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Seasonality in fruiting of fig and non-fig species in a tropical dry evergreen forest in Sriharikota Island, southern India

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Abstract: The fruiting seasonality of fig and non-fig species was studied for two years in a tropical dry evergreen forest (TDEF) in Sriharikota, southern India, to assess the influence of rainfall on fleshy-fruit production and to compare the fruiting seasonality of fig with non-fig species. Fifty non-fig species and four fig species were monitored to record fruiting seasonality. A majority (37) of the 50 non-fig fleshy-fruit species produced ripe fruits during the rainy season. There was a positive correlation between rainfall and number of species with ripe fruits. In contrast, figs did not show any seasonality, conforming to the universal pattern of asynchrony. Fruiting peak in figs coincided with some lean fruiting periods of non-fig species, but not with all lean periods of non-fig fruiting. This study confirms the strong influence of rainfall on fleshy-fruit production in non-fig species. It also reveals that figs are an important fruit resource for frugivores during periods of fruit scarcity, but not during all periods of fruit scarcity.

Resumen: Durante dos años se estudió la estacionalidad de la fructificación de los higuerones (Ficus) y de otras especies en un bosque seco perennifolio en Sriharikota, sur de la India, para evaluar la influencia de la precipitación sobre la producción de frutos carnosos y comparar la estacionalidad de la fructificación de los higuerones con la de otras especies. Se monitorearon cuatro especies de higuerones y 50 especies de otros géneros para registrar la estacionalidad de la fructificación. La mayoría (37) de las 50 especies de frutos carnosos que no eran higuerones produjeron frutos maduros durante las lluvias. La precipitación y el número de especies con frutos maduros se correlacionaron positivamente. Por el contrario, los higuerones no mostraron estacionalidad alguna, conformándose al patrón universal de asincronía. El pico de fructificación en los higuerones coincidió con algunos períodos de producción débil de frutos de las otras especies, pero no con todos los períodos de producción débil de frutos de estas especies. Este estudio confirma la fuerte influencia de la precipitación sobre la producción de frutos carnosos en las especies que no son higuerones y revela que los higuerones constituyen una fuente importante de recursos para los frugívoros en algunos periodos de escasez de frutos, pero no en todos ellos.

Resumo: A sazonalidade na frutificação de espécies produtoras de figo e de outros frutos não-figo numa floresta tropical seca sempreverde (TDEF), foi estudadadurante dois anosem Sriharikota, no sul da Índia, para avaliar a influência das chuvas sobre a produção de frutos carnudos e comparar a sazonalidade da frutificação de tipo figo com outras espécies não-figo. Monitorizaram-se cinquenta espécies sem serem do tipo figo e quatro espécies de figueiras para registar asazonalidade da frutificação. A maioria (37) das 50 espécies carnudasnão-figo, produziu frutos maduros na estação chuvosa. Houve uma correlação positiva entre a precipitação e o número de espécies com frutos maduros. Em contraste, as produtoras de figo não apresentaram sazonalidade, em conformidade com o padrão universal de assincronia. O pico de frutificação em figos coincidiu com alguns períodos de baixa frutificação de espécies não-figo,

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mas não com todos os períodos de escassez de frutificação não-figo. Este estudo confirma a forte influência da precipitação sobre a produção de frutos carnudos em espécies não-figo. Ela também revela que os figos são um recurso importante para os frugívoros durante os períodos de escassez de frutos, mas não durante todos os períodos de escassez.

Key words: Figs, frugivores, fruit scarcity, fruiting seasonality, rainfall, Sriharikota.

Introduction

Almost all tropical environments vary seasonally in rainfall, temperature, humidity, wind speed and day length (Richards 1952). These variations in abiotic factors strongly influence the pattern of flowering and fruiting. In fact, most studies of tropical fruiting phenologies report seasonalities and also reveal extreme seasonality in annual fruiting patterns among plants with fleshy-fruits in forests with distinct wet and dry season (Engel & Martins 2005; Howe & Smallwood 1982). It has been found that a majority of the fleshy-fruit species across the globe produce fruits during the peak rainy season or just before the onset of the peak rainy season (Bhat 1992; Lieberman 1982; Luciana & Machado 2001; McLaren & McDonald 2005; Murali & Sukumar 1994; Sundarapandian *et al*. 2005; Van Schaik *et al*. 1993). This fruiting pattern may reduce seedling mortality by dispersing seeds when soil moisture conditions are favourable for seed germination and rapid seedling growth (van Schaik *et al*. 1993).

In contrast to other plants, the fruiting pattern of figs at a community level does not show any seasonality (Kannan & James 1999; Kinnaird *et al*. 1996; Lambert & Marshall 1991; Terborgh 1986). Fig fruits are found throughout the year because of intra-crown synchrony of fruit ripening, relatively short intervals between fruiting and intra-population fruiting asynchrony (Lambert & Marshall 1991). Since fig fruits are available throughout the year, they are very important for a variety of birds and mammals in most tropical forests (Bleher *et al*. 2003; Kelvin & Chong 2003; Lambert & Marshall 1991; Stevenson 2005; Terborgh 1986).

Studies pertaining to frugivory have always taken into consideration community level patterns of fruiting and flowering since they represent the food supply of frugivores and nectarivores (Chapman *et al*. 1999). Furthermore, monitoring fruiting in plants helps discern annual periods of fruit scarcity and abundance and identifies potentially important fruiting plants for frugivores (Howe 1984). This paper reports the findings of a study on fruiting seasonality of fleshy fruit species that serve as food plants for frugivores, which was part of a larger project on fruit-frugivore interactions undertaken from November 2004 - May 2008. The objectives of the study were to assess the influence of rainfall on fleshy-fruit production, to compare the fruiting seasonality of figs with non-fig species and to know if figs were a reliable resource during periods of fruit scarcity. We also compared the findings from Sriharikota with those reported in other tropical dry evergreen forests in India.

Materials and methods

Study area

Sriharikota is a spindle shaped island (181 km^2) situated largely in Nellore district of Andhra Pradesh and bounded on the east by the Bay of Bengal and on the west by Pulicat Lake (Fig. 1). The island has a coastline of *ca*. 56 km from north to south, and its east to west dimensions vary from *ca*. 9.6 km in the central part to 1 km in the southern parts. Sriharikota has been connected by road to Sulurpet (18 km) on the mainland since 1970. Prior to this, access to the island was mainly by boat from Tada.

The island comprises low ridges of sand, marine and aeolian in origin, rising 4.5 - 6 m and sloping from west to east. The northern and southern parts of the island are largely made up of sand dunes. The water table is *ca*. 2 to 5 m. Low-lying areas of Sriharikota get inundated during the north east monsoon rains, creating streams and pools. Besides the monsoonal inundation, the wetlands of Sriharikota comprise of fresh and brackish water lakes (kayyas), streams (vagus), creeks, and natural and man-made freshwater ponds (guntas) (Agrawal *et al*. 1985; Rao 1977; Rao 1998; Reddy 1981; Reddy 1983; Samant & Rao 1996).

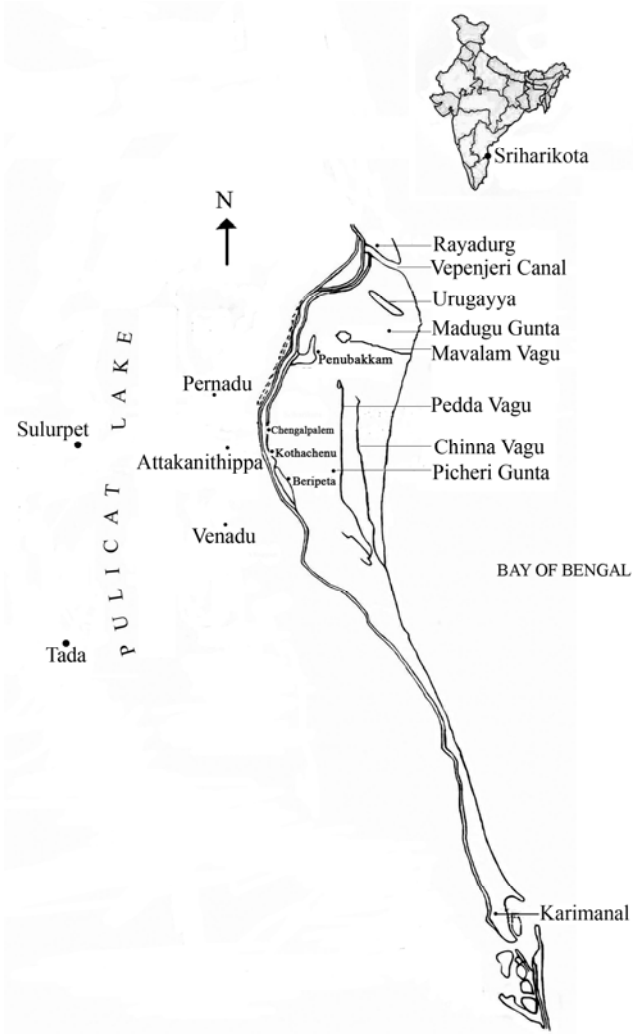

Fig. 1. Sriharikota Island and its adjoining areas.

Though the island is affected by both the monsoons, the principal rainfall is from the north-east (NE) monsoon. The annual rainfall averages 1200 mm and the average humidity varies from 55 % in summer to 75 % during the monsoon (Sriharikota Meteorological Department). Temperature fluctuates from 20 °C in winter to 40 °C in summer. The year may be broadly divided into four seasons: Summer (March - May), South-west (SW) monsoon season (June - September), NE monsoon season (October - mid-December), mild winter (mid-December - February).

According to the classification of forest types of India (Champion & Seth 1968), the forest of Sriharikota is termed as tropical dry evergreen forest. Due to the varied ecological conditions and past and present anthropogenic impacts, the structure of the vegetation is not uniform even within a vegetation type. The vegetation of Sriharikota may be broadly classified into the following types:

Tropical dry evergreen forest

Tropical dry evergreen forests (TDEF) are found in the central part of the island, stretching from south of Urugayya Lake till around Picheru Gunta, except in sandy tracts or areas under plantations. The common species are *Atlantia monophylla*, *Garcinia spicata*, *Syzygium cumini, Strychnos nux-vomica, Cordia dichotoma, Memecylon umbellatum, Glycosmis pentaphylla* and *Eugenia bracteata.* Climbers such as *Jasminum* spp., *Carissa spinarum, Olax scandens, Coccinia grandis* and *Zizyphus oenoplia* make the forest dense and impenetrable. Along streams and shallow basins, which are inundated during the monsoon, *Terminalia arjuna*, *Barringtonia acutangula* and *Pongamia pinnata* are dominant. Cane brakes line most of the waterways.

Open scrub

Open scrub forest is largely present in the sandy tracts of the island, which mostly occur in the northern, eastern and southern fringes of the Island. There is also a sandy track in the central part of the Island. The ground is sandy and much exposed with predominance of shrubs like *Gmelina asiatica, Diospyros ferrea, Securinega leucopyrus, Catunaregum spinosa, Maytenus emarginatus, Dodonea viscosa, Capparis* spp., and *Pavetta indica.* Scattered trees of *Syzygium cumini, Lannea coromandelica, Azadirachta indica, Albizzia amara, Walsura trifolia* and *Ochna obtusata* are also seen.

Forests on abandoned village sites

The stretch of land situated on a low basin between Kothachenu to Tethupeta, and to a lesser extent around Penubakkam to the former Chengalapalem was under cultivation in the past. Ponds were maintained to irrigate the paddy fields in the basin and the other crops along the borders. Now abandoned, these areas have their own characteristic vegetation, composed of *Coccos nucifera*, *Borassus flabellifer*, *Azadirachta indica*, *Tamarindus indica*, *Ficus* spp., *Albizia amara, Albizia lebbeck* and *Lannea coromandelica* which contrast with the open scrub forest that run parallel east of the basin. The irrigation ponds have now been colonized by canebrakes. *Barringtonia acutangula* saplings have taken root in some of the former paddy fields.

Table 1. Plant species with fleshy-fruits and fruiting frequency. Nomenclature follows Suryanarayana *et al.* (1998).

Species	No. of plants tagged	% of individuals with ripe fruit	
		2006-07	2007-08
	Shrubs		
Allophylus serratus	5	60	0
Breynia vitis- idaea	6	50	17
Canthium parviflorum	11	36	27
Capparis brevispina	1	100	100
Carissa spinarum	7	100	57
Casearia esculenta	8	37	13
Catunerigun malabarica	17	94	41
Eugenia bracteata	10	20	0
Flacourtia indica	10	20	0
Glycosmis pentaphylla	9	56	0
Grewia rhamnifolia	19	0	79
Memecylon umbellatum	22	100	0
Pavetta indica	10	30	0
Securinega leucopyrus	31	84	84
Toddalia asiatica	1	100	100
	Climbers		
Cansjera rheedii	10	90	30
Coccinia grandis	9	100	44
Hugonia mystax	7	100	71
Olax scandens	17	82	94
Opilia amantaceae	5	80	100
Pachygone ovata	8	88	63
Salacia chinensis	10	100	50
Scutia myrtina	2	50	50
Zizyphus oenoplia	22	91	77
	Small Trees		
Atlantia monophylla	9	55	67
Canthium dicoccum	9	44	0
Cordia dichotoma	10	0	10
Diospyros ferrea	28	25	11
Ehretia pubescens	11	100	64
Garcinia spicata	10	0	0
Lepisanthes tetraphylla	10	0	40
Ochna obtusata	8	88	100
Pamburus missionis	11	100	55
Premna latifolia	4	25	25
Salvadora persica	10	100	0

Contd...

Table 1. Continued.

Species	No. of plants tagged	% of individuals with ripe fruit	
		2006-07	2007-08
	Small Trees		
Walsura trifolia	11	73	18
Zizyphus mauritiana	10	80	70
Unidentified species	3	67	100
	Large Trees		
Alangium salvifolium	10	60	80
Azadirachta indica	10	100	100
Calophylum inophyllum	8	75	0
Cassine glauca	1	100	100
Lannea coromandelica	13	69	77
Manilkara hexandra	18	0	28
Mimusops elengi	5	60	80
Strychnos nux-vomica	10	70	10
Syzygium cumini	16	69	69
Tamarindus indica	10	80	50

Eucalyptus and Casuarina plantations

Eucalyptus was introduced into the Island in the 1950s by the State Forest Department. They are mainly seen from about Urugayya Lake to the south of Picheri Gunta. Stunted shrub stages of plants such as *Memecylon umbellatum*, *Securinega leucopyrus*, *Catunaregum spinosa, Atlantia monophylla* form the undergrowth. An understorey of *Strychnos nux-vomica*, *Garcinia spicata* and *Ochna obtusata* has also come up in some of the more open plantations.

Casuarina plantations are seen in a narrow stretch all along the sea coast. Shrubs and trees like *Securinega leucopyrus, Azadirachta indica, Pavetta indica, Calotropis gigantea,* and *Borassus flabellifer* form the understorey. *Olax scandens* is a common climber, while *Dendrophthoe falcata* is a common stem parasite on *Casuarina* trees.

A total of 445 species of plants (terrestrial and aquatic), belonging to 117 families have been reported from the Island (Suryanarayana *et al*. 1989, 1998). The recorded fauna of this Island is represented by 27 mammal species, 223 species of birds, 12 species of amphibians, 34 species of reptiles, 44 species of fish and 51 species of butterflies (Manakadan *et al*. 2009; Manakadan & Sivakumar 2004a,b; Sivakumar & Manakadan 2004; Sivakumar *et al*. 2004).

Methods

Fruiting seasonality

A total of 50 fleshy-fruit species were monitored for the study in 4 vegetation types (excluding eucalyptus) along the transects laid out for censusing birds. Of these, 48 species were tagged which included 10 large trees, 14 small trees, 15 shrubs and 9 climbers (Table 1). Not less than ten individuals were tagged for common species; for rare species, the numbers depended on the availability in the area. These tagged plants were monitored twice a month for presence/ absence of fruits from June 2006 to May 2008. Additionally, the fruiting phenology of four fig species *Ficus benghalensis, F. amplissima, F. microcarpa* and *F. racemosa* was monitored from September 2006 - May 2008.

Fruiting intensity

Fruiting intensity of a species was measured as the proportion of the tagged individuals bearing ripe fruits. If < 20 % of tagged individuals were with ripe fruits then it was considered as very low fruiting intensity. Similarly 21 - 49 % was considered as low fruiting intensity, 50 - 70 % as moderate fruiting intensity and > 70 % as high fruiting intensity.

Table 2. Comparative data on patterns of rainfall and ripe fruit availability in three Tropical Dry Evergreen Forest (TDEF) sites in southern India.

Parameters	Point Calimere	Oorani	Sriharikota
Co-ordinates	10˚18′ N-79˚57′ E	12˚11′ N-79˚57′ E	13°43′ N-80°13′ E
Mean annual rainfall (mm)	746	1282	1200
Duration of rainfall (> 50 mm)	4 months	7 months	7 months
No. of fleshy-fruit species sampled	64	18	50
Duration of sampling	2 years	1 year	2 years
Peak fruiting season	Post-monsoon (before onset of summer)	Summer	SW Monsoon

Sources: Balasubramanian & Bole (1993); Selwyn & Parthasarathy (2007); Present study.

Results

Fruiting seasonality of non-fig species

Community pattern

Fruiting in Sriharikota was highly seasonal with 37 of the 50 fleshy-fruit species producing ripe fruits during the two rainy seasons from June to December, i.e., during the SW monsoon (June to September) and NE Monsoon (October to December). The number of species with ripe fruits began to increase from May (summer) after some showers are received (Fig. 2). Fruiting attained a peak during the period of moderate rainfall (August and September), just before the commencement of the major wet season in October, with 28 of the 37 species containing ripe fruits. The number of species with ripe fruits declined from November onwards and remained low till April. There was a positive correlation between rainfall and number of species with ripe fruits (Pearson r = 0.55, $P < 0.005$).

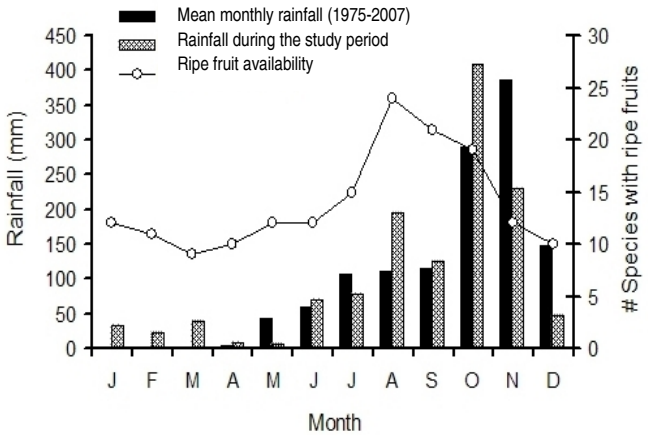

Fig. 2. Fruiting seasonality in Sriharikota in relation to rainfall.

The most common and abundant species in the island produced fruits during the wet season, except for *Ochna obtusata*. These include *Memecylon umbellatum*, *Syzygium cumini*, *Diospyros ferrea* and *Olax scandens*. Species such as *Eugenia bracteata*, *Phoenix farinifera* and *Lepisanthes tetraphylla* produced ripe fruits during the summer (March to May). Seven of these species are rare or confined to specific sites in the Island. Thirteen species were with ripe fruits during the mild winter (December to February). Seven species produced fruits exclusively during the period of very low rainfall from January to April. They include *Cansjera rheedii*, *Manilkara hexandra, Mimusops elengi*, *Salvadora persica, Toddalia asiatica*, *Zizyphus mauritiana* and *Zizyphus oenoplia*. *Hugonia mystax* showed bimodal fruiting pattern, producing ripe fruits once in January and again in August - September. Fruiting pattern in Sriharikota was different from two other coastal tropical dry evergreen forest sites in southern India (Table 2).

Life-forms

The number of tree species with ripe fruits gradually increased from May and peaked in August, similar to the general fruiting pattern (Fig. 3). Among shrubs, the number of species with ripe fruits was high in September and October, but very low in June and July compared to January and February. Among the climbers, number of species with ripe fruits was high in August, September, and October, but low in May and June. Peak fruiting of all life-forms occurred during the wet season.

Inter-year variation

There was annual variation in the number of species with ripe fruits and the number of

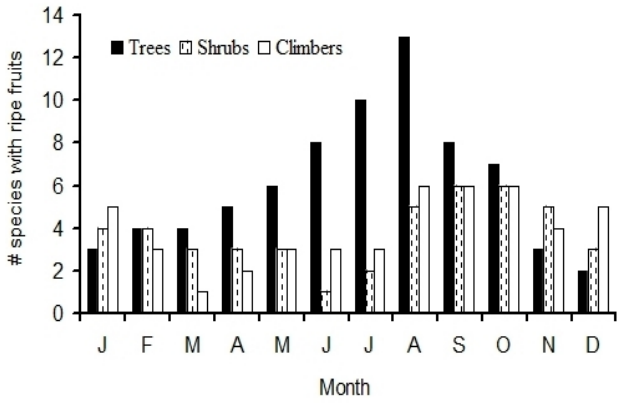

Fig. 3. Fruiting seasonality of life-forms in Sriharikota.

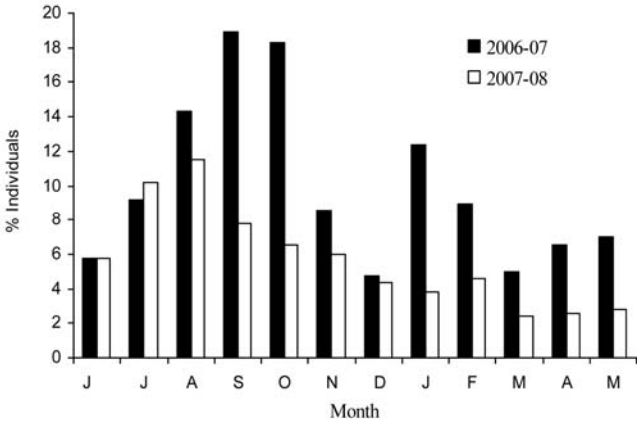

Fig. 4. Percentage of individuals with ripe fruits across months (n = 512).

individuals with ripe fruits. A total of 36 species produced ripe fruits during the first year and 26 species in the second year. Species such as *Glycosmis pentaphylla*, *Memecylon umbellatum*, *Salvadora persica*, *Calophyllum inophyllum* and *Walsura trifolia* produced fruits only during the first year, and it was opposite the case in *Manilkara hexandra* and *Grewia rhamnifolia.*

There was also variation in the number of individuals with ripe fruits between years. Three-hundred and fourteen individuals produced ripe fruits during the first year and 223 during the second year. The number of individuals with ripe fruits was high in September and October 2006 (Fig. 4). During this period the maximum number of individuals was contributed by *Memecylon umbellatum* (39 %) and *Securinega leucopyrus* (39 %), two common plants in the Island. The same trend was not observed in the following year, when the highest number of individuals with ripe fruits was in July and August. The number of individuals in fruit was very low during the summer months of March, April and May 2008.

Fruiting intensity and duration

About 47 % of species had high fruiting intensity during the first year (n = 43 species). In contrast, during second year only 26 % of species had high intensity fruiting. High intensity fruiting was observed during both the years in *Azadirachta indica*, *Lannea coromandelica*, *Olax scandens*, *Securinega leucopyrus* and *Syzygium cumini*. Moderate intensity fruiting was witnessed in 23 % of the species during the first year and 21 % during the second year. Fruiting intensity was low during both the years in species such as *Casearia esculenta*, *Canthium parviflorum*, *Eugenia bracteata* and *Flacourtia indica*. About 12 % of the species did not fruit during the first year and during the second year the percentage of species which did not fruit was high at 23 %.

The longest duration of fruiting was in *Olax scandens*, with ripe fruits available for 7 months of a year from June to December during the first year (2006-07), but was not so in the second year, when ripe fruits were available only from August to October. About 42 % (n = 50) of the enumerated species had ripe fruits for 3 months; 26 % for 4 months; 20 % for 2 months and 10 % for 5 months.

Availability of fruits preferred by birds and mammals

Though fruits were available throughout the year for birds, those attractive to birds such as *Eugenia bracteata*, *Salvadora persica*, *Walsura trifolia, Lepisanthes tetraphylla, Azadirachta indica* and *Lannea coromandelica* were mainly available during the summer and early SW monsoon season (March to July) (Fig. 5). Fruits of climbers used by birds such as *Olax scandens*, *Scutia myrtina*, *Hugonia mystax* and *Zizyphus oenoplia* were available during the wet and winter season. Fruits preferred by fruit bats such as *Atlantia monophylla, Garcinia spicata, Pamburus missionis, Opilia amantacea* and *Syzygium cumini* were available from June to October.

Fig fruiting pattern

Community pattern

Fig fruits, an important resource for frugivores in tropical forests were available throughout the year in Sriharikota. At community level, the highest number of individuals with ripe fruits was

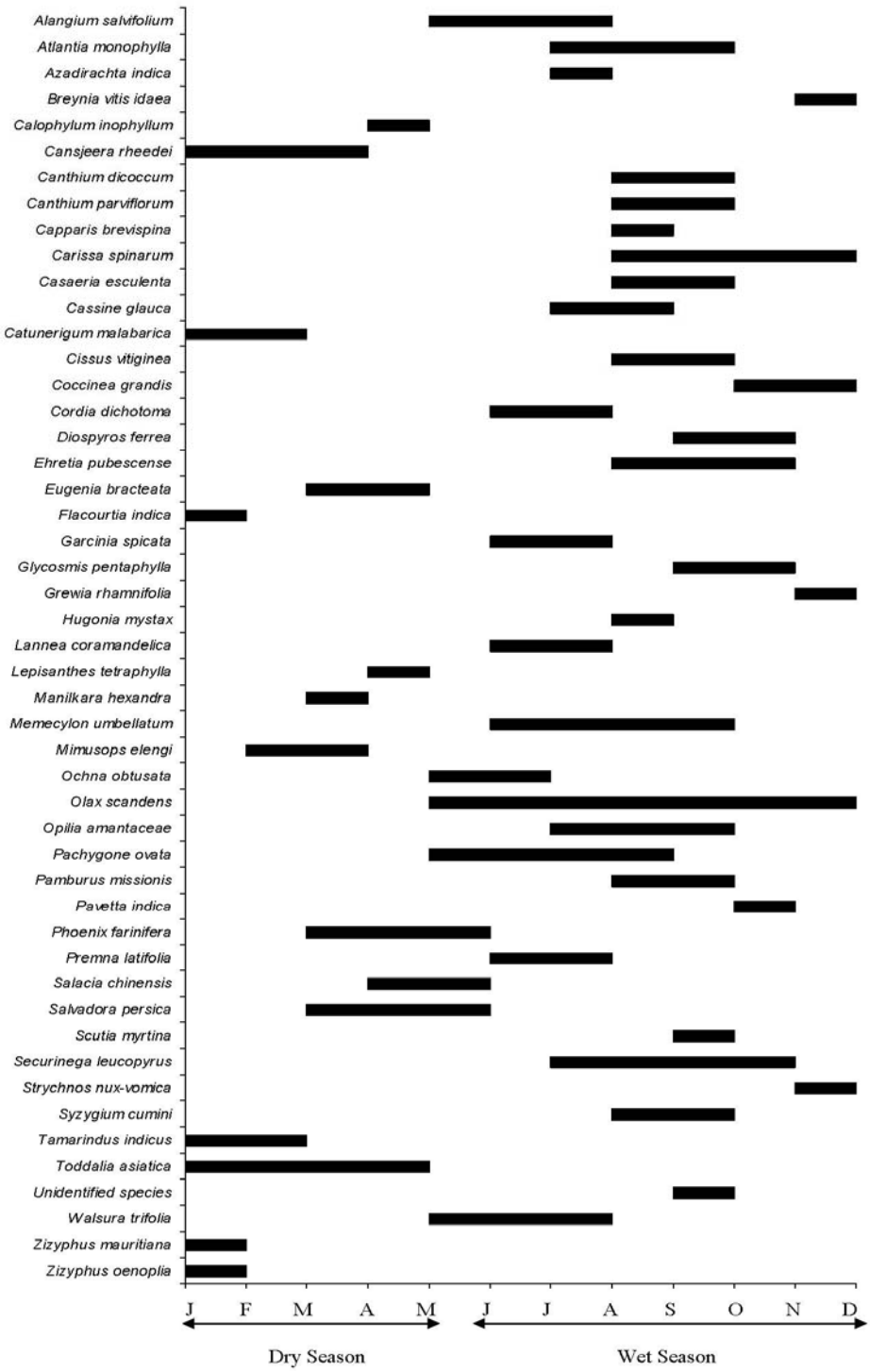

Fig. 5. Seasonality of fleshy-fruit species.

in April 2007, November 2007 and May 2008; when 26 out of the 119 individuals produced ripe fruits and lowest in December 2007 and January 2008 (Fig. 6). At least 2 trees were with ripe fruits in each month throughout the study period. In total, 88 % (n = 119) trees produced ripe fruits during the study period. Peak in fruiting happened both during the dry season (April 2007 and May 2008) and wet season (November 2007). During the first and second peaks, the majority of fruiting

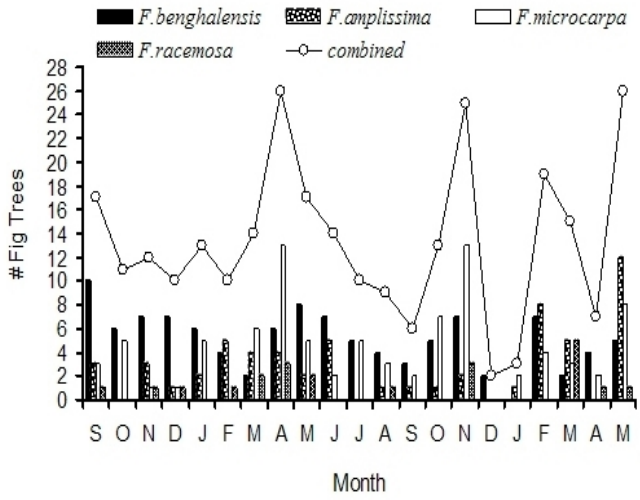

Fig. 6. Number of fig (*Ficus*) trees with ripe fruits (n = 119 trees) from September 2006 - May 2008.

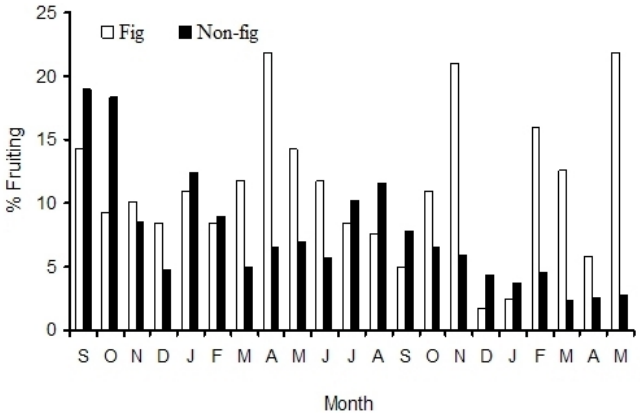

Fig. 7. Fruiting seasonality of figs in relation to non-fig species (n = 119 fig trees, 502 non-fig plants).

trees consisted of *Ficus microcarpa* (50 %), and during the third peak the majority of trees were contributed by *F. amplissima* (46 %). Fig fruiting pattern did not show positive correlation with rainfall (r = -0.22, $P < 0.32$).

Species-level pattern

At the species level, fig fruits were not continuously available during the study period. Fruits of *Ficus benghalensis* were not available in January 2008; *F. amplissima* did not fruit for 2 months during the first year (2006 - 07) and 2 months during the second year (2007 - 08) and *F. microcarpa* for one month during each year. *F. racemosa* did not fruit for 4 months during the first year and 5 months during the second year. There was a single fruiting peak in *F. benghalensis* (September 2006) and *F. amplissima* (May 2008), while in *F. microcarpa* fruiting peaked twice during the study period (April 2007 and November 2007).

Inter-year variation

There was no recurrent annual pattern in fruiting both at community level and species level. Seventeen individuals were in fruit in September 2006, while just 6 individuals were in fruit in September 2007. About 86 % of fig trees (n = 119) were in fruit during 2006 - 07 (12 months of sampling) and 72 % during 2007 - 08 (9 months of sampling). Similarly at species level too there was no similarity in fruiting pattern between years.

Figs vs. non-figs

Three of the fig fruiting peaks coincided with periods of scarcity of non-fig species. However, at the same time, the number of fig trees with ripe fruits was lowest in December 2008 and January 2009, when the number of non-fig species with ripe fruits was also low (Fig. 7). Hence, fig fruiting peaks did not always correspond with periods of non-fig fruit scarcity. This implies that fruiting peak/peaks in figs may not always coincide with lean periods of non-fig fruiting to help frugivores tide over such periods.

Discussion

Rainfall and seasonality

Rainfall and irradiance have been stated to strongly influence fruiting in plants in the tropics (Van Schaik *et al.* 1993). Rainfall is crucial because the two major environmental conditions necessary for germination of seeds are access to water and air (Noggle & Fritz 1991). In Sriharikota too, there seems to be a strong influence of rainfall on ripe fruit production. Fruiting season of fleshy-fruit species in Sriharikota was largely during the rainy season with 71 % of the plant species bearing ripe fruits during this period. This is a general pattern observed in tropical dry forests (Lieberman 1982; Luciana & Machado 2001; McLaren & McDonald 2005; Murali & Sukumar 1994), and has a distinct advantage as soil moisture conditions are favourable for seed germination and rapid seedling growth (Tesfaye *et al.* 2011; Van Schaik *et al.* 1993). Furthermore, drought conditions (higher temperatures and lower humidity and low soil moisture) experienced by tropical dry forest trees during the dry season impair growth and cell expansion, and put plants under more severe water stress and render inability to produce new organs (see McLaren & McDonald 2005).

Species synchronizing with the community level fruiting peak tend to be relatively more abundant in the plant community than those fruiting outside the peak (Herrera 1984). The most abundant and common species such as *Atlantia monophylla*, *Memecylon umbellatum*, *Syzgyium cumini*, *Diospyros ferrea* and *Olax scandens* produced ripe fruits during the community level fruiting peak in August and September. Species that fruited outside this peak such as *Zizyphus mauritiana*, *Lepisanthes tetraphylla*, *Salvadora persica*, *Toddalia asiatica* and *Lannea coromandelica* are rare or confined to specific sites in the island. However, this is not true in all the cases. *Allophylus serratus*, *Strychnos nux-vomica* and *Ochna obtusata* which are equally abundant and widespread did not produce ripe fruits during the community level fruiting peak.

Comparisons with other TDEF

When compared with two other TDEF (Point Calimere 10˚18′ N, 79˚57′ E and Oorani 12˚11′ N, 79˚57′ E in Tamil Nadu), differences in fruiting seasonality emerged. The fruiting peak in Sriharikota (n = 50 species), was in August and September, before the major rainy season; February and March after the rainy season in Point Calimere (n = 64 species, 2 year study) (Balasubramanian & Bole 1993) and April and May during the dry season in Oorani (n = 18 species, 1 year study) (Selwyn & Parthasarathy 2007). In Oorani, a minor fruiting peak was recorded in September, December and January and shrubs showed a peak during the late wet season.

Since rainfall is considered to be the major factor affecting fruiting, it was expected that both at Sriharikota and Oorani patterns of fleshy-fruit production would be similar, but in Sriharikota the number of species with ripe fruits was high in August and September (before the NE monsoon), whereas it was high during April (Summer) in Oorani, i.e., the fruiting peak (number of species with ripe fruits) in Oorani was three months before peak fruiting in Sriharikota. Hence, it appears that other factors (besides rainfall) could also affect the fruiting pattern of fleshy-fruits. However, it must be noted that only 18 species were monitored for seasonality in Oorani, whereas 50 species were monitored in Sriharikota.

Fruiting pattern of figs

Fig fruiting pattern at the community level was similar to what is reported in other tropical forests as they showed asynchronous fruiting pattern (Bleher *et al*. 2003; Borges 1993; Kannan & James 1999; Kinnaird *et al*. 1996; Lambert & Marshall 1991). The major advantage of an asynchronous fruiting in *Ficus* is to increase seed success through saturation of the environment with seeds as frequently and in as many months of the year as possible (Milton *et al*. 1982). As a colonizing species, this strategy can give better chances of seeds to get deposited at suitable germination sites. The year round flowering and fruiting of figs are also necessary for the survival of short-lived pollinators, which breed within the urn-shaped fig inflorescence (see Patel 1997).

In Sriharikota, the highest proportion of fig trees with ripe fruits in a month was 22 % (26 out of 119 trees in fruit). This was about the same as at Kuala Lompat (Malaysia) where the highest proportion of fig trees with ripe fruits in a particular month was 20.3 % (n = 316 trees) (Lambert & Marshall 1991) and higher than in Anamalais where it was 13 % (n = 100 trees) (Kannan & James 1999). In Sriharikota, figs fruited throughout the year at community level, but not at species level. This is true in other areas as well. In Kuala Lompat, medium and small-sized fig species did not fruit for 2 months out of the 36 months of study, and large-sized fig species did not fruit for 14 months (Lambert & Marshall 1991). During this study, *F. racemosa* (large-sized fig) did not produce fruit for 9 months of the study (n = 21 months).

Fruiting peak in figs coincided with some lean periods of non-fig fruiting, but not with all lean periods of non-fig fruiting. In fact, in some months, the low availability of fig trees with ripe fruits coincided with periods of scarcity of ripe fruits of non-fig plants. Similarly, Borges (1993) in one of her study sites (Magod, North Kanara District, Karnataka) reported fig fruit production to be low when there was shortage of non-fig fruits. Chapman *et al*. (2005) reported that figs did not fruit in 17 of the 34 months when fruits were scarce in Kibale National Park, Uganda. However, Patel (1997) reported the peak fruiting in figs coincided with peak in non-fig fruiting in a wet evergreen forest site in the Western Ghats.

The maximum number of individuals bearing fruits during fruit scarcity was contributed by *F. amplissima* and *F. microcarpa,* but not *F. benghalensis*. The fig species contributing during non-fig fruit scarcity may vary by year and season, and some fig species may not contribute fruits

during scarcity at all, which was the case with *F. benghalensis* in Sriharikota. Thus figs on the whole cannot be generalized as keystone resource, and instead, the fruiting pattern of figs needs to be evaluated at species level to assess the role of individual species as a keystone resource.

Conclusions

The fruiting pattern of fleshy-fruits in Sriharikota appears to be dictated by rainfall. This pattern is similar to that reported in most other tropical forests. Though fleshy-fruits were available throughout the year, there was annual variation in the number of species and number of individuals producing fruits. Inter-year variations in fruiting pattern and low fruiting intensity of some species makes non-fig fruits an unreliable and unpredictable resource in Sriharikota.

Fruiting seasonality of figs conforms to what has been reported for other forests, as they did not show seasonality in fruiting (asynchronous fruiting pattern). At community level, fig fruits were available throughout the year, but not at species level. There were differences in fruiting pattern at the species level and some individuals of a species fruit 2-3 times in a year. Due to the overall availability of ripe fruits throughout the year, figs can serve as an important food resource for frugivores during periods of non-fig fruit scarcity, but is not a reliable resource during all periods of non-fig fruit scarcity due to the random fruiting pattern.

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