms of India: Status, threats and conservation strategies. *In* R. Uma Shaanker, K.N. Ganeshaiah and K. S. Bawa (eds.) *Forest Genetic Resources: Status, Threats and Conservation Strategies.* Oxford & IBH publishing Co. Pvt. Ltd. Pp.197-209.

Renuka, C. 2003. Maintenance of seed stands and species trial plots of rattans. Phase II. KFRI Research Report No. 254. Kerala Forest Research Institute, Peechi. Pp.43.

Renuka, C., E. P. Indira and E. M. Muralidharan 1998. Genetic diversity and conservation of certain species of rattans in Andaman and Nicobar islands and southern India. KFRI Research Report. No. 157. Kerala Forest Research Institute, Peechi, Kerala, India. 35p.

Sarukhan, J.1980. Demographic problems in tropical systems. *In*: O. Solbrig (ed.) Demography and evolution in plant populations. Bnlackwell scientific publications Oxford. Pp. 161-188.

Sarukhan, J. and D. Pinero. 1993. Direct and indirect estimates of neighbourhood and effective population size in a tropical palm, *Astrocaryum mexicanum*. Evolution 47(1): 75-87.

Savage, A. J. P. and P. S. Ashton. 1983. The population structure of the double cococnut and some other Seychelles palms. Biotropica 15: 15-25.

Silva Matos, D. M., R. P. Freckleton and A. R. Watkinson. 1999. The role of density dependence in the population dynamics of a tropical palm. Ecology 80: 2635-2650.

Silvertown, J., M. Franco and E. Menges. 1996. Interpretation of elasticity matrices as an aid to the management of plant populations for conservation. Conserv. Biol. 81: 465-476.

Silvertown, J., M. Franco, I. Pisanty and A. Mendoza. 1993. Comparative plant demography-relative importance of life cycle components to the finite rate of increase in woody and herbaceous perennials. J. Ecol. 81:465-476.

Sist, P. 1989. Demography of *Astrocaryum sciophilum* an understory palm of French Guiana. Princepes 33(3); 142-151.

Slade, N. 1990. Models of structured populations; age and mass transition matrices. *In:* R. J. Kendall and T. E. Lacher (eds.), Wild toxicology and population modeling. Lewis, London. UK. Pp. 189-199.

Sulekha, K. 2004. Reproductive biology and micro propagation of selected species of *Calamus* L. (Arecaceae). Ph. D. Thesis submitted to the University of Calicut.

Svenning, J. C. and H. Balslev. 1997. Small scale demographic disequilibrium of *Iriartea deltiidea* (Arecaceae) in Amazonian Equador. *In* R. Valenceia and H. Balslev (eds.), Estudios sobre diversidad y ecologia de plantas; memorias del ll Congreso

Equotoriana de Botanica. Pp. 263-274. Pontificia Universidad del Equdor. Quito. Ecuador.

Svenning, J. C. and H. Balslev. 1999. Microhabitat dependent recruitment of *Iriartea deltoidea* (Arecaceae) in Amazonian Equador. Ecotropica 5(1): 69-74.

Tuljapurkar, S. and H. Caswell. 1997. Structured – population models in marine terrestrial and fresh water systems. Capman and Hall, new York, USA.

van Groenendael J., H. de Kroon and H. Caswell. 1988. Projection matrices in population biology. Trends in Ecology and Evolution 3: 264-269.

van Tienderen, P. H. 2000. Elasticities and the link between demographic and evolutionary dynamics. Ecology 81: 666-679.

Van Valen, L. 1975. Life, death and energy of a tree. Biotropica 7: 260-269.

Vandermeer, J. 1990. Growth and survival of Welfia georgii seedlings in a rain forest on the Caribbean coast of Costa Ricca. Revista-de-Biologia Tropical 38(2): 73-79.

Vandermeer, J. 1993. Successional pattern of understory palm in an old Cacao plantation on the Caribbean cost of Costs Ricca. Princepes 37(2); 73-79.

Wootton, M. J. and D. A. Bell 1992. A metapopulation model of the Peregrine Falcon in California; viability and management strategies. Ecological applications 2: 307-321.

Zakaria, R. M., J. Dransfield and M. Keith-Lucas. 1999. Population dynamics of two wild Arenga (Arecaceae) at Bukit Lagong forest reserves, Selangor, Malaysia. The Malay. For. 62(1): 42-52.

Zar, J. H. 1974. Biostatistical Analysis. Pretice Hall, Englewood Cliffs, NJ. Pp.270.