
Fungal colonisation of wood in a freshwater stream at Tad Ta Phu, Khao Yai National Park, Thailand

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A study of the fungus colonisation of two timbers (*Dipterocarpus alatus* and *Xylia dolabriformis*) was initiated in a freshwater stream at Tad Ta Phu at Khao Yai National Park, Thailand. Wood was exposed and recovered every month for 12 months, then incubated in moist chambers and fungal colonisation recorded. Data on sequence of fungal sporulation, the frequency of occurrence of the fungi and percentage cover on the test blocks are presented. Seventy-three species were recorded: 48 on *D. alatus* and 47 on *X. dolabriformis*. Fungi were categorised into 3 groups: Group 1 those present on over 60% of the test blocks: with *Helicomyces roseus* and *Halosarpheia aquadulcis* on *D. alatus* and *Helicomyces roseus* on *X. dolabriformis*. Group 2 fungi were those present on more than 20% of the test blocks and numbered 8 each on *D. alatus* and *X. dolabriformis*. Group 3 fungi constituted those present on less than 20% of the test blocks. Fungi could also be grouped into those that appeared early on the wood: *Bombardia* sp., *Cancellidium applanatum*, *Dictyochaeta* sp. 1, *H. roseus*, Pycnidial sp. 1, *Sporidesmiella hyalosperma* var. *novae-zelandiae*, *Sporoschisma saccardoii* and unidentified hyphomycete sp. 05 on *D. alatus*; and with *Chaetopsina fluva*, *Dictyochaeta* sp. 1, *H. roseus*, *Cosmospora chaetopsinae*, *Stilbella holubovae* and *Trematosphaeria* sp. 2 on *X. dolabriformis*. Intermediate colonisers included: *Aquasphaeria dimorphospora*, *Eluviespora bipolaris*, *Hymenoscyphus varicosporoides*, *Sirospora* sp. 1, *Tricladium* anamorph of *Hymenoscyphus varicosporoides* on *D. alatus*, and *Biflagellospora gracilis*, *B. japonica*, *B. papillata*, *B. siamensis*, *Cancellidium applanatum*, *Halosarpheia aquadulcis* and *Thozetella nivea* on *X. dolabriformis*. Late colonisers were *Massarina* sp. 3 and *Vargamyces aquaticus* on *D. alatus* and *Helicosporium vegetum*, *Savoryella verrucosa* and *Tricladium* anamorph of *Hymenoscyphus varicosporoides* on *X. dolabriformis*. The data shows a clear difference in the dominant species on each timber and is compared with other studies from tropical and temperate regions.

Key words: *Dipterocarpus alatus*, fungal succession, *Xylia dolabriformis*.

Introduction

Most studies of lignicolous freshwater fungi are descriptions of new taxa with the number increasing dramatically over the past decade and especially in

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tropical regions (Hyde *et al.*, 1992, 1997, 1998a,b, 1999; Hsieh *et al.*, 1995; Goh and Hyde, 1996; Hyde and Goh, 1997, 1998a,b; Chang *et al.*, 1998; Sivichai *et al.*, 2000; Ho *et al.*, 2001). However, only a few studies focus on colonisation studies (Eaton and Jones, 1971a,b; Sivichai *et al.*, 2000; Tsui *et al.*, 2000; Ho *et al.*, 2002).

The objective of this study was to document the pattern of fungal colonisation and succession; examine fungal recurrence and to compare freshwater fungal diversity on different timber species. Results are compared with other studies from tropical and temperate regions.

Materials and methods

A stream at Tad Ta Phu at Khao Yai National Park, Nakorn Ratchassima Province, Thailand was selected for study. Two timbers were selected: *Dipterocarpus alatus* and *Xylia dolabriformis*, low and high-density timbers respectively, and submerged on 12 August 1997. All test blocks were 15 x 2.5 x 2.5 cm and free of preservatives. Five test blocks of the same timber were threaded on rope in the form of ladder, and twelve sets of these ladders were submerged in the water. Five test blocks of both timbers were recovered monthly for 12 months, on 9 September, 8 October, 6 November, 9 December of 1997 and 6 Jan, 10 Feb, 11 Mar, 14 April, 14 May, 10 June, 13 July, and 14 Aug of 1998. More detailed procedures are found in Sivichai *et al.* (2000).

Results

Biodiversity

A total of 73 taxa were recorded from Tad Tha Phu (Table 1). Overall species diversity was similar on both timbers, 48 (15 ascomycetes, 1 basidiomycete, 32 anamorphic fungi) on *D. alatus* compared with 47 species (14 ascomycetes, 33 anamorphic fungi) on *X. dolabriformis*. All test blocks were colonised even after a month's exposure, 22 fungal taxa occurred on both timbers with a 30 percent similarity between both timbers (Table 1). The number of species per test block varied from 4.6-9.6 (*D. alatus*: Table 2) and 1.2-10 (*X. dolabriformis*: Table 3) with an average of 6.4 and 5.6 per block over the year. The Shannon index (S') was 4.5 and 4.6, while Evenness (J') was 0.8 on *D. alatus* and *X. dolabriformis*. These two indices reflect the similarity in the diversity of fungi on both timbers. The ratio of anamorphic fungi to ascomycetes was 2.1 on *D. alatus* and 2.3 on *X. dolabriformis*. There was little change in the total number of species on the test blocks with the seasons, although numbers did peak on both timbers in the February retrievals (month 6).

Table 1. Percent frequency of occurrence of fungi on *Dipterocarpus alatus* and *Xylia dolabriformis* exposed test blocks at Tad Ta Phu, Khao Yai National Park.

Species	<i>D. alatus</i>			<i>X. dolabriformis</i>		
	M	N	Y	M	N	Y
<i>Annulatascus</i> sp. 1	-	-	-	2	20	3.3
<i>Anthostomella aquatica</i> K.D. Hyde & Goh	1	20	1.7	-	-	-
<i>Aquaphila albicans</i> Goh, K.D. Hyde & W.H. Ho	5	40	16.7	2	20	3.3
<i>Aquasphaeria dimorphospora</i> K.D. Hyde	3	26.7	6.7	-	-	-
<i>Articulospora</i> sp. 1	-	-	-	1	20	1.7
Basidiomycete sp. 6	1	20	1.7	-	-	-
<i>Berkleasium</i> sp. 1	-	-	-	1	20	1.7
<i>Biflagellospora japonica</i> Matsush.	-	-	-	5	48	20
<i>Biflagellospora papillata</i> Sivichai & Hywel-Jones	-	-	-	7	42.9	25
<i>Biflagellospora siamensis</i> Sivichai & Hywel-Jones	-	-	-	5	36	15
<i>Biflagellospora simplex</i> Sivichai & Hywel-Jones	-	-	-	6	53.3	26.7
<i>Bionectria hongkongensis</i> W.H. Ho	1	20	1.7	-	-	-
<i>Bombardia</i> sp.	10	38	31.7	2	20	3.3
<i>Brachydesmiella caudata</i> Rao & de Hoog	1	20	1.7	-	-	-
<i>Brachydesmiella verrucosa</i> Goh, T.K., Sivichai, K.D. Hyde & Hywel-Jones	5	36	15	-	-	-
<i>Cancellidium applanatum</i> Tubaki	9	35.6	26.7	7	45.7	26.7
<i>Candelabrum brocciatum</i> Tubaki	7	28.6	16.7	5	32	13.3
<i>Chaetopsina fluva</i> Rambelli	-	-	-	7	57.1	33.3
<i>Chaetopsina penicillata</i> Samuels	-	-	-	2	20	3.3
<i>Chaetopsina polyblastiae</i> Samuels	-	-	-	2	40	6.7
<i>Cirrenalia</i> sp. 1	1	20	1.7	-	-	-
<i>Cosmospora chaetopsinae</i> (Samuels) Rossman & Samuels	-	-	-	5	28	11.7
<i>Cosmospora chaetopsinae-polyblastiae</i> (Samuels) Rossman & Samuels	-	-	-	1	20	1.7
<i>Cryptophiale udagawae</i> Pirozynski & Ichinoe	1	20	1.7	-	-	-
<i>Cylindrocarpon</i> sp. 1	-	-	-	1	40	3.3
<i>Dactylaria</i> sp. 3	-	-	-	1	20	1.7
<i>Dendrosporium lobatum</i> Plakidas & Edgerton ex Crane	-	-	-	1	20	1.7
<i>Dictyochaeta gyrosetula</i> Kuthub., Nawawi & G.M. Liew	-	-	-	1	40	3.3
<i>Dictyochaeta</i> sp. 1	7	45.7	26.7	8	52.5	35
<i>Dictyosporium digitatum</i> J.L. Chen, Hwang & S.S. Tzean	4	35	13.3	-	-	-
<i>Dictyosporium elegans</i> Corda	1	20	1.7	-	-	-
<i>Dictyosporium nigroapice</i> Goh, W.H. Ho & K.D. Hyde	2	20	3.3	-	-	-
<i>Dictyosporium subramanianii</i> B. Sutton	1	20	1.7	-	-	-

M = Number of month that fungi occur; N = Percent frequency of fungi present divide by numbers of months which fungi present; Y = Percent frequency of fungi occurrence.

Table 1 continued.

Species	<i>D. alatus</i>			<i>X. dolabriformis</i>		
	M	N	Y	M	N	Y
<i>Dinemasporium</i> sp.	1	20	1.7	-	-	-
Discomycete sp. 1	1	20	1.7	1	20	1.7
<i>Ellisembia brachypus</i> (Ellis & Everh.) Subram.	1	20	1.7	-	-	-
<i>Eluviespora bipolaris</i> K.D. Hyde	7	82.9	48	1	20	1.7
<i>Halosarpheia aquadulcis</i> S.Y. Hsieh, H.S. Chang & E.B.G. Jones	11	72.7	66.7	5	28	11.7
<i>Helicoma</i> sp. 3	-	-	-	1	20	1.7
<i>Helicomycetes roseus</i> Link	12	83.3	83.3	12	63.3	63.3
<i>Helicosporium griseum</i> -like	4	35	11.7	-	-	-
<i>Helicosporium vegetum</i> -like	9	31	23.3	5	28	11.7
<i>Hymenoscyphus varicosporoides</i> Tubaki	7	34.3	20	1	20	1.7
<i>Massarina ingoldiana</i> Shearer & K.D. Hyde	1	60	5	-	-	-
<i>Massarina</i> sp. 3	2	20	3.3	-	-	-
<i>Nawawia filiformis</i> (Nawawi) Marv.	-	-	-	2	30	5
<i>Nectria</i> sp. 1	-	-	-	1	20	1.7
<i>Ophioceras dolichostomum</i> (Berk. & Curt.) Sacc.	1	20	1.7	-	-	-
<i>Oxydothis</i> sp.-like	-	-	-	1	20	1.7
<i>Phaeoisaria clementidis</i> (Fuckel) Hughes	1	20	1.7	-	-	-
Pycnidial sp. 1	4	70	23.3	4	25	8.3
<i>Savoryella aquatica</i> K.D. Hyde	2	30	5	10	64	53.3
<i>Savoryella verrucosa</i> Minoura & Muroi	2	20	3.3	3	53.3	13.3
<i>Scutisporus brunneus</i> Ando et Tubaki	-	-	-	10	64	53.3
<i>Spirosphaera</i> sp. 1	8	55	36.7	2	20	3.3
<i>Spirosphaera</i> sp. 2	1	20	1.7	-	-	-
<i>Sporidesmiella hyalosperma</i> var. <i>novae-zelandiae</i> (S. Hughes) P.M. Kirk	4	35	11.7	2	30	5
<i>Sporodesmium</i> sp. 1-like	-	-	-	1	20	1.7
<i>Sporoschisma saccardoi</i> E.W. Mason & S. Hughes	3	20	5	-	-	-
<i>Sporoschisma uniseptatum</i> Bhat & W.B. Kendr.	2	20	3.3	-	-	-
<i>Stilbella holubovae</i> Seifert, S.J. Stanley & K.D. Hyde	-	-	-	11	58.2	53.3
<i>Thozetella nivea</i> (Berk. & F. Muell.) O. Kuntze	1	20	1.7	3	20	5
<i>Trematosphaeria</i> sp. 2	4	50	16.7	5	20	8.3
<i>Tricladium</i> anamorph of <i>Hymenoscyphus</i> <i>varicosporoides</i>	10	72	60	4	25	8.3
<i>Tubeufia cylindrothecia</i> (Seaver) Höhnelt	1	20	1.7	-	-	-
Unidentified ascomycete sp. 29	-	-	-	1	20	1.7
Unidentified hyphomycete sp. 05	3	60	10	-	-	-
Unidentified hyphomycete sp. 08	1	20	1.7	-	-	-
Unidentified hyphomycete sp. 10	1	20	1.7	-	-	-
Unidentified hyphomycete sp. 17	1	20	1.7	1	20	1.7
<i>Vargamyces aquaticus</i> (Dudka) Tóth	4	20	6.7	2	20	3.3

Table 1 continued.

Species	<i>D. alatus</i>			<i>X. dolabriformis</i>		
	M	N	Y	M	N	Y
<i>Volutella</i> sp.	-	-	-	3	20	5.0
<i>Xylomyces elegans</i> Goh, W.H. Ho, K.D. Hyde & K.M. Tsui	2	20	3.3	1	20	1.7
Average no. species per block	6.4			5.7		
Total no. of species per 5 blocks	14.3			14		
Total no. species on each timber	48			47		
% similarity between two timbers	30.13					
Total no. species on two timbers	73					

Fungal recurrence on two timbers

The dominant species on *D. alatus* were *Helicomyces roseus*, *Halosarpheia aquadulcis*, *Tricladium* anamorph of *Hymenoscyphus varicosporoides* and *Eluviespora bipolaris* (83.3, 66.6, 60, 48.3% respectively), while on *X. dolabriformis*, *H. roseus*, *Savoryella aquatica*, *Scutisporus brunneus*, and *Stilbella holubovae* were common (63.3, 53.3, 53.3, 53.3% respectively). In comparing the dominant fungi on the two timbers, only one species was common to both, *H. roseus*. Only 4 were common when considering the 17 most frequent fungi on the test blocks, thus each timber supported a different mycota.

More fungi colonised *D. alatus* (5.2 fungi per test block, 12 fungi on 5 blocks) than *X. dolabriformis* (1.2, 4) after 4 weeks submergence (Tables 2, 3). Over the entire period of study, the number of fungi colonising the test blocks was high, 9-19 on each set of *D. alatus* samples (5-9.6 per block) and 4-23 on each set of *X. dolabriformis* samples (1.2-10 per block) (Tables 2, 3).

Percent coverage of test blocks

Tables 4 and 5 present data on the percentage cover of each fungus on both timbers. On *D. alatus*, *Eluviespora bipolaris* and *Helicomyces roseus* were not only present on most of the test blocks, but percent cover on each block was also high (20, 19.2% respectively) (Table 4). Pycnidial sp. 1 *Trematosphaeria* sp. 2 had a high percent cover on test blocks in the early colonisation period (100%, 96.2% at months 3 and 2, respectively) with a 100% frequency of occurrence for the same month (Table 2). On *X. dolabriformis*, *Helicomyces roseus* had the greatest percent cover (13.5%) and was present at a frequency of 63% (Table 3) on the test blocks. Thus, there was good correlation between the frequency of occurrence on the wood and percent cover on each test block.

Table 2. Colonisation and percent frequency of fungi present more than 20% on test blocks of *Dipterocarpus alatus* at Tad Ta Phu, Khao Yai National Park.

Species	S	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12Aug	N	Y
<i>Helicomycetes roseus</i>	E	100	100	100	60	100	80	80	60	100	60	80	80	83.3	83.3
<i>Halosarpheia aquadulcis</i>	E	-	80	100	100	40	60	80	100	80	100	20	40	72.7	66.7
<i>Tricladium</i> anamorph of <i>H. varicosporoides</i>	I	-	-	80	100	40	60	80	80	100	20	60	100	72	60
<i>Eluviespora bipolaris</i>	I	-	-	-	-	80	80	100	40	-	80	100	100	82.9	48.3
<i>Spirosphaera</i> sp. 1	I	-	-	-	40	-	20	20	80	80	40	80	80	55	36.7
<i>Bombardia</i> sp.	E	20	20	20	60	20	-	-	60	20	40	60	60	38	31.7
<i>Cancellidium applanatum</i>	E	-	40	20	60	-	20	20	20	20	40	-	80	35.6	26.7
<i>Dictyochoaeta</i> sp. 1	E	40	80	80	40	20	40	20	-	-	-	-	-	45.7	26.7
Pycnidial sp. 1	E	100	-	100	20	60	-	-	-	-	-	-	-	70	23.3
<i>Helicosporium vegetum</i> -like	E	-	20	40	20	40	-	40	20	-	40	20	40	31	23.3
<i>Hymenoscyphus varicosporoides</i>	I	-	-	20	40	20	20	40	-	-	-	40	60	34.3	20
<i>Aquaphila albicans</i>	E	-	60	40	20	-	-	-	60	-	-	-	20	40	16.7
<i>Candelabrum brocchiatum</i>	E	-	20	40	40	-	20	-	-	20	40	-	20	28.6	16.7
<i>Trematosphaeria</i> sp. 2	E	60	100	-	20	-	-	20	-	-	-	-	-	50	16.7
<i>Brachydesmiella verrucosa</i>	E	-	40	60	-	40	20	20	-	-	-	-	-	36	15
<i>Dictyosporium digitatum</i>	E	-	40	-	40	40	20	-	-	-	-	-	-	35	13.3
<i>Helicosporium griseum</i> -like	E	40	40	40	-	-	20	-	-	-	-	-	-	35	11.7
<i>Sporidesmiella hyalosperma</i> var. <i>novae-zelandiae</i>	E	40	60	20	20	-	-	-	-	-	-	-	-	35	11.7
Unidentified hyphomycete sp. 05	E	40	20	60	-	-	-	-	-	-	-	-	-	60	10
<i>Aquasphaeria dimorphospora</i>	I	-	-	-	-	-	20	20	-	-	-	40	-	26.7	6.7
<i>Vargamyces aquaticus</i>	L	-	-	-	-	-	-	20	-	-	20	20	20	20	6.7
<i>Massarina ingoldiana</i>	L	-	-	-	-	-	-	-	-	-	-	60	-	60	5
<i>Savoryella aquatica</i>	E	-	40	-	-	-	-	-	-	-	20	-	-	30	5

S = succession stages (E = early colonisers; I = intermediate colonisers; L = late colonisers); Y = Percent frequency of fungi occurrence; N = Percent frequency of fungi present divide by numbers of months which fungi present.

Table 2 continued.

Species	S	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12 Aug	N	Y
<i>Sporoschisma saccardoi</i>	E	20	20	20	-	-	-	-	-	-	-	-	-	20	5
<i>Dictyosporium nigroapice</i>	E	20	-	-	-	20	-	-	-	-	-	-	-	20	3.3
<i>Massarina</i> sp. 3	L	-	-	-	-	-	-	-	-	-	-	20	20	20	3.3
<i>Savoryella verrucosa</i>	L	-	-	-	-	-	-	-	-	20	-	-	20	20	3.3
<i>Sporoschisma uniseptatum</i>	I	-	-	-	20	-	20	-	-	-	-	-	-	20	3.3
<i>Xylomyces elegans</i>	-	-	-	-	-	-	-	20	-	-	-	-	20	20	3.3
<i>Anthostomella aquatica</i>	-	-	-	-	-	-	20	-	-	-	-	-	-	20	1.7
<i>Bionectria hongkongensis</i>	-	-	-	-	-	-	-	20	-	-	-	-	-	20	1.7
<i>Ophioceras dolichostomum</i>	-	-	-	-	-	-	-	-	-	-	-	-	20	20	1.7
<i>Phaeoisaria clementidis</i>	-	-	-	-	-	-	-	-	20	-	-	-	-	20	1.7
<i>Spirosphaera</i> sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	20	20	1.7
Basidiomycete sp. 6	-	20	-	-	-	-	-	-	-	-	-	-	-	20	1.7
<i>Brachydesmiella caudata</i>	-	-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Cirrenalia</i> sp.	-	-	-	-	-	-	-	-	-	20	-	-	-	20	1.7
<i>Cryptophiale udagawae</i>	-	-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Dictyosporium elegans</i>	-	-	-	-	-	-	20	-	-	-	-	-	-	20	1.7
<i>Dictyosporium subramanianii</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	20	1.7
<i>Dinemasporium</i> sp.	-	-	-	20	-	-	-	-	-	-	-	-	-	20	1.7
Discomycete sp. 1	-	-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Ellisembia brachypus</i>	-	-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Thozetella nivea</i>	-	-	-	20	-	-	-	-	-	-	-	-	-	20	1.7
<i>Tubeufia cylindrothecia</i>	-	20	-	-	-	-	-	-	-	-	-	-	-	20	1.7
Unidentified hyphomycete sp. 008	-	-	20	-	-	-	-	-	-	-	-	-	-	20	1.7
Unidentified hyphomycete sp. 010	-	-	20	-	-	-	-	-	-	-	-	-	-	20	1.7
Unidentified hyphomycete sp. 017	-	-	-	-	-	-	-	-	-	-	-	-	20	20	1.7
Average no. species per block		5.2	8.4	9.6	7	6	5.4	6	5.4	4.6	5	6	8.2	6.4	
Total no. species per 5 blocks		12	18	19	16	16	16	15	10	9	11	12	20	14.5	

Table 3. Colonisation and percent frequency of fungi present on 20% or more on the test blocks of *Xylia dolabriformis* at Tad Ta Phu, Khao Yai National Park.

Species	S	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12Aug	N	Y
<i>Helicomycetes roseus</i>	E	20	20	20	20	100	80	80	100	80	60	80	100	63.3	63.3
<i>Savoryella aquatica</i>	I	-	-	20	20	60	60	80	100	80	80	40	100	64	53.3
<i>Scutisporus brunneus</i>	I	-	-	40	100	80	80	80	40	20	40	80	80	64	53.3
<i>Stilbella holubovae</i>	E	-	100	60	80	100	40	100	40	20	40	40	20	58.2	53.3
<i>Dictyochaeta</i> sp. 1	E	-	20	20	60	60	100	100	40	-	-	20	-	52.5	35
<i>Chaetopsina fluva</i>	E	40	100	20	40	40	100	60	-	-	-	-	-	57.1	33.3
<i>Biflagellospora simplex</i>	I	-	-	40	20	100	100	40	20	-	-	-	-	53.33	26.7
<i>Cancellidium applanatum</i>	I	-	-	-	-	-	40	60	80	20	20	20	80	45.7	26.7
<i>Biflagellospora papillata</i>	I	-	-	-	-	-	40	60	20	40	40	20	80	42.9	25
<i>Biflagellospora japonica</i>	I	-	-	100	80	20	20	20	-	-	-	-	-	48	20
<i>Biflagellospora siamensis</i>	I	-	-	40	40	60	20	20	-	-	-	-	-	36	15
<i>Candelabrum brocciatum</i>	I	-	-	-	-	20	20	40	60	-	20	-	-	32	13.3
<i>Savoryella verrucosa</i>	L	-	-	-	-	-	20	-	-	-	60	80	-	53	13.3
<i>Halosarpheia aquadulcis</i>	I	-	-	-	-	-	40	40	-	20	20	20	-	28	11.7
<i>Helicosporium vegetum</i> -like	I	-	-	-	-	20	20	-	-	-	20	20	60	28	11.7
<i>Cosmospora chaetopsinae</i>	E	20	40	40	20	20	-	-	-	-	-	-	-	28	11.7
<i>Pycnidial</i> sp. 1	E	20	-	-	20	20	-	40	-	-	-	-	-	25	8.3
<i>Trematosphaeria</i> sp. 2	E	-	20	20	20	-	-	-	20	-	-	-	20	20	8.3
<i>Tricladium</i> anamorph of <i>H. varicosporoides</i>	I	-	-	-	-	-	-	20	-	20	-	20	40	25	8.3
<i>Chaetopsina polyblastiae</i>	I	-	-	-	-	-	40	40	-	-	-	-	-	40	6.7
<i>Nawawia filiformis</i>	I	-	-	-	-	40	20	-	-	-	-	-	-	30	5
<i>Sporidesmiella hyalosperma</i> var. <i>novae-zelandiae</i>	E	-	20	-	-	-	-	-	40	-	-	-	-	30	5
<i>Thozetella nivea</i>	I	-	-	-	-	20	20	20	-	-	-	-	-	20	5
<i>Volutella</i> sp.	E	-	20	20	-	-	-	20	-	-	-	-	-	20	5

S = succession stages (E = early colonisers; I = intermediate colonisers; L = late colonisers); Y = Percent frequency of fungi occurrence; N = Percent frequency of fungi present divide by numbers of months which fungi present.

Table 3 continued.

Species	S	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12Aug	N	Y
<i>Annulatascus</i> sp. 1	I	-	-	-	20	20	-	-	-	-	-	-	-	20	3.3
<i>Aquaphila albicans</i>	I	-	-	-	-	-	20	-	-	20	-	-	-	20	3.3
<i>Bombardia</i> sp.	L	-	-	-	-	-	-	-	-	20	-	20	-	20	3.3
<i>Chaetopsina penicillata</i>	I	-	-	-	20	-	20	-	-	-	-	-	-	20	3.3
<i>Cylindrocarpon</i> sp. 1	E	-	40	-	-	-	-	-	-	-	-	-	-	40	3.3
<i>Dictyochaeta gyrosetula</i>	I	-	-	-	-	-	-	40	-	-	-	-	-	40	3.3
<i>Spirosphaera</i> sp. 1	L	-	-	-	-	-	-	-	-	20	-	20	-	20	3.3
<i>Vargamyces aquaticus</i>		-	-	-	20	-	-	-	-	-	-	20	-	20	3.3
<i>Articulospora</i> sp. 1		-	-	-	-	-	-	20	-	-	-	-	-	20	1.7
<i>Dactylaria</i> sp. 3		-	-	-	-	-	20	-	-	-	-	-	-	20	1.7
<i>Dendrosporium lobatum</i>		-	-	-	-	-	-	-	20	-	-	-	-	20	1.7
<i>Berkleasium</i> sp. 1		-	-	-	20	-	-	-	-	-	-	-	-	20	1.7
Discomycete sp. 1		-	-	-	20	-	-	-	-	-	-	-	-	20	1.7
<i>Helicoma</i> sp. 3		-	-	-	-	-	20	-	-	-	-	-	-	20	1.7
<i>Hymenoscyphus varicosporoides</i>		-	-	-	-	-	-	-	-	-	-	20	-	20	1.7
<i>Eluviespora bipolaris</i>		-	-	-	-	-	-	20	-	-	-	-	-	20	1.7
<i>Cosmospora chaetopsinae-polyblastiae</i>		-	-	-	-	-	20	-	-	-	-	-	-	20	1.7
<i>Nectria</i> sp. 1		-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Oxydothis</i> sp. 1		-	-	-	-	20	-	-	-	-	-	-	-	20	1.7
<i>Sporodesmium</i> sp. 1-like		-	-	-	20	-	-	-	-	-	-	-	-	20	1.7
Unidentified ascomycete sp. 29		-	-	-	-	-	-	-	-	-	-	20	-	20	1.7
Unidentified hyphomycete sp. 17		-	-	-	-	-	-	-	-	-	-	20	-	20	1.7
<i>Xylomyces elegans</i>		-	-	-	-	-	-	-	-	-	-	20	-	20	1.7
Average no. species per block		1.2	3.8	4	6.4	8	9.4	10	5.8	3.6	4	5.8	5.8	5.6	
Total no. species per 5 blocks		4	9	12	18	18	23	21	12	11	10	18	9	13.8	

Table 4. Percentage cover of the most common fungi on test block of *Dipterocarpus alatus* at Tad Ta Phu Khao Yai National Park.

Species	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12 Aug	N
<i>Pycnidial</i> sp. 1	18	-	100	2.22	14.22	-	-	-	-	-	-	-	33.6
<i>Trematosphaeria</i> sp. 2	7.55	96.22	-	0.44	-	-	0.44	-	-	-	-	-	26.7
<i>Eluviespora bipolaris</i>	-	-	-	-	32.66	43.55	24	3.77	-	21.77	3.48	14.66	20.6
<i>Helicomycetes roseus</i>	10.44	71.55	56.22	16.22	6.88	28.22	6.22	9.11	12.44	3.33	6.22	3.55	19.2
<i>Halosarpheia aquadulcis</i>	-	6.44	19.33	27.77	1.11	4.66	4.22	9.55	8	18.44	-	1.33	10.1
<i>Spirosphaera</i> sp. 1	-	-	-	4.66	-	0.66	0.66	11.33	4.22	4.88	6.88	5.33	4.8
<i>Tricladium</i> anamorph of <i>H. varicosporides</i>	-	-	1.77	4.44	0.66	3.55	3.11	7.33	6.44	0.22	6.88	11.33	4.6
<i>Dictyochaeta</i> sp. 1	2	3.55	8.66	4	1.33	0.66	0.22	-	-	-	-	-	2.9
<i>Brachydesmiella verrucosa</i>	-	2	3.11	-	3.11	3.55	0.88	-	-	-	-	-	2.5
<i>Helicosporium griseum</i> -like	7.33	0.66	1.11	-	-	0.66	-	-	-	-	-	-	2.4
<i>Bombardia</i> sp.	0.22	0.44	0.22	10.44	0.66	-	-	2.44	0.44	0.88	3.55	2.88	2.2
<i>Dictyosporium digitatum</i>	-	0.88	-	1.77	1.11	2	-	-	-	-	-	-	1.4
<i>Helicosporium vegetum</i> -like	-	1.11	2.88	1.11	1.33	-	1.33	0.44	-	1.77	1.11	1.77	1.4
<i>Aquaphila albicans</i>	-	1.77	1.11	0.44	-	-	-	2	-	-	-	1.11	1.3
<i>Cancellidium applanatum</i>	-	0.44	0.44	1.11	-	0.44	0.22	0.22	0.88	0.88	-	4.88	1.1
<i>Sporidesmiella hyalosperma</i> var. <i>novae-zelandiae</i>	1.77	0.88	0.22	0.22	-	-	-	-	-	-	-	-	0.8
Unidentified hyphomycete sp. 05	0.88	0.44	0.88	-	-	-	-	-	-	-	-	-	0.7
<i>Candelabrum brocciatum</i>	-	0.22	0.66	0.66	-	0.22	-	-	0.44	1.11	-	0.44	0.5
<i>Hymenoscyphus varicosporoides</i>	-	-	0.22	0.44	0.22	0.44	0.66	-	-	-	-	-	0.4

N = Percent frequency of fungi present divide by numbers of months which fungi present.

Table 5. Percentage cover of the most common fungi on test block of *Xylia dolabriformis* at Tad Ta Phu Khao Yai National Park.

Species	1 Sep	2 Oct	3 Nov	4 Dec	5 Jan	6 Feb	7 Mar	8 Apr	9 May	10 Jun	11 Jul	12 Aug	N
<i>Helicomyces roseus</i>	0.66	0.66	0.66	0.44	40	29.55	20.22	14.22	12.44	18.88	14	10.44	13.5
<i>Savoryella aquatica</i>	-	-	1.33	0.44	13.11	9.11	11.77	13.33	15.11	10.88	8.2	31.11	11.4
<i>Scutisporus brunneus</i>	-	-	1.77	21.33	7.11	11.55	9.11	3.11	1.33	2.22	12.44	5.55	7.6
<i>Stilbella holubovae</i>	-	2	12.88	9.11	6	10.66	20.22	1.77	3.33	2.22	6.88	0.66	6.9
<i>Savoryella verrucosa</i>	-	-	-	-	-	1.77	-	-	-	3.55	11.11	-	5.5
<i>Biflagellospora gracilis</i>	-	-	0.66	0.66	15.77	6.88	2.88	0.66	-	-	-	-	4.6
<i>Dictyochaeta</i> sp. 1	-	0.22	0.88	1.77	4.88	16.66	7.33	2	-	-	0.22	-	4.3
<i>Biflagellospora papillata</i>	-	-	-	-	-	6.22	12.22	1.55	1.33	1.55	2.22	3.11	4.1
<i>Biflagellospora japonica</i>	-	-	3.55	10.44	0.66	2	0.44	-	-	-	-	-	3.4
<i>Chaetopsina fluva</i>	2.22	6.22	2.22	2.66	2	4.44	3.33	-	-	-	-	-	3.3
<i>Halosarpheia aquadulcis</i>	-	-	-	-	-	1.33	4	-	5.55	1.33	3.55	-	3.2
<i>Biflagellospora siamensis</i>	-	-	2.66	1.33	6.66	1.11	0.88	-	-	-	-	-	2.5
<i>Cancellidium applanatum</i>	-	-	-	-	-	0.44	1.11	4	0.44	1.33	0.44	3.33	1.6
<i>Helicosporium vegetum</i> -like	-	-	-	-	0.22	0.88	-	-	-	0.88	2.66	3.11	1.6
<i>Candelabrum brocchiatum</i>	-	-	-	-	0.22	1.11	0.66	0.66	-	0.44	-	-	0.6
<i>Cosmospora chaetopsinae</i>	0.22	0.44	0.44	0.44	0.22	-	-	-	-	-	-	-	0.4

N = Percent frequency of fungi present divide by numbers of months which fungi present.

Succession

Fungi colonising test blocks were arbitrarily categorised into 4 groups with twenty-three species considered as early colonisers on both timbers (Tables 2 and 3). On *D. alatus* 18 species were present as early colonisers, while on *X. dolabriformis* there were 10 species. Five species: Pycnidial sp. 1, *Dictyochoaeta* sp. 1, *Helicomycetes roseus*, *Sporidesmiella hyalosperma* var. *novae-zelandiae* and *Trematosphaeria* sp. 2 were common to both timbers (Tables 2, 3).

Dipterocarpus alatus test blocks were colonised rapidly by 12 fungi in the first month. Three fungi occurred at a high frequency of occurrence: *Helicomycetes roseus*, Pycnidial sp. 1 and *Trematosphaeria* sp. 2 which occurred on more than 50% of the test blocks. *Aquaphila albicans*, *Brachydesmiella verrucosa*, *Cancellidium applantum*, *Candelabrum brocchiatum*, *Dictyosporium digitatum*, *Halosarpheia aquadulcis*, *Helicosporium vegetum*-like, *Savoryella aquatica* and two unidentified hyphomycetes were present in month two. Seven of the 18 early colonisers were present through to the end of exposure period. The remaining early colonisers were present in the intermediate period, with the exception of *Savoryella aquatica*, which occurred only once in the second month (Table 2).

On *X. dolabriformis* four fungi colonised the test blocks in the first month (Table 3): Pycnidial sp. 1, *Chaetopsina fluva*, *Helicomycetes roseus* and *Cosmospora chaetopsinae* and all of these are regarded as early colonisers. *Helicomycetes roseus* was the most common species from the early to late colonisation stage, while *Cylindrocarpon* sp. 1 occurred only in the second month. Six species occurred first time in month two, with only *Stilbella holubovae* present every month and through to the end of the exposure period.

A number of species were regarded as intermediate colonisers on both timbers (Table 3). However, in contrast to the early colonisation stage only six species could be considered intermediate colonisers on *D. alatus* with a high percent frequency by two taxa (*Tricladium* anamorph of *Hymenoscyphus varicosporoides*, *Eluviespora bipolaris*). On *X. dolabriformis* eighteen species were considered to be intermediate colonisers and again two species were present at high frequencies (*Savoryella aquatica*, *Scutisporus brunneus*). There was only one species (*Tricladium* anamorph of *H. varicosporoides*) that overlapped in the intermediate stage of colonisation between the two timbers.

Six species colonised the timbers during the latter stages of exposure (Tables 4, 5): four on *D. alatus* (*Massarina* sp. 3, *M. ingoldiana*, *Savoryella verrucosa*, *Vargamyces aquaticus*), and three on *X. dolabriformis* (*Bombardia* sp. 1, *S. verrucosa*, *Spirosphaera* sp. 1). Only *S. verrucosa* occurred on both timbers.

A number of fungi were only infrequently recorded, generally only encountered once on a test block during the whole exposure period for example: *Cryptophiale udagawae*, *Ophioceras dolichostomum*, *Ellisemia brachypus* and *Thozetella nivea* on *D. alatus*, and *Cosmospora chaetopsinae-polyblastiae*, *Dendrosporium lobatum*, *Eluviespora bipolaris* and *Hymenoscyphus varicosporoides* on *X. dolabriformis*.

Discussion

Numerous studies of the fungal colonisation of wood in freshwater have now been undertaken, involving examination of naturally occurring wood and on submerged test blocks (Sivichai *et al.*, 2000; Tsui *et al.*, 2000; Ho *et al.*, 2001; Shearer, 2001). Data is available from both tropical and temperate locations and on diverse substrata (Shearer, 2001), yet no clear picture emerges as to the sequence of fungal colonisation. All are studies of the sequential sporulation of the fungi on the wood (Jones and Hyde, 2002).

So what general conclusions can be made on the basis of these studies? Firstly, lignicolous freshwater fungi in temperate localities differ from those encountered in tropical waters (Ho *et al.*, 2001; Kane *et al.*, 2002) (Table 6). There are also marked differences in species composition within the same stream population, as in the community on *D. alatus* at km 29.2 and Tad Ta Phu (Sivichai *et al.*, 2000 and this study) and with studies in different tropical areas (Ho *et al.*, 2001) (Table 6). Secondly, a greater diversity of species has been reported for submerged test blocks as opposed to naturally occurring wood. For example more fungi per sample have been reported for submerged wood: 1-11 (average 6.4 fungi) (Sivichai *et al.*, 2000) and 1.2-10 (average 6 fungi) (this study), as opposed to 0.7-2.9 on natural wood (Ho *et al.*, 2001). Key factors here include surface area available for colonisation, the presence of bark or treatment of the baits by autoclaving before exposure. Sanders and Anderson (1979) showed a clear correlation between the number of fungi per test blocks and the dimensions of the exposed wood. Generally, the percentage occurrence of fungi on submerged wood is greater with up to 100% colonisation (Sivichai *et al.*, 2000; Kane *et al.*, 2002; this study). However, on naturally occurring wood percentage occurrence can be quite low: 0-34 (Ho *et al.*, 2001); 2-24 (Tsui *et al.*, 2000).

Thirdly, we can discern distinct fungal communities on submerged substrata in freshwater streams and rivers. Senescent falling leaves support largely highly branched, tetra- or sigmoid conidia (so called Ingoldian hyphomycetes) with few ascomycetes (Webster, 1992). Submerged wood supports a high diversity of anamorphic fungi, generally dematiaceous species. Ascomycetes are also present and often have characteristic appendaged

Table 6. Comparison of percent frequency of the dominant fungi colonising wood test blocks in four selected studies.

Thailand (present study)		Hong Kong		UK, River Severn		UK, River Dee			
At km29.9		Tad Ta Phu		(Ho <i>et al.</i> , 2002)		(Kane <i>et al.</i> , 2002)		(Eaton and Jones, 1971a)	
<i>Dipterocarpus alatus</i> (53)*		<i>Dipterocarpus alatus</i> (48)		<i>Machilus velutina</i> (59)		<i>Fagus sylvatica</i> (41)		<i>Fagus sylvatica</i> (34)	
<i>Helicomyces roseus</i>	82	<i>Helicomyces roseus</i>	83	<i>Savoryella lignicola</i>	13.1	<i>Camposporium</i>	95	<i>Clasterosporium</i>	11
<i>Trematosphaeria</i> sp. 2	63	<i>Halosarpheia</i>	67	<i>Aniptodera</i>	12.3	<i>pellucidum</i>		<i>caricinum</i>	
Sporodochial sp. 1	45	<i>aquadulcis</i>		<i>chesapeakeensis</i>		<i>Codinaea parva</i>	85	<i>Helicoon sessile</i>	10
<i>Dictyochaeta</i> sp. 1	45	<i>Tricladium</i> anamorph of	60	<i>Sporoschisma</i>	10.0	<i>Pseudohalonectria</i>	85	<i>Trematosphaeria</i>	8
<i>Ophioceras</i>	28	<i>H. varicosporoides</i>		<i>nigroseptatum</i>		<i>lignicola</i>		<i>pertusa</i>	
<i>dolichostomum</i>		<i>Eluviespora bipolaris</i>	48	<i>Spirosphaera</i>	7.1	<i>Trichocladium lignicola</i>	80	<i>Monodictys putredinis</i>	6
<i>Bombardia</i> sp. 1	25	<i>Spirosphaera</i> sp. 1	37	<i>floriformis</i>		<i>Fusarium</i> sp.	65	<i>Tricladium splendens</i>	6
Teleomorph of	25	<i>Bombardia</i> sp. 1	32	<i>Aquaticola ellipsoidea</i>	5.7	<i>Ophioceras</i>	60	<i>Ceratosphaeria</i>	6
sporodochial sp. 1		<i>Cancellidium</i>	27	<i>Dictyosporium elegans</i>	5.6	<i>dolichostomum</i>		<i>lampadophora</i>	
Unidentified	17	<i>applanatum</i>		<i>Massarina ingoldiana</i>	3.4	<i>Trematosphaeria pertusa</i>	35		
ascomycete sp. 11		<i>Dictyochaeta</i> sp. 1	27						
<i>Xylia dolabriformis</i> (62)		<i>Xylia dolabriformis</i> (47)		<i>Pinus massoniana</i> (60)		<i>Pinus sylvestris</i> (28)		<i>Pinus sylvestris</i> (20)	
<i>Savoryella aquatica</i>	83	<i>Helicomyces roseus</i>	63	<i>Massarina ingoldiana</i>	9.6	<i>Trichocladium lignicola</i>	95	<i>Monodictys putredinis</i>	10
<i>Helicomyces roseus</i>	58	<i>Savoryella aquatica</i>	53	<i>Sporoschisma</i>	9.5	<i>Fusarium</i> sp.	95	<i>Sterigmatobotrys</i>	7
<i>Ellisembia opaca</i>	57	<i>Scutisporus brunneus</i>	53	<i>nigroseptatum</i>		<i>Heliscus lugdunensis</i>	35	<i>macrocarpa</i>	
<i>Dictyochaeta</i> sp. 1	47	<i>Stilbella holubovae</i>	53	<i>Spirosphaera</i>	9.5	<i>Codinaea parva</i>	30	<i>Tricladium</i>	2
<i>Sporidesmium</i> sp.-like	43	<i>Dictyochaeta</i> sp. 1	35	<i>floriformis</i>		<i>Alatospora acuminata</i>	20	<i>alpollonellum</i>	
<i>Scutisporus brunneus</i>	42	<i>Chaetopsina fulva</i>	33	<i>Aniptodera</i>	7.8	<i>Trichocladium</i>	20	<i>Heliscus lugdunensis</i>	2
<i>Biflagellospora</i>	32	<i>Biflagellospora gracilis</i>	27	<i>chesapeakeensis</i>		<i>alopallonellum</i>		<i>Septonema</i> sp.	2
<i>siamensis</i>		<i>Cancellidium</i>	27	<i>Eluviespora bipolaris</i>	6.6	<i>Camposporium</i>	20		
<i>Biflagellospora gracilis</i>	32	<i>applanatum</i>		<i>Aquaticola ellipsoidea</i>	6.6	<i>pellucidum</i>			
				<i>Dictyosporium elegans</i>	6.1				
Total species both timbers	Total species both timbers	Total species both timbers	Total species both timbers	Total species on both timbers: 60	Total species on both timbers: 60	Total species on both timbers: 43	Total species on both timbers: 43		
89	73	80							

* total number of fungi recorded.

ascospores. However, the anamorphic taxa appear to be more like their terrestrial counterparts. A third group are those anamorphic fungi, again generally dematiaceous, that occur on submerged litter (Kuthubutheen and Nawawi, 1991; Kuthubutheen, 1993). Many of these have also been observed on submerged woody tissue. These fungi may be better adapted for aerial dispersal of their spores and in withstanding dehydration and subsequent hydration in a river system, often prone to drying out (Sivichai *et al.*, 2000). Many of the lignicolous freshwater ascomycetes have active discharge of their ascospores, and asci often with an elaborate apical ring, as in the *Annulatascaceae* (Wong *et al.*, 1998).

Fourthly, different timbers submerged in streams support distinct fungal communities with often little overlap in species. This has been observed in a number of studies (Eaton and Jones, 1971a; Tsui 1999; Sivichai *et al.*, 2000; Ho *et al.*, 2002; Kane *et al.*, 2002).

In conclusion, our study has shown that the two timbers exposed at Khao Yai National Park: support a wide range of taxa; a high percentage colonisation of the test blocks (60% and above); the test blocks support a high number of species (5-9.6 species per sample); the population is dominated by anamorphic fungi and the timbers support a divergent fungal community with only a single species of *Helicomyces roseus* overlapping among the dominant species. There was little decay of the exposed timbers even after 12 months exposure. This suggests that 12 months is too short a period for any major change in fungal colonisation, and future studies should consider longer periods of exposure.

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Fungal Diversity

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