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*Full Length Research Paper*

# A demographic study of a mangrove palm, *Nypa fruticans*

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**A demographic study of a mangrove palm; *Nypa fruticans* on Carey Island in Malaysia was conducted for 16 months. Four life stages were considered, based on the number of crown leaves: seedling, juvenile, adult and mature. The population structure of *N. fruticans* showed a majority of adults with 67.9%, while seedlings were the least represented. Density ranged from 1025 to 6400 plants per hectare. A total of 162 germinated seeds were observed, but only 3 became established within the plots, while the rest were washed away by high water. Seedlings, juveniles, adults and mature plants all showed a mainly regular spatial distribution pattern. Seedlings produced 2.9 leaves per year while juvenile, adult and mature plants produced about 1 leaf each per year. Leaf elongations for juvenile, adult and mature specimens were 55.5, 81.0 and 91 cm per month, respectively. Total mean age was estimated at 33.2 years. The flowering cycle lasted between 8.2 - 9.6 months with an annual rate of 1.1 and 1.0 inflorescences and infructescences per tree, respectively.**

**Key words:** Population, spatial distribution, growth, age, reproductive phenology, nipah.

## INTRODUCTION

More than 30 species of palms have been studied demographically, from montane forest (Homeier et al., 2002) to hill forest (Rozainah et al., 2000) and lowland forest (Pinero et al., 1986). A demographic study usually looks into population dynamics, spatial distributions, growth rates, flowering and fruiting sequences, age structure and age estimation and life table. Demographic studies are important in understanding the long-term population dynamics of any particular species, to predict its future population and assist in forest management. A successful study was conducted on the demography of *Astrocaryum mexicanum*, a typical palm of tropical evergreen forest in Mexico (Pinero et al., 1986). Not only are palms easily recognized in the forest, they also exhibit a uniform growth pattern, by means of producing and shedding leaves sequentially, and this is generally reflected in height increments. Depending on a reasonable size of population within the same locality, this has enabled many demographic studies to be successfully conducted in small sized plots.

However, this type of demographic study is not restricted to the palm family. Perez-Farrera et al. (2006) studied the demography of a threatened cycad in Mexico. With the same applications, they were able to describe the demography of the species as to explain the environmental events surrounding the species' population history. Demographic study also has been applied to cactus, *Mammillaria crucigera* by Contreras and Valverde (2002) and oaks (Alfonso-Corrado et al., 2007).

*Nypa fruticans* Wurmb or nipah is a mangrove palm that grows well in calm estuaries and coastal zones. The species can prevail in a simple channel or complex tributaries, bays, tidal flats and creeks, as long as there is a tide and a freshwater outflow action (Fong, 1982). Nipah usually thrive well in the sediments deposited by an accreting process by the sea, creating a clayish type of soil, with brackish water that promotes an anaerobic system.

The species lacks a visible upright trunk, and the leaves appear from the ground. The younger leaves appear from the middle of the crown and push the older leaves aside before they dry and fade away, leaving bulbous leaf bases or scars behind. The diameter of the

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cluster could be up to 75 cm and a single leaf may attain a height of 8 m. The mature crown may contain 6 to 8 living leaves and 12 to 15 bulbous leaf bases at a time. It differs from most other palms by having a subterranean, dichotomous, and rhizomatous branch (Tomlinson, 1986). Nipah is a monoecious and a pleonanthic palm and it also exhibits viviparous germination (Tomlinson, 1986) as in many other mangrove species. The distribution of this species ranges from Sri Lanka, Southeast Asia, Australia and to the Ryukyu Islands (Uhl and Dransfield, 1987). This species is found in the landward side of a mangrove forest that is subject to frequent tidal inundation and is exposed to saline water at high tide but freshwater at low tide. As an adaptation for the submerged environment, the fruit is designed to float, and this buoyancy is attributed to its thick fibrous mesocarp and endocarp (Uhl and Dransfield, 1987).

Mangrove forest has become an important ecosystem in coastal zones for economic, ecological and inland protection reasons. In Malaysia, mangrove forest occupies approximately 645,852 ha, making it the third largest mangrove area in the Asia-Pacific region (Azahar and Nik, 2003). 105 mangrove species have been recorded in Malaysia (Japar, 1994). Malaysia has 4,809 km of coastline, and 29% of it is facing erosion (Othman, 1994) as a result of natural phenomena like storm surges and human intervention like land conversion. Undoubtedly the coastal zone is facing serious threat. Since 2005, the Government of Malaysia has intensified protection of the coastal zone by rehabilitating degrading mangrove forest and other coastal vegetation.

This study focuses on the demography of a mangrove palm, *N. Fruticans.* Although *N. fruticans* is known for its economic importance for sugar, vinegar, cigarette wrappers and roof thatch (Fong, 1982), the ecological implication of colonization of this species has raised some concerns. For example in West Africa, Sunderland and Morakinyo (2002) noted that this species created a highly monospecific stand, hindering the possibility of re-colonization of the indigenous mangrove species and fish population.

Therefore, the objective of this study is to increase the broader understanding of the ecology of mangrove forest that could assist in its management by providing a substantial demographic data of the species. As in most other sessile palms, the growth rate of *N. fruticans* is based on leaf production in a given time. This allows age estimation by multiplying the total number of leaves with the plastochrone (the interval between the production of one spear leaf and the next). The age estimation is usually calculated based on the predeter-mined life stage of each individual within the population, in which the total age of a particular individual must add on the age estimated or time spent for its prior stages.

The objectives of this study were to (i) assess the population structure, (ii) determine the spatial distribution pattern, (iii) study the growth rates, (iv) estimate the age of each nipah palm and (v) determine the period of reproductive events.

## MATERIALS AND METHODS

### Study site

Carey Island is located about 70 km to the south west of Kuala Lumpur, the Malaysian capital, and about 10km south of Port Klang, the biggest port on the west coast of Peninsular Malaysia. Carey Island is one of the 8 islets that constitute the Klang Isles, a large mangrove forest reserve on the Straits of Malacca. At 32,000 ha in area, Carey Island is the largest of the Klang Isles. Almost 70% of the island is planted with oil palm under the management of Sime Darby Plantation. Although only the fringe area of the island is covered with mangrove forest, a survey conducted in 2007-2008 recorded 31 mangrove species on Carey Island (Rozainah et al., 2008).

The climate of Malaysia is characterized by uniform high temperature between 22 to 33°C, humidity as high as 80 to 90% and annual rainfall of 1790 mm. The average tidal range varies from 1.5 to 2.5 m and spring tides and neap tides occur twice a month. The exact location of the study site was at N 02°53'26.1" and E 101° 20'48.4" (Figure 1).

### Population structure and spatial distribution

After a quick survey around the island, 6 plots were set up, containing enough representatives of the species. Three plots were 20 x 20 m each in size and another three were of 10 x 10 m each. The unequal size of plots was due to some technical field problems. The classification of each individual was based on leaf numbers. Four developmental stages were identified:

1. Seedlings - from small individuals with one intact leaf to plants with three leaves.
2. Juveniles - a stage with four to seven larger leaves
3. Adults - individuals with eight to fourteen leaves, with or without reproductive organs.
4. Mature - individuals with fifteen and more leaves, with or without reproductive organs.

All individuals of nipah within the plots were classified, tagged and numbered in arbitrary order. The location of each individual was calculated in x-y coordinates by using compass and measuring tape. The data was transferred into Microsoft Excel and 6 spatial distribution maps were produced. To determine the distribution type, the coefficient of dispersion has to be calculated. By employing an equation by David and Moore (1954), the variance: mean ratio can be determined. The results can be interpreted as follows: a value close to one indicates that individuals were distributed randomly; a value higher than one shows a clumped distribution, and a value less than one shows a regular distribution.

### Growth rate and age estimation

Initially all the tagged individuals within the plots were inspected for the number of scars and dead leaves and living leaves including spear leaves in the crown. For the next 16 months, a few randomly selected individuals representing every stage were observed monthly for the emergence of new spear leaves, and each leaf was measured until it was fully expanded. The period between the appearances of two successive spear leaves is known as the plastochrone. Age estimation was obtained by multiplying the

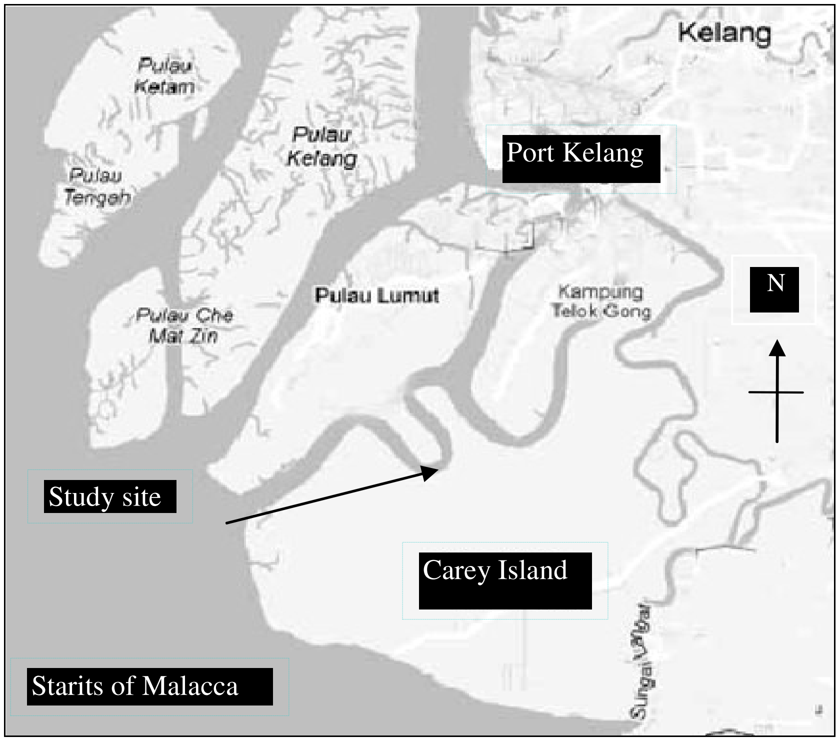


**Figure 1**. Location of study site at Carey Island, Malaysia.

**Table 1.** Spatial distribution pattern of *N. fruticans* in six study plots.

| Plot | Seedling | Juvenile | Adult | Mature |
|---|---|---|---|---|
| 1 | - | Random | Clumped | Regular |
| 2 | - | Regular | Regular | Clumped |
| 3 | - | Regular | Regular | Regular |
| 4 | Random | Regular | Regular | Regular |
| 5 | - | Random | Clumped | Random |
| 6 | Regular | Clumped | Regular | Random |

plastochrone with the total number of leaves (Tlf) at the end of the study, including scars and dead leaves, and adding an age estimate (time spent) for its prior stages.

**Reproductive phenology**

A total of 115 individuals with signs of reproductive organs were observed monthly for 14 months to determine the changes in reproductive development. Some weekly field observations were also conducted to note the changes in stages that took less than a month.

Seven developmental stages were considered:

1. No inflorescence
2. Unexpanded inflorescence
3. Expanded inflorescence with unopened flowers enclosed by bracts
4. Expanded inflorescence with opened flowers and signs of insect visitations. The globular female flowers with green or yellow colour can be distinguished from yellow catkin-like male flowers
5. Immature fruits appearing in female flowers and male flowers releasing pollen and turning black
6. Mature fruit with the first fallen fruit
7. Dry inflorescence with completely dropped fruits.

A total of 54 seeds of mature nipah were sown in a glasshouse. The germination rate was recorded for 12 weeks. The total number of new inflorescences and infructescences and the number of fruits per infructescence were counted to estimate data on annual flower and fruit production.

## RESULTS

### Population structure and spatial distribution

Table 1 presents the spatial distribution pattern of *N. fruticans* in 6 study plots. The distribution patterns in all stages can be random, regular or clumped, though

**Table 2.** Percentage of each life stage.

| Seedling (%) | Juvenile (%) | Adult (%) | Mature (%) |
|---|---|---|---|
| 2.2 | 13.7 | 67.9 | 16.2 |

**Table 3.** The growth data of seedling, juvenile, adult and mature (mean ± sd) of *Nypa fruticans*.

| | Seedling | Juvenile | Adult | Mature |
|---|---|---|---|---|
| Tlf | 4.3 ± 2.6 | 7.7 ± 1.6 | 12.3 ± 2.2 | 17.7±2.1 |
| Elongation (month$^{-1}$) | n.a. | 55.5 ± 23.2 | 81.0 ± 13.5 | 91.0 ± 13.7 |
| Nlf (year$^{-1}$) | 2.9± 0.9 | 1.0 ± 0.8 | 1.0± 0.7 | 1.0 ± 0.9 |
| Pl (month) | 3.5 ± 0.8 | 9.1 ± 1.1 | 10.2 ± 0.5 | 10.1 ± 0.4 |
| Time spent (year) | 1.3 ± 1 | 5.7 ± 1.4 | 10.9 ± 6.7 | 15.3 ± 1.8 |

Tlf = total leaves, Nlf = new leaves per year, Pl = plastochrone.

regular distribution seems to be the main pattern for this species.

More than 67% of the population of *N. fruticans* was in the adult stage (Table 2). Seedlings were poorly represented at 2.2%. Although the plot size is not the same at both sites, the data obtained was converted into density counts per hectare, and showed a range of 1025 – 6400 ha$^{-1}$ and averaged as 3267 ha$^{-1}$. A total of 162 new recruits (germinated seeds) can be observed until the end of the study but only 3 seedlings were established as new plants, while most of them were washed away during periods of inundation.

## Growth rate and age estimation

### Seedling stage

At the end of the study period, 4 seedlings produced 1 spear leaf, 1 seedling produced 6 spear leaves, 1 seedling produced 4 spear leaves and 2 seedlings did not produce any new leaf. On average the seedlings produced in a range of 2.4 - 3.9 with an average of 2.9 ± 0.9 leaves per year (Table 3). On average, the mean estimated time spent in the seedling stage was 1.3 ± 1.0 years, and the oldest sampled plant being 3.3 years old.

### Juvenile stage

In total, 18 juveniles produced 1 spear leaf, 16 juveniles produced 2 spear leaves, 6 juveniles produced 3 spear leaves, and 10 juveniles did not produce any spear leaf. The leaf growth of juveniles is shown in Table 3 and Figure 2a. The average total number of leaves in juvenile stage was between 5.7 and 6.4, with average of 7.7 ± 1.6. Juvenile stage plants produced 1 leaf per year, which is slower than the seedling stage. The average plastochrone observed was 10.3 months. The plastochrone was reflected in the time spent estimation. The maximum time spent in the juvenile stage was 8.3 years (averaged at 5.7 ± 1.4).

### Adult stage

There were 89 adults that produced 1 spear leaf, 71 adults producing 2 spear leaves, 23 adults producing 3 spear leaves, 1 adult producing 4 spear leaves, and there were 61 adults that did not produce any spear leaf by the end of the study. The leaf production and spear elongation of 2 sampled adults that produced 4 new spear leaves are shown in Figure 2b.

Table 3 showed that the adult stage produced on average 1.0 ± 0.7 leaves per year, which is roughly similar to the juvenile stage. The spear elongation grew at average of 81.0 ± 13.5 cm per month. The plastochrone is about 10.2 months, not significantly different between plots. The time spent in this stage was averaged at 10.9 ± 6.7 years; and the maximum was estimated at 16.9 years old.

### Mature stage

At the end of the study, 21 mature trees produced 1 spear leaf, 11 trees produced 2 spear leaves, 5 trees produced 3 spear leaves, 3 trees produced 4 spear leaves, and there were 17 trees that did not produce any spear leaf at Site 1. Figure 2c shows the leaf growth in mature stage.

Table 3 showed that the total number of leaves in the mature stage is averaged at 17.7 ± 2.1. The average number of leaves produced was also similar to the adult and juvenile stages; 1.0 ± 0.9. The plastochrone is a bit shorter than in the adult stage. The time spent in the mature stage is averaged at 15.4 ± 1.8 years old; and the maximum was estimated at 19.9 years.

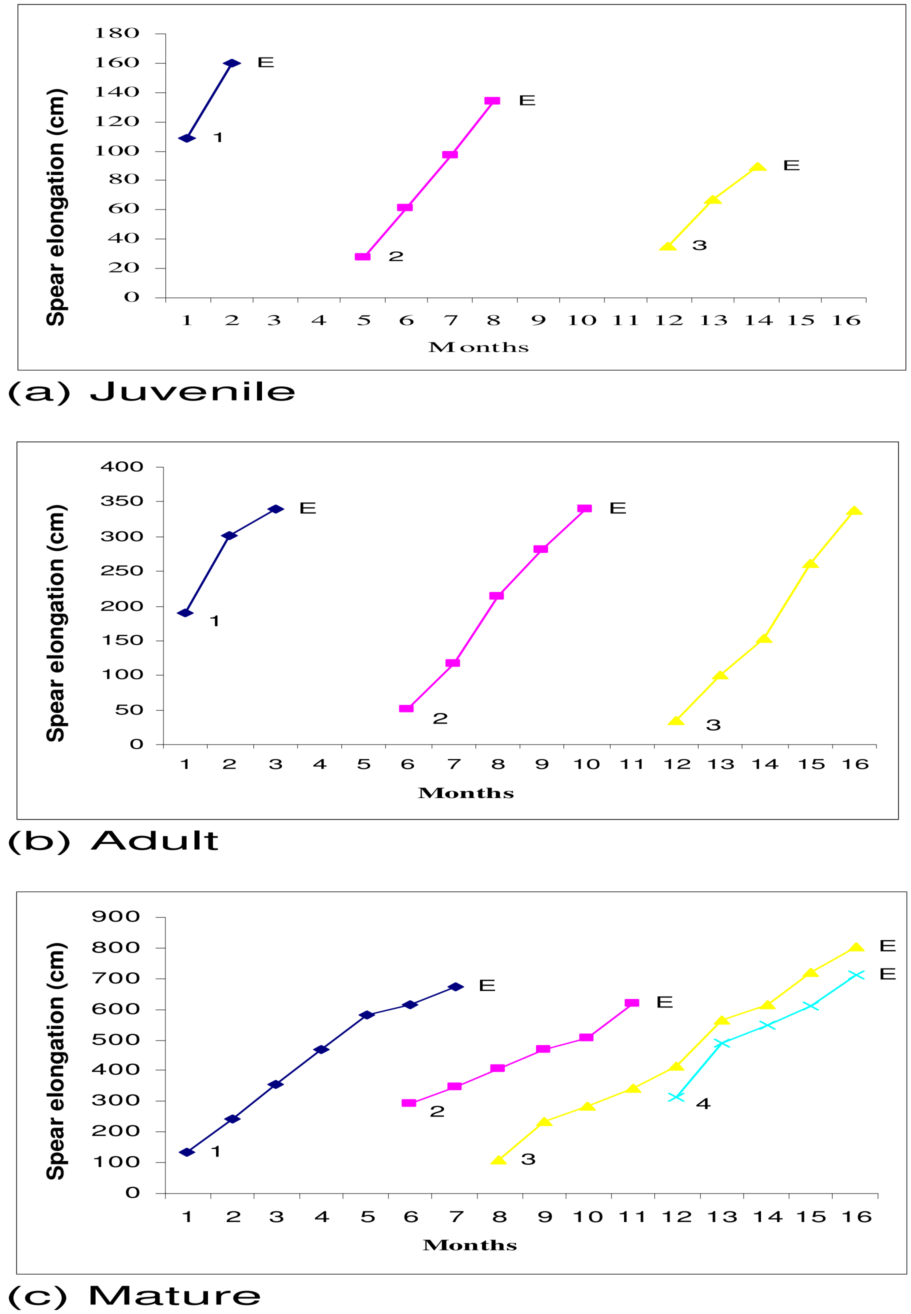


**Figure 2.** Leaf production, spear elongation and plastochrone in three life stages of *Nypa fruticans*. Growth is characterized by appearance of new spear leaves and spear leaf elongation until the leaf became fully expanded, noted by symbol E. The plastochrone was obtained by counting the time period between 2 successive spear leaves.

By summation of average time spent estimation in all stages, the oldest age estimated for *N. fruticans* in Carey Island is averaged at 33.2 years.

## Reproductive phenology

The results indicated that the range of each stage was as follow: Stage 2 - 3: 16 - 23 days, Stage 3 - 4: 7 - 16 days, Stage 4 - 5: 14 - 21 days, Stage 5 - 6: 180 days, Stage 6-7: 30 to 50 days. Therefore, the total flowering cycle took between 8.2-9.6 months. In Stage 3, the female flower can be distinguished from the male by its single spherical shape that contains a cluster of yellow flowers, around 6 cm in diameter and positioned at the tip of the inflorescence trunk, while the male flowers are about 6 to

7 clusters, yellow, oval shaped and positioned below the female flowers. This continues until the female flowers turn into young fruits in stage 5, when they are round and brown in colour. Male flowers release their pollen and turn black in stage 5. Then in stage 6, the young fruits became mature, when the first fruit was detached from the cluster of fruits. The fruit bunch was measured at about 85 cm in circumference, and held 60 to 120 mature fruits of 8 - 12 cm diameter each. The germination rate in the glasshouse was low, only 16.6%.

Initial data showed that only 115 individuals from both sites had a sign of reproductive organs out of a total of 306 adult and mature trees. Within the 14 months study, 61 out of 115 trees (53.0%) actively produced a total of 78 inflorescences and only 45 trees (39.1%) produced 54 infructescences. Therefore, a productive tree could produce 1 inflorescence and 1.0 infructescence per year, on average. A single tree may bear between 1 - 4 inflorescences and 1-3 infruitescences but most of them bore only 1-2 at any time.

## DISCUSSION

As a primary rule, seed dispersal and final rest are key factors that impact on the distribution of any population. Many studies showed a 'reverse J' structure or pyramid shaped distribution i.e. higher proportion of younger or early life stages than in older or later life stages (e.g. Homeier et al., 2002, Perez-Farrera et al., 2006). In this study, seeds of *N. fruticans* were subject to being washed away by the daily high water. Therefore, the results indicated a 'J' structure, that is, seedlings were almost completely absent from the population of this species but the adult and mature stages showed the highest proportion. As the plants grow older, competition for resources like sunlight and space might contribute to the decreasing number of mature stage compared to adult stage. This population structure remains throughout because no deaths and few newly settled or established recruits were observed. Although many seeds germinated throughout the study, only 3 individuals were established as new members of the population within the plots, while the rest were washed away to an unknown fate (they may have settled somewhere else). However, regeneration of nipah forest by underground suckering is known to be a habit of this species – i.e. producing new individuals straight into juvenile stage and bypassing the seedling phase. The same phenomenon was also observed in a hill forest palm, *Arenga obtusifolia* (Rozainah et al., 2002).

It is unknown whether all individuals of *N. fruticans* would exhibit vegetative multiplication habits at a certain time of life. But this habit may be responsible for the spatial distribution pattern shown. All stages except seedling stage showed a combination of random, clumped and regular distribution patterns, although a regular pattern was mostly the norm. The lack of clumped pattern results in the seedling stage (Table 1) could be due to a small number of individuals available. However, at this point it is quite difficult to tell the distribution pattern of the species since it showed all patterns, and no conspicuous environmental factors could relate to it.

The high density of *N. fruticans* in this area is amazing and a pure stand of nipah is very common everywhere this species occur, especially fringing riverbanks. The current study recorded up to 1025-6400 trees per hectare and this could have many implications for forest management. This is more than was recorded by Paivoke (1985) who encountered a range of 2150 - 4700 trees of nipah per hectare in Papua New Guinea. Rodriques-Buritica et al. (2005) recorded *Geonoma orbignyana*, an under storey palm in Colombia at 10800 – 31100 trees per hectare, and this was considered as an opportunistic species taking advantage of any forest gap. Nipah does not appear as an opportunistic species but more of complementing the saline environment that is conducive for this species but not for other terrestrial species. Although dense, penetration of the area is still possible by other mangrove species like *Xylocarpus granatum* and *X. mollucensis*. This behaviour of nipah is like other major mangrove trees like *Rhizophora* sp or *Bruguiera* sp that form pure stands and thrive in this saline environment.

Palms in general may only expand its girth or diameter at breast height at the beginning of their life, but focus more on vertical height towards the later stages. Therefore, it is important to retain the same method in growth measurement, that is, leaf growth, which is reflected by annual leaf production or to a lesser extent, spear leaf elongation until it is fully opened. A small data in seedling stage recorded the highest leaf production, up to 2.9 leaves per year followed by the older stages, which rarely go beyond 1 leaf per year. This is very slow growth but is very common for palms, although low rate of leaf production results in a low rate of forest generation. The older the stage, the quicker the spear elongates. Generally the spear has to fully open first before the next spear leaf emerges, as shown in the juvenile and adult stages (Figures 2a and b). However, in mature trees, there have been occasions where one spear leaf emerged soon after another and both elongated together (Figure 2c).

The total mean age of mature trees is estimated to be 33.2 years, although this could be an underestimate since the number of dead leaves could be higher than was observed. It seems to be quite a young population, but since some individuals are originating from another individual (underground suckering), the exact age determination is quite problematic. We can only estimate as it stands vertically in the population, and had to treat each individual separately even though they may have originated from another tree and therefore could be much older (or much younger) than estimated. The underground suckering is not conspicuous; an extensive excavation would need to be conducted and since nipah grow up to 8 m tall, the task would be laborious and impractical, with it being inundated twice daily.

The whole reproductive sequence of *N. fruticans* including the developmental process from bud to ripe fruits is quite short; about 8.2 - 9.6 months, and flowering and fruiting can be observed throughout the year without significant preference for month or season, although December to February recorded slightly more frequent flowering events. There were less than 40% of adult and mature plants in the flowering state, only 1.1 inflorescences and 1.0 infructescence per tree per year, and low germination rate at 16.6%. Thus it is clear that low rate of reproduction coupled with frequent fruit and seedling loss by strong waves does not play a major role in regeneration of the population. The underground suckering behaviour seems most likely to be positively and actively contributing to the massive density of this species. It is interesting that nipah's fruits are less important for its own regeneration but are widely used for a sugar drink locally known as nira, or for sugar, alcohol or vinegar production depending on the fermentation level of the sap (Fong, 1982). This implies that good forest management to maximize the number of nipah trees could generate income for local people. The sugar production and related uses could be increased for economic benefits especially for the local folks within the vicinity. Currently the potential of nipah as a sugar source is only for the local market. It could be further commercialized with proper support in tapping processes, packaging, branding and marketing. In Mexico, the Maya farmers have been using leaves of *Sabal* palm for thatching the roofs of their traditional houses. They have successfully managing the population of this palm by harvesting the plants once or twice per year leaving one or two young leaves in each event to simulate new leaves production (Martinez-Balleste et al., 2008).

Environmental factors play an important role in determining a species' population history (for example; fire, although considered as a disturbance, is important in stimulating cone production of the cycad, *Ceratozamia mirandae* leading to high number of new recruits (Perez-Farrera et al., 2006). There is no record as to why or when a single nipah tree would trigger its underground growth. Could it be a reaction to changes in environmental factors?

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