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Macrofungi on the coastal sand dunes of south-western India

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Abstract

This paper documents the distribution and diversity of macrofungi in coastal sand dunes characterized by less, moderate and severe disturbance regimes of the south-western India. Diversity was higher in moderately disturbed dunes compared to less or severely disturbed dunes. Among the 38 macrofungi recovered, ten, six, two and one species were edible, ectomycorrhizal, medicinal and considered to be of decorative value, respectively. Ten macrofungi were dominant (≥5 fruit bodies/625 m^2) on the coastal sand dunes. These were *Amanita* sp., *Collybia dryophila* var. *extuberans, C. fusipes, Coprinus plicatilis, Dacryopinax spathularia, Lactarius* sp., *Lentinus squarrosulus, Marasmius kisangensis, Marasmius* sp. 2 and *Scleroderma citrinum*). The coastal sand dunes are under severe anthropogenic pressure, especially urbanization, sand extraction, agricultural activities and seawall construction. The revegetated dunes are mainly represented by exotic tree species (e.g., *Acacia* and *Casuarina*), which are often harvested. Due to the removal of native vegetation and the 'grow and harvest' policy associated with exotic trees, the native flora, fauna and macrofungi of the coastal sand dunes are severely threatened. The results obtained in the present pilot study point out the need for long-term temporal and spatial investigation of the macrofungal resource of coastal sand dunes to gain a more comprehensive knowledge on their abundance, diversity, ecological significance, benefits and what must be done to implement strategies necessary for conservation.

Key words – dunes **–** mushrooms **–** woodrot fungi **–** disturbance **–** conservation

Introduction

Coastal sand dunes (CSD) are the most dynamic and ecologically sensitive transition zones linking terrestrial and marine ecosystems. They are versatile habitats owing to several direct and indirect ecological services, especially the filtration of seawater, recycling of nutrients, prevention of floods and protection against storms (McLachlan & Brown 2006, Maun 2009). However, the CSD are the most threatened habitats throughout the world and have been transformed considerably due to urbanization, industrialization, deforestation and agricultural activities (Clark 1996, Schlacher et al. 2007, Malavasi et al. 2013). Being highly vulnerable for severe anthropogenic pressures, the ecological services of CSD are hampered mainly due to the loss of biodiversity (EEA Technical Report 2001-2006). Although the landscape restoration and management of CSD has become a daunting task, there is an urgent need to conserve and restore this ecosystem for biodiversity protection and long-term benefits.

One of the major ways in which CSD stabilization can occur is to depend on the vegetation, especially the psammophytes, since they play vital role in building and stabilizing the dunes due to

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their sand-binding and salt-tolerant capabilities (Banerjee et al. 2002, Rodrigues et al. 2011). Apart from vegetation, micro- and macrofungi (saprophytic, mycorrhizal and endophytic fungi) are directly or indirectly responsible for the stability and perpetuation of psammophytes in CSD habitats (Brundrett 1991, Maun 2009, Sridhar 2009). Several reports (Japan, Europe, United States, Brazil and Seychelles) have revealed that macrofungi are inseparable components of CSD (ECCF 2001, Ashkannejhad & Horton 2005, O'Hanlon & Harrington 2011, Høiland 2012, Sulzbacher et al. 2013). The macrofungal resource of CSD encompass a variety of ectomycorrhizal fungi (Ashkannejhad & Horton 2005,Tedersoo et al. 2007, Wolfe et al. 2010, Sulzbacher et al. 2013), agarics (O'Hanlon & Harrington 2011, Takehashi et al. 2012), new records and new species (Vila et al. 1999, Takehashi et al. 2007, Hoshino et al. 2009, Taiga et al. 2011, Akata & Yaprak 2013, Sá et al. 2013). In contrast, there seems to be no literature available on the macrofungi of CSD of south-western India, although there are reports on the occurrence of marine, arbuscular mycorrhizal and endophytic fungi (Beena et al. 2000, Prasannarai & Sridhar 2001, Seena & Sridhar 2004). Therefore, in an effort to advance conservation, the objectives of the current pilot study were to document and assess the diversity of mushrooms and woodrot fungi prevailing in CSD in south-western India under different disturbance regimes.

Materials & Methods

Study site and vegetation

As evident throughout the rest of the world, the CSD of south-western India are also facing anthropogenic pressures. Figure 1 shows the past and present status of the CSD in south-western India. The major human interference on these dunes include building roads, residential construction, agricultural development, boat building/fishing, recreation activities and seawall construction (Sridhar 2009). Based on the status of disturbance, three CSD regions were chosen for the macrofungal survey. These were Someshwara (12°47′N, 74°51′E) consisting of fairly less disturbed dunes, Thannir Bavi (12°53′N, 74°48′E) encompassing moderately disturbed dunes and Kaup dunes (13°12′N, 74°44′E) facing severe disturbances. According to the extent of anthropogenic pressure, the natural vegetation is declining and leading to a preponderance of disturbance-tolerant vegetation. The areas of former dune vegetation are now occupied mainly by paddy fields (*Oryza sativa*) and plantations (e.g. *Cocos nucifera*). In addition, exotic tree species (e.g. *Acacia* and *Casuarina*) have been planted on the dunes to prevent erosion. Table 1 gives existing natural and exotic vegetation (trees, shrubs, herbs, creepers and grasses) in and around the sampling stations. The vegetation pattern differs, with highest diversity in moderately disturbed dunes of Thannir Bavi, followed by less disturbed dunes (Someshwara) and severely disturbed dunes (Kaup).

Table 1 Vegetation in and around the sampling stations of coastal sand dunes on the south-western coast of India surveyed for macrofungi.

Type of vegetation	Taxon
Trees	*Acacia auriculiformis, Borassus flabellifer, Casuarina equisetifolia, Cocos nucifera* and *Erythrina variegata*
Shrubs	*Calotropis gigantea, Cassia tora, Scaevola plumieri, S. sericea* and *S. taccada* and *Sesbania bispinosa*
Herbs	*Acanthospermum hispidum, Ageratum conyzoides, Alysicarpus rugosus, Borreria articularis, Cassia tora, Chromolaena odorata, Crotalaria retusa, C. verrucosa, Cyanotis cristata, Eclipta alba, Emilia sonchifolia, Evolvulus alsinoides, Hedyotis corymbosa, Launaea sarmentosa, Ludwigia hyssopifolia, Mimosa pudica, Phyla nodiflora, Polycarpaea corymbosa, Sesbania bispinosa, Sesuvium portulacastrum* and *Tephrosia purpurea*
Creepers	*Bulbostylis barbata, Canavalia cathartica, C. maritima, Derris trifolorum, Fimbristylis argentea, Ipomoea pes-caprae, Paspalum vaginatum, Panicum repens, Perotis indica, Spinifex littoreus, Tridax procumbens* and *Wedelia biflora*
Grasses	*Cyperus arenarius, C. compressus* and *C. pedunculatus*

Fig. 1 – a, Remnant of well-established CSD on the beach of Beejadi (13°33′N, 74°40′E) in south-western India (note the road construction beside the dune); b, partially excavated CSD near Saligrama (13°30′N, 74°41′E) (note the construction and plantation activities on the dune surroundings); c, and d, recent small dunes at the formation stage on the beach of Thannir Bavi (12°53′N, 74°48′E), with surrounding creepers also evident.

Survey of macrofungi

The survey of macrofungi was carried out in the mid- and hind-dune regions of three localities (Someshwara, Thannir Bavi and Kaup) during June 12–20, 2013. The range of rainfall, humidity, air temperature, soil temperature and organic carbon during the survey period was 24.5–145.8 mm/day, 85-99%, 22.4–29.3°C, 25.5–30.1°C and 0.7–1.6%, respectively. In three transects (25 × 25 m) at a distance of 500 m on each location, the fruit bodies of macrofungi were scored. They were identified based on the standard descriptions (e.g., Pegler 1990, Jordan 2004, Phillips 2006, Cannon & Kirk 2007, Mohanan 2011) and preserved in the mycological herbarium of the Department of Biosciences, Mangalore University (MUBSSDGKRSMF # 1-38).

Results

Species composition

Table 2 provides the list of macrofungi recorded and the average number of fruit bodies in an area of 625 m^2 (n=9). Out of 38 macrofungi, 23 were identified to the species level, 14 were identified to genus and one was an unidentified agaric species. Macrofungi in the present study were represented by a wide range of species from perennial forms (e.g., *Ganoderma lucidum*) to delicate (e.g. *Marasmius* spp.) forms. Based on the present study and traditional knowledge of the coastal dwellers, ten fungi were considered as edible (which includes one *Amanita* sp.), six fungi were ectomycorrhizal (associated with *Acacia* or *Casuarina* or native plants), two were medicinal and one had a decorative value. Macrofungi were recorded on various substrates such as sand, sandy soil, termite mounds, leaf litter, twigs, bark, wood stubs and live roots (see Table 2; Fig. 2). Based on the average number of fruit bodies (≥5 per 625 m^2), 10 macrofungi were dominant on CSD. These were *Amanita* sp., *Collybia dryophila* var. *extuberans, C. fusipes, Coprinus plicatilis, Dacryopinax spathularia, Lactarius* sp., *Lentinus squarrosulus, Marasmius kisangensis, Marasmius* sp. 2 and *Scleroderma citrinum*.

Table 2 Macrofungi on the CSD of south-western of India.

Taxon	Mean fruit bodies/625 m^2 (mean, n=9)	Substrate	Disturbance status***
Edible			
Dacryopinax spathularia (Schwein.) G.W. Martin (Fig. 2g)	11.8	Wood stub	LD, SD
Amanita sp.*	7.2	Sandy soil with roots	LD, MD
*Lentinus squarrosulus*Mont. (Fig. 2h)	5.2	Wood stub	LD
Lycoperdon decipiens Durieu & Mont. (Fig. 2k)**	4.4	Sand	LD, MD
Termitomyces schimperi (Pat.) R. Heim	2.0	Termite mound	SD
Termitomyces umkowaan (Cooke & Massee) D.A. Reid (Fig. 2q)	1.6	Termite mound	LD, MD, SD
Lycoperdon utriforme Bull. (Fig. 2l)	1.4	Sandy soil	LD
Macrolepiota rachodes (Vittad.) Singer (Fig. 2m)	0.8	Sandy soil	SD
Pleurotus flabellatus Sacc. (Fig. 2p)	0.4	Bark	MD
Lycoperdon sp.*	0.2	Sandy soil with roots	SD
Ectomycorrhizal			
Collybia fusipes (Bull.) Quél. (Fig. 2c)	6.8	Sandy soil with roots	MD
Scleroderma citrinum Pers.	5.0	Sandy soil with roots	LD, MD
Pisolithus sp.	1.6	Sandy soil with roots	LD
Pisolithus albus (Cooke & Massee) Priest	1.0	Sandy soil with roots	MD
Medicinal			
Collybia dryophila var. *extuberans* (Fr.) P. Roux (Fig. 2a, b)	7.6	Sandy soil	MD
Ganoderma lucidum (Curtis) P. Karst.	0.4	Wood stub	MD
Decorative			
Microporus xanthopus (Fr.) Kuntze	0.6	Twig	MD
Miscellaneous			
Marasmius kisangensis Singer (Fig. 2n)	7.0	Leaf litter	SD
Marasmius sp. 2	5.4	Sandy soil	MD
Coprinusplicatilis (Curtis) Fr. (Fig. 2d, e)	5.2	Sand	MD
Lactarius sp.	5.0	Sandy soil	SD
Crepidotus reversus (Berk. & Broome) Sacc.	4.0	Twig	SD
Marasmius sp. 1	3.4	Sandy soil	LD
Unidentified (agaric sp. with yellow pileus and stipe)	3.0	Sandy soil	LD, SD
Macrolepiota sp.	2.8	Sandy soil	MD
Crepidotus uber (Berk. & M.A. Curtis) Sacc.	2.6	Twig	LD
Lepiota clypeolaria (Bull.) P. Kumm. (Fig. 2i)	2.4	Sand	MD
Marasmius spegazzinii (Kuntze) Sacc. & P. Syd. (Fig. 2o)	2.2	Leaf litter	MD
Crepidotus sp.	2.0	Twig	MD
Agaricus sp. 2	1.6	Sandy soil	MD
Daedalea sp.	1.4	Wood stub	SD
Lenzites sp.	1.4	Wood stub	LD
Lepiota sp. (Fig. 2j)	0.8	Sandy soil	MD
Agaricus sp. 1	0.6	Sandy soil	MD
Cystolepiota sp.	0.6	Sandy soil	MD
*Lentinus patulus*Lév	0.4	Bark	SD
Agaricus caribaeus Pegler	0.2	Sandy soil	LD
Cystoagaricus trisulphuratus (Berk.) Singer (Fig. 2f)	0.2	Sandy soil	LD

*species that is also ectomycorrhizal

**vulnerable or extinct in Britain (Evans et al. 2006)

***LD, less disturbance; MD, moderate disturbance; SD, severe disturbance

Fig. 2 –Representative macrofungi occurring on the coastal sand dunes of south-western India: a, b, *Collybia dryophila* var. *extuberans* on sandy soil amidst needles of *Casuarina*; c, *C. fusipes* on sandy soil amidst needles of *Casuarina*; d, *Coprinus plicatilis* on sandy soil (pileus top); e, *C. plicatilis* (gills); f, *Cystoagaricus trisulphuratus* on sandy soil with grass bed; g, *Dacryopinax spathularia* on dead *Casuarina* stub; h, *Lentinus squarrosulus* on dead *Casuarina* stub; i, *Lepiota clypeolaria* on sandy soil with *Acacia* litter; j, *Lepiota* sp. on sandy soil amidst needles of *Casuarina*; k, *Lycoperdon decipiens* on sandy soil; l, *L. utriforme* on sandy soil with *Acacia* litter; m, *Macrolepiota rachodes* on sandy soil; n, *Marasmius kisangensis* on *Acacia* phyllode litter; o, *M. spegazzinii* on *Acacia* phyllode litter; p, *Pleurotus flabellatus* on *Acacia* bark, and q, *Termitomyces umkowaan* on termite mound.

Distribution

The specific pattern of macrofungal distribution on CSD in disturbed regimes has been presented in a venn diagram (Fig. 3). Moderately disturbed dunes represented by the highest number of macrofungi (20 species), followed by less disturbed (14 species) and severely disturbed (11 species) dunes. Exclusive macrofungi were also higher in moderately disturbed dunes (16 species), compared to the dunes with less and severe disturbance (8 species each). *Termitomyces umkowaan* was the only fungus recorded in CSD with less, moderate and severe disturbances, whereas *Crepidotus reversus, Daedalea* sp., *Lactarius* sp., *Lentinus patulus, Lycoperdon* sp., *Macrolepiota rachodes, Marasmius kisangensis* and *Termitomyces schimperi* were confined to only the severely disturbed dunes (Table 2).

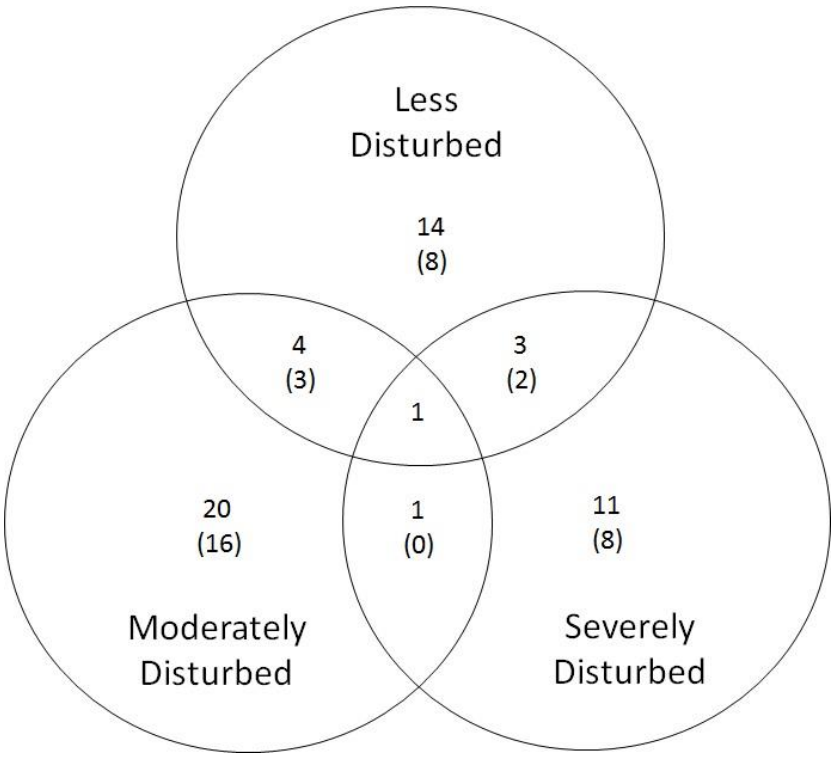

Fig. 3 –Venn diagram showing the pattern of distribution and richness of macrofungi on the coastal sand dunes with different disturbance regimes (less, moderate and severe) in south-western India (number of exclusive species in parenthesis).

Discussion

It is notable that several edible fungi occur on the CSD, and those are eaten by the coastal dwellers based on their traditional knowledge. The *Amanita* sp. (called 'motte anabe' in the vernacular name, Kannada, means 'egg mushroom') will be eaten in basidiocarp stage (egg or bulbous shape) or just erect out from basidiocarp (dumbbell shape: bulbous cap and bulbous base). It is interesting to note the occurrence of two termitomycetes (*Termitomyces schimperi* and *T. umkowaan*) on the CSD. Individual fruit bodies of termitomycetes found were big and constitute considerable weight and quantity for edible purposes. The occurrence of termitomycetes indicates the activities of termites or the presence of termite mounds underneath the CSD. According to Evans et al. (2006), *Lycoperdon decipiens* found in our study is vulnerable or extinct in Britain. Organic matter, especially the leaf litter or woody debris (authchthonous or allochthonous or both) on the CSD seems to constitute an important source of nutrition for macrofungal perpetuation. Human interference such as harvesting the vegetation and dismantling the dunes reduces the surface area as well as the accumulation of organic matter. Similarly, construction of seawalls by granite boulders prevents the deposition of allochthonous organic debris on the dunes from the sea. Natural and anthropogenic disturbances on the CSD should be at moderate level to maintain the

biodiversity on the dunes at its peak (Connell 1978). Diversity of macrofungi on CSD seems to conform to Connell's hypothesis as evident in the numbers of arbuscular mycorrhizal fungi of the CSD (Beena et al. 2000).

The present survey revealed a wide variety of economically viable macrofungi on the CSD of south-western India despite their threatened status. Similar to the flora and fauna, macrofungi serve as a major decomposer component of CSD ecosystems (edible, ectomycorrhizal and medicinal) and it is warranted to develop their baseline data by temporal and spatial scales in different parts of the world. Removal of natural vegetation and 'grow and harvest' policy of exotic vegetation on the CSD have severe impact on the macrofungal distribution, richness and diversity. Several questions remain to be answered on the macrofungal community on CSD. These include (a) To what extent do the exotic plant species on the dunes support macrofungi? (b) Do they serve as indicators of status of CSD disturbance? (c) Are the macrofungi on CSD salt-tolerant? and (d) Are there any vulnerable or threatened or red-listed taxa in CSD?

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