Biodiversity of manglicolous fungi on selected plants in the Godavari and Krishna deltas, East coast of India

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Sarma, V.V. and Vittal, B.P.R. (2001). Biodiversity of manglicolous fungi on selected plants in the Godavari and Krishna deltas, East coast of India. Fungal Diversity 6: 115-130.

The examination of decaying mangrove materials belonging to 9 host plant species collected from Godavari and Krishna deltas (Andhra Pradesh), east coast of India from August, 1993 to November, 1995 resulted in the identification of 88 fungi. These include 65 Ascomycetes (74%), one Basidiomycete and 22 Mitosporic fungi (25%) (including 6 Coelomycetes and 16 Hyphomycetes). Among the 9 plants examined, maximum number of species (64) were recorded from *Rhizophora apiculata*, followed by *Avicennia officinalis* (55), *A. marina* (45), *Excoecaria agallocha* (12), *Aegiceras corniculatum*, *Ceriops decandra*, *Lumnitzera racemosa* (8 each), *Sonneratia apetala* (5), *Acanthus ilicifolius* (2). *Verruculina enalia* was recorded on all the host plants examined. *Hypoxylon* sp., *Lulworthia* sp., *Trichocladium achrasporum* were recorded on 6 out of 9 host species. *Lophiostoma mangrovei*, *Lulworthia grandispora*, *Halorosellinia oceanica* and *Hysterium* sp. were recorded in 5 out of 9 host plants. Others were recorded on any one or up to 4 host plants.

Key words: biodiversity, Intertidal fungi, new records, manglicolous fungi, mangroves, marine fungi.

Introduction

Mangrove vegetation contributes to the primary production in the aquatic environment in the form of leaf and litter fall. Decomposition of this organic material by bacteria and fungi results in protein enriched fragments of detritus. Fungi rather than bacteria have been considered to be principal sources of this increase in nitrogen (Odum and Heald, 1972). Despite better understanding of the importance of mangroves, they continue to be destroyed at an alarming rate (Ong, 1995). Therefore it is imperative to record and quantify the abundance of marine fungi in the mangrove ecosystem and to isolate them to ensure their conservation for future biochemical, genetic and molecular studies (Jones and Mitchell, 1996). In recent years, mycologists have documented the fungi on tropical and

subtropical mangrove substrata. Apart from isolating several interesting fungi, information was also gathered on the ecology of these fungi. Although mangroves are dominant on the Indian coasts providing niches and habitats for many marine and estuarine organisms, few attempts have been made to investigate the fungi associated with decaying substrata of these plants. This is especially true with mangroves of the east coast of India which covers approximately 33% of the total Indian mangroves (Untawale, 1987). Maharashtra coast (west coast) was extensively surveyed for marine fungi by Patil and his colleagues (Patil and Borse, 1983, 1985; Borse, 1984, 1985, 1987, 1988; Borse *et al.*, 1988; Borse and Hyde, 1989). Recently, Chinnaraj (1992, 1993) and Chinnaraj and Untawale (1992) have published reports on marine mangrove fungi from Lakshadweep islands and other areas on the west coast. In this paper results of a fungal diversity study carried out at two different deltaic mangroves of the East coast of India, Godavari and Krishna, on 9 different host plants are presented.

Materials and methods

The general laboratory techniques followed in the present investigation were as outlined by Kohlmeyer and Kohlmeyer (1979) and Jones and Hyde (1988).

The Coringa and Balusutippa mangroves at Godavari delta (16° 38' N, 82° 16' E) and Kothapalem mangrove at Krishna delta (15° 52' N, 80° 48' E) on the east coast of India in the state of Andhra Pradesh, India were selected for the present investigation. Substrata such as decaying wood, roots, pneumatophores, seedlings, prop roots and leaf litter belonging to the following 9 plant species were collected and examined for the enumeration of fungi:

Avicennia marina (Forsk.) Vierh.	(*Avicenniaceae*)
A. officinalis L.	(*Avicenniaceae*)
Aegiceras corniculatum (L.) Blasco	(*Myrsinaceae*)
Rhizophora apiculata Blume	(*Rhizophoraceae*)
Ceriops decandra (Griff.) Ding Hou	(*Rhizophoraceae*)
Excoecaria agallocha L.	(*Euphorbiaceae*)
Lumnitzera racemosa Willd.	(*Combretaceae*)
Sonneratia apetala Buch.-Ham	(*Sonneratiaceae*)
Acanthus ilicifolius L.	(*Acanthaceae*)

In addition to two initial collection trips, one in August 1993 to Coringa and one to Kothapalem of Krishna delta in November, 1993, 12 regular bimonthly collections were made from Godavari and Krishna deltas beginning January, 1994 till November 1995. During the 12 bimonthly collections samples

belonging to only *Rhizophora apiculata*, *Avicennia officinalis* and *A. marina* were collected. In total 1706 and 1283 samples belonging to *R. apiculata*, and 1294 and 710 samples belonging to *Avicennia* spp. (*A. officinalis* and *A. marina*) at Godavari and Krishna deltas, respectively, were collected which were supporting sporulating fungi.

Abiotic features

The Godavari and Krishna deltaic mangroves owing to their geographical proximity show similarity in certain climatic factors. The region enjoys tropical humid climate with a mean annual temperature of 27.7°C and with a dry season extending from 5 to 6 months from December to May. The air temperature fluctuates throughout the year with a mean minimum of 18.9-26.9°C at night and a mean maximum of 28.8-38.7°C during the day. The Indian coast is influenced by two monsoon cycles viz., south west and north east. Along the east coast major precipitation is experienced from September to December. The area receives monsoon rains during July-September and cyclonic rains in October-November. As a general rule these rains coincide with the depressions in the sea (Bay of Bengal) which blow over the coasts. During the rainy period of at least 5 months the fresh water covers the mangrove vegetation. Consequently, the salinity of the water is low. On the other hand the salinity increases considerably in the hot dry season from March-June because of excessive evaporation. The salinity varies from 35 ‰ between March-June to 5 ‰ between October and December. The magnitude of the freshwater input controls the salinity regime. The rainfall together with the freshwater discharge seems to affect the sequence of zones in the tidal region. The mean Relative Humidity (RH) along the east coast is generally high throughout the year. The surface water temperature rises above 30°C during summer and remains around 25°C during winter. The pH is about neutral to alkaline. The soil is entirely river borne alluvial silt and extremely fine mud forming extensive muddy flats.

Results and discussion

General

The examination of decaying mangrove materials belonging to 9 plant species resulted in the identification of 88 fungi. Of these 65 belonged to Ascomycetes, one Basidiomycete and 22 to Mitosporic fungi of which 6 species belonged to Coelomycetes and 16 species to Hyphomycetes (Table 1). A great majority of fungi belonged to Ascomycetes (74%) indicating their importance in the mangrove habitat. This is not unique to this study as the preponderance of Ascomycetes over the other groups of fungi on mangrove substrata has been

Table 1. Fungi recorded on different species of mangrove plants from Godavari and Krishna deltas, east coast of India.

Name of the species	AC	AM	AO	CD	EA	LR	RA	SA	AI	No. of hosts
Ascomycotina										
Aigialus grandis Kohlm. and S. Schatz		+					+			2
A. mangrovei Borse		+	+							2
A. parvus S. Schatz and Kohlm.		+					+			2
Aniptodera chesapeakensis Shearer and M.A. Mill.		+	+	+			+			4
[1]*A. haispora* Vrijmoed, K.D. Hyde and E.B.G. Jones			+				+			2
A. mangrovei K.D. Hyde			+				+			2
Anthostomella leptospora (Lev. and Sacc.) Francis							+			1
Anthostomella sp.		+	+							2
[2]*Ascocratera manglicola* Kohlm.		+					+			2
Bathyascus avicenniae Kohlm.		+								1
Chaetomastia typhicola (P. Karst.) M.E. Barr							+			1
[2]*Corollospora pulchella* Kohlm., I. Schmidt and Nair							+			1
Cryptosphaeria mangrovei K.D. Hyde							+			1
Cryptovalsa sp.		+	+							2
Dactylospora haliotrepha (Kohlm. and E. Kohlm.) Hafellner		+	+				+			3
Eutypa bathurstensis K.D. Hyde and Rappaz		+	+							2
[1]*Gnomonia* sp.-like			+				+			2
Halorosellinia oceanica Whalley, E.B.G. Jones, K.D. Hyde and Laessøe		+	+		+		+	+		5
Halosarpheia abonnis Kohlm.		+					+			2
H. marina (Cribb and J.W. Cribb) Kohlm.			+				+			2
H. minuta W.F. Leong		+	+							2
H. ratnagiriensis S.D. Patil and Borse		+	+				+			3
[2]*Halosarpheia* sp.		+					+			2

Table 1. continued

Name of the species	AC	AM	AO	CD	EA	LR	RA	SA	AI	No. of hosts
[2]*Hapsidascus* sp.-like		+								1
[2]*Heleococcum japonense* Tubaki		+					+			2
[2]*Hypocrea* sp.							+			1
Hypoxylon sp.		+	+	+	+	+	+			*6*
Hysterium sp.	+	+	+		+		+			5
Julella avicenniae (Borse) K.D. Hyde		+	+							2
Kallichroma tethys (Kohlm. and E. Kohlm.) Kohlm. and Volkm.-Kohlm.		+					+			2
[1]*Lautospora gigantea* K.D. Hyde and E.B.G. Jones			+							1
Lecanidion atratum (Hedw.) Endl.			+				+			2
Leptosphaeria australiensis (Cribb and J.W. Cribb) G.C. Hughes		+	+				+			3
L. peruviana Speg.			+			+	+			3
Leptosphaeria sp.		+	+				+			3
[1]*Lignincola laevis* Höhnk			+							1
L. longirostris (Cribb and J.W. Cribb) Kohlm.		+	+							1
L. tropica Kohlm.		+	+				+			3
[2]*Lineolata rhizophorae* (Kohlm. and E. Kohlm.) Kohlm. and Volkm.-Kohlm.							+			1
Lophiostoma mangrovei Kohlm. and Vittal		+	+	+		+	+			5
Lulworthia grandispora Meyers		+	+			+	+	+		5
Lulworthia sp.	+	+	+		+		+	+		6
Marinosphaera mangrovei K.D. Hyde		+	+							2
Massarina thalassiae Kohlm., Volkm.-Kohlm. and O.E. Erikss.	+				+		+			3
M. velatospora K.D. Hyde and Borse			+		+		+			3
Massarina sp.	+	+	+				+			4
Kirschsteiniothelia maritima (Linder) D. Hawksw.							+			1

Table 1. continued

Name of the species	AC	AM	AO	CD	EA	LR	RA	SA	AI	No. of hosts
[1]*Mycosphaerella pneumatophorae* Kohlm.			+							1
[1]*Nais glitra* J.L. Crane and Shearer			+							1
[2]*Passeriniella obiones* (H. Crouan and P. Crouan) K.D. Hyde and Mouzouras		+			+		+			3
Pedumispora rhizophorae K.D. Hyde and E.B.G. Jones							+			1
[2]*Quintaria lignatilis* (Kohlm.) Kohlm. and Volkm.-Kohlm.	+			+			+			3
Rhizophila marina K.D. Hyde and E.B.G. Jones							+			1
[1]*Saccardoella marinospora* K.D. Hyde			+							1
S. rhizophorae K.D. Hyde							+			1
Savoryella lignicola E.B.G. Jones and R.A. Eaton			+			+	+			3
Splanchnonema brtizelmayriana (Rehm) Boise-like							+			1
[1]*Tubeufia setosa* Sivan. and W.H. Hsieh							+			1
Verrruculina enalia (Kohlm.) Kohlm. And Volkm.-Kohlm.	+	+	+	+	+	+	+	+	+	9
[1]*Zopfiella latipes* (N. Lundq.) Malloch and Cain			+							1
[1]*Z. marina* Furuya and Udagawa			+							1
[1]*Zopfiella* sp.			+		+					2
[1]Ascomycete 1			+							1
Basidiomycotina										
Halocyphina villosa Kohlm.		+	+		+		+			4
Mitosporic taxa										
[1]*Alveophoma sp.*							+			1
Bactrodesmium linderi (Crane and Shearer) Palm and Stewart							+			1
Camarosporium roumeguerii Sacc.		+	+							2
Cirrenalia basiminuta Raghuk. and Zainal							+			1
[2]*C. macrocephala* (Kohlm.) Meyers and R.T. Moore							+			1
C. pygmea Kohlm.							+			1
[1]*C. tropicalis* Kohlm.			+				+			2

Table 1. continued

Name of the species	AC	AM	AO	CD	EA	LR	RA	SA	AI	No. of hosts
Corynespora cassiicola (Berk. and Curt) Wei									+	1
[2]*Cytospora rhizophorae* Kohlm. and E. Kohlm.				+			+			2
[1]*Dictyosporium sp.*			+							1
Ellisembia vagum (C.G. and C.G. and T.F.L.) Subram.			+				+			1
Epicoccum purpurascens Ehrenb.: Schlecht.		+	+		+		+			4
Monodictys sp.		+	+				+			3
Periconia prolifica Anastasiou		+	+				+			3
Phoma sp.		+	+			+	+			4
[1]*Phomopsis mangrovei* K.D. Hyde							+			1
Phomopsis sp.		+	+		+		+			4
Trichocladium achrasporum (Meyers and R.T. Moore) Dixon	+	+	+	+		+	+			6
T. alopallonellum (Meyers and R.T. Moore) Kohlm. and Volkm.-Kohlm.			+				+			2
Trimmatostroma sp.		+	+	+			+			4
Zalerion varium Anastasiou			+		+		+			4
Zygosporium gibbum (Sacc., Rouss. and Bomm.) Hughes			+	+						2
Total number of fungi recorded on each host species	**8**	**45**	**55**	**8**	**12**	**8**	**64**	**5**	**2**	

AC= *Aegiceras corniculatum*; AM=*Avicennia marina*; AO=*Avicennia officinalis*; CD=*Ceriops decandra*; EA=*Excoecaria agallocha*; LR=*Lumnitzera racemosa*: RA=*Rhizophora apiculata*; SA=*Sonneratia apetala*; AI=*Acanthus ilicifolius*

[1] Recorded only at Godavari delta

[2] Recorded only at Krishna delta

reported by several workers (Kohlmeyer, 1984; Kohlmeyer and Volkmann-Kohlmeyer, 1987 a,b, 1989; Hyde and Jones, 1988; Hyde, 1988; Jones *et al.*, 1988). Alias *et al.* (1995) reported that Ascomycetes constituted 80% of the collected species from Malaysian mangroves. Tan and Leong (1990) observed that the Ascomycetes were the most common taxonomic group in the intertidal mangrove region. Ascomycetes appears to have evolved to take full advantage of aquatic habitats with their small (microscopic) fruit bodies, appendaged spores that may aid in dispersal and attachment, and an ability to withstand fluctuating saline conditions (Jones and Alias, 1997).

Species composition

An analysis of the data on the nature and composition of fungi recorded in this study revealed that of the 88 species, *Verruculina enalia* was the only fungus found commonly on all the 9 mangrove plants examined (Table 1). Some were found common to any two of the 9 plants, while some others were common to 3-6 plant species. Thus, *Aigialus mangrovei*, *Anthostomella* sp., *Bathyascus avicenniae*, *Cryptovalsa* sp., *Eutypa bathurstensis*, *Halosarpheia minuta*, *Julella avicenniae*, *Ophiodeira monosemeia*, *Camarosporium roumeguerii* were recorded only from *Avicennia officinalis* and *A. marina*. On the contrary, *Hypoxylon sp.*, *Lulworthia* sp., *Trichocladium achrasporum* were recorded on 6 out of 9 host species. Fungi such as *Lophiostoma mangrovei*, *Lulworthia grandispora*, *Halorosellinia oceanica* and *Hysterium* sp. were recorded in 5 out of 9 host plants.

In addition to fungi common to different host plants, a few were present only on a particular host plant. Thus eighteen species were found only on *Rhizophora apiculata*; 9 on *Avicennia officinalis*; 2 on *A. marina* and one on *Acanthus ilicifolius*. However, no such exclusive species was recorded on *Aegiceras corniculatum*, *Ceriops decandra*, *Lumnitzera racemosa*, *Sonneratia apetala* and *Excoecaria agallocha*. Such variation in the composition of fungi on individual host species in the same locality has been previously reported by Ravikumar (1991), Hyde (1990) and Steinke (1995).

Among the 9 plants examined, maximum number of species (64) were recorded from *Rhizophora apiculata*, followed by *Avicennia officinalis* (55), *A. marina* (45), *Excoecaria agallocha* (12), *Aegiceras corniculatum*, *Ceriops decandra*, *Lumnitzera racemosa* (8 each), *Sonneratia apetala* (5), *Acanthus ilicifolius* (2). Hyde (1990) also recorded a large number of fungi on *Rhizophora apiculata*. Fewer fungi recorded on some of the host plants may be due to the fact that only few samples were collected and examined belonging to these plants (e.g., *Aegiceras corniculatum*, *Ceriops decandra*, *Lumnitzera racemosa*, *Acanthus ilicifolius*) when compared to *R. apiculata* and *Avicennia* spp. which were intensively studied for the ecological studies (reported elsewhere). Another possibility is that these substrata are not favourable for fungal colonization when compared to *R. apiculata* and *Avicennia* spp. However care should be taken for this interpretation as few samples were examined belonging to the hosts viz., *A. corniculatum*, *C. decandra*, *L. racemosa* and *Acanthus ilicifolius*, etc. The other important reason is the less abundance of these plants in the study area in general when compared with the intensity of *A. officinalis*, *A. marina* and *Rhizophora apiculata*. Because these plants were most common along the study sites they were also sampled most frequently. The high occurrence of fungi on *R. apiculata*

and *Avicennia* spp. is, therefore, not necessarily an indication of greater susceptibility to colonization of lignicolous marine fungi. The amount of substrata available for colonisation is the overriding factor for diversity of fungi in mangrove ecosystem (Jones and Alias, 1997). However, one exception is *Excoecaria agallocha*. This plant, although dominant in all the mangrove areas of the two deltas, did not support a rich diversity of fungi. In future, uniformity should be maintained in the number of samples collected belonging to various host plants to make any meaningful comparisons.

Rare and interesting fungi

Apart from the commonly occurring manglicolous fungi, a few recently described species have been recorded during this study. For some of the taxa this is only second or third reference to their collection. The present report therefore extends their geographical distribution.

Lautospora gigantea K.D. Hyde and E.B.G. Jones: This fungus was described from drift wood and prop roots of *Rhizophora* spp. in Brunei (Hyde and Jones, 1989) and was also recorded on wood of *Sonneratia griffithii* Kurz in Thailand (Hyde *et al.*, 1990). Four spored asci having large distoseptate ascospores are the interesting features of this taxon. Recently Kohlmeyer *et al.* (1995) reported another new species (*L. simillima* Kohlm., Volkm.-Kohlm. and O.E. Erikss.) and raised a new family to accommodate the genus. This species is reported for the first time from India and Indian mangroves.

Ophiodeira monosemeia Kohlm. and Volkm.-Kohlm.: This species was described by Kohlmeyer and Volkmann-Kohlmeyer (1988) from Saint Croix (Virgin Islands), USA on subtidal wood of *Rhizophora mangle*. While most members of Halosphaeriales have appendages at both ends, either placed apically or laterally, this taxon has a single appendage. This is recorded for the first time from India and Indian mangroves.

Cryptosphaeria mangrovei K.D. Hyde: This is the second report of this species described by Hyde (1993b) from *Rhizophora apiculata* from Thailand. It was frequent on *Rhizophora apiculata* in the present study. The occurrence of this species, along with *Eutypa bathurstensis* and a *Cryptovalsa* sp. in large numbers on mangrove substrata demonstrates successful colonization of mangroves by diatrypalean fungi.

Phomopsis mangrovei K.D. Hyde: This coelomycetous fungus was reported by Hyde (1991) on prop roots of *R. apiculata* from Ranong mangrove, Thailand who also suspected it to be a pathogen on this host. In the present study this fungus occurred more on seedlings than on prop roots of *Rhizophora apiculata*.

Table 2. Marine fungi belonging to different biogeographical groups recorded in the present study.

Tropical/subtropical	Cosmopolitan
Ascomycetes	**Ascomycetes**
Aigialus grandis	*Aniptodera chesapeakensis*
A. mangrovei	*Corollospora pulchella*
A. parvus	*Halosarpheia viscosa*
Aniptodera haispora	*Lignincola laevis*
Ascocratera manglicola	*Savoryella lignicola*
Bathyascus avicenniae	**Mitosporic fungi**
Dactylospora haliotrepha	*Camarosporium roumeguerii*
Halorosellinia oceanica	*Cirrenalia macrocephala*
Halosarpheia abonnis	*Phoma* sp.
H. minuta	*Trichocladium alopallonellum*
H. ratnagiriensis	*T. achrasporum*
Julella avicenniae	*Zalerion varium*
Kallichroma tethys	
Lautospora gigantea	
Leptosphaeria australiensis	
Lignincola longirostris	
L. tropica	
Lineolata rhizophorae	
Lophiostoma mangrovei	
Lulworthia grandispora	
Marinosphaera mangrovei	
Massarina thalassiae	
M. velatospora	
Massarina sp.	
Mycosphaerella pneumatophorae	
Nais glitra	
Ophiodeira monosemeia	
Pedumispora rhizophorae	
Quintaria lignatilis	
Rhizophila marina	
Verruculina enalia	
Basidiomycetes	
Halocyphina villosa	
Mitosporic fungi	
Cirrenalia basiminuta	
C. pygmea	
C. tropicalis	
Periconia prolifica	
Phomopsis mangrovei	

viz., muddy flats and continuous change in salinity over different seasons due to mix up of freshwater poses a different type of environment than the wood submerged in the open sea.

Marine and terrestrial fungi associated with mangroves

Kohlmeyer (1969) classified fungi collected on mangrove plants into "marine" and "terrestrial" depending on their occurrence in relation to the position of the plant. According to him the marine fungi encountered in the mangrove habitat live on roots, stems and twigs submerged in water and their terrestrial counterparts inhabit leaves, stems, branches and upper parts of the roots above the water surface (Kohlmeyer, 1974; Kohlmeyer and Kohlmeyer, 1979). A critical analysis of the fungi recorded in the present study in the light of the above definitions reveal that of the 88 species recorded, 72 species can be classified as marine as these belong to those genera which were hitherto recorded commonly from marine environments and regarded as typically marine. The remaining 16 species, viz., *Anthostomella leptospora*, *Anthostomella* sp., *Hypocrea* sp., *Gnomonia* sp.-like, *Hysterium* sp., *Lecanidion atratum*, *Tubeufia setosa*, *Alveophoma* sp., *Corynespora cassiicola*, *Dictyosporium* sp., *Epicoccum purpurascens*, *Phomopsis* sp., *Ellisembia vagum*, *Trimmatostroma* sp., *Zygosporium gibbum* and Ascomycete 1 were terrestrial fungi. Although the above fungi can be considered as terrestrial fungi their occurrence on the mangrove forest floor where tidal waters frequently inundate during high tides makes them salt-tolerant fungi. The fact that few samples collected belonging to plants like *Acanthus ilicifolius* has been a limiting factor for a complete discussion. Sadaba *et al.* (1995) studied the vertical distribution of fungi on *A. ilicifolius* in Hong Kong and most of the fungi they encountered were typical terrestrial fungi (34 out of 44). Some marine fungi (e.g. *Aniptodera chesapeakensis*, *Trichocladium achrasporum*) were also recorded which were mostly found on the basal parts of this herbaceous plant and their percentage occurrence far less when compared to the terrestrial fungi. Vertical zonation studies (Sarma, 1998) showed that most of the terrestrial fungi recorded in the present study present above the tidal level except for few records where they were also recorded at the intertidal level. But, based on the fact that the aerial parts in mangroves are exposed to salt spray (Kohlmeyer and Kohlmeyer, 1979), these fungi can be said to have salt-tolerances. However, whether there is any distinct mycota on the aerial parts of mangroves which are not recorded on other land plants (but restricted to mangroves) or not is a question remains to be answered. Future studies on the biodiversity of fungi on non-marine parts of mangroves coupled with physiological studies should let us known how adaptive these fungi to halophytic conditions when compared to other terrestrial fungi. Finally, it can

be concluded from the present investigation that the salinity levels (mostly freshwater to brackish water prevalent in the study areas except during summer) reflected on the marine mycota which showed more number of fungi with an active release mechanism and also considerable number of terrestrial fungi.

Acknowledgements

We would like to thank the Ministry of Environment and Forests, Government of India for financial assistance; to the Forest Department of East Godavari and Guntur districts for permission to collect samples from Godavari and Krishna delta mangroves respectively; to the Director, C.A.S. in Botany for facilities.

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(Received 3 May 2000, accepted 1 September 2000)