# Fungal colonisation of wood in a freshwater stream at Khao Yai National Park, Thailand

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Test blocks of *Dipterocarpus alatus* and *Xylia dolabriformis* were exposed in a freshwater stream for 12 months at km 29.2 at Khao Yai National Park, Thailand and recovered every month, incubated in moist chambers and fungal colonization recorded. The sequence of colonisation of fungi, the frequency of occurrence and the percentage cover on the test blocks are presented. Eighty-nine species were recorded, including 53 on *Dipterocarpus alatus* and 62 on *Xylia dolabriformis*. Fungi were categorised into 3 groups: group 1 fungi present on over 60% of the test blocks, including: *Helicomyces roseus*, *Trematosphaeria* sp. 2 on *Dipterocarpus alatus* and *Savoryella aquatica*, *Helicomyces roseus* and *Ellisembia opaca* on *Xylia dolabriformis*. Group 2 fungi were present on more than 20% of the test blocks numbered 5 and 8 respectively on *Dipterocarpus alatus* and *Xylia dolabriformis*. Group 3 were fungi present on less than 20% of the test blocks. There was no evidence of a succession of fungi on the wood, however fungi could be grouped into those that appeared early on the wood: *Dictyochaeta* sp. 1, *Ellisembia brachypus*, *Helicomyces roseus*, *Helicosporium griseum* and *Trematosphaeria* sp. 2 on *Dipterocarpus alatus*; with *Biflagellospora siamensis*, *Canalisporium pulchrum*, *Dictyochaeta* sp. 1, *Ellisembia opaca*, *Helicomyces roseus* and *Savoryella aquatica* on *Xylia dolabriformis*. Intermediate colonisers included: coelomycete sp. 1 and *Ophioceras dolichostomum* on *Dipterocarpus alatus*, while ascomycete sp. 11 and *Anthostomella aquatica* were late colonisers. Intermediate colonisers of *Xylia dolabriformis* were *Biflagellospora gracilis*, *B. papillata* and *Thozetella nivea* and late colonisers were *Canalisporium pulchrum and C. elegans*. Dominant species on each timber are different. This study is compared with other studies from tropical and temperate regions.

**Key words:** aquatic fungi, colonization, freshwater fungi.

## Introduction

In recent years a wide range of lignicolous freshwater fungi have been described (Jones and Eaton, 1969; Eaton and Jones, 1971a,b; Lamore and Goos, 1978; Shearer and Bodman, 1983; Hyde *et al*., 1992, 1995; Shearer, 1993a,b; Goh and Hyde, 1996a; Hyde *et al*., 1998). Shearer (1993a) listed 288 species of ascomycetes from freshwater habitats, while Goh and Hyde (1996b)

quote a figure of 340 ascomycetes and 300 mitosporic fungi. Most of these are temperate freshwater species with only 11 tropical freshwater ascomycetes (Shearer, 1993a). This number has dramatically changed with the studies of Hyde and his co-workers (Ho *et al.*, 1997; Hyde and Goh, 1997; Hyde *et al.*, 1997) and others (Hsieh *et al.*, 1995; Chang *et al.*, 1998).

While ascomycetes dominate the mycota on submerged marine wood (Kohlmeyer and Volkmann-Kohlmeyer, 1991), both ascomycetes and mitosporic fungi occur in equal numbers on wood in freshwater habitats. Most of these studies are descriptions of new taxa, a few examine the enzyme degrading capability of freshwater fungi (Eaton, 1976; Jones, 1981; Zare-Mairan and Shearer, 1988); interference competition (Shearer and Zare-Mairan, 1988) and the ultrastructure of freshwater ascomycetes (Hyde *et al.*, 1992; Wong *et al.*, 1998; Jones *et al.*, 1999). Studies on the ecology of these fungi are few in number, with early observations on temperate species by Jones and Oliver (1964), Eaton and Jones (1971a,b), Shearer and Bodman, (1983), Lamore and Goos (1978), and Hyde and Goh (1997). As can be seen few have examined the colonisation of wood submerged in tropical streams, and this is the primary objective of this paper.

## Materials and methods

A stream at Roadmaker km 29.2 at Khao Yai National Park, Nakorn Ratchassima Province, Thailand was selected for this study. Two timbers were selected: *Dipterocarpus alatus* and *Xylia dolabriformis*, low and high-density timbers respectively, and submerged in August 1997. All test blocks were 15 × 2.5 × 2.5 $cm^3$ and free of wood preservatives. Two holes were drilled in each test block (1 cm diam.), which was then threaded on nylon rope to make a ladder. Each set contained 5 test blocks of the same species, and each bloch was separated by knots in the rope at about 2 cm intervals. All the test blocks were sterilised three times by autoclaving at 1.5 $kgf/cm^2$, 121 C for 15 minutes. Test blocks were exposed by attaching the ladders to root of trees. Ladders were anchored with bricks to keep them submerged in the water. Test blocks were recovered monthly (beginning in September 1997) until the 12 sets had been withdrawn (Table 1). All samples were placed in separate polyethylene bags and then placed immediately in a clean foam box for transportation to the laboratory. During each field visit the water temperature and pH were recorded and water samples collected for chemical analysis.

### *Incubation of test blocks*

Test blocks were returned to the laboratory and washed in tap water to remove silt and mud from the surface. These were then incubated in a pre-

**Table 1.** Date of retrieval of exposed test blocks at Khao Yai National Park.

| Sampling number | Period of exposure (month) | Date of exposure | Date of retrieval |
|---|---|---|---|
| 1 | 1 | 12 Aug. 1997 | 9 Sep. 1997 |
| 2 | 2 | 12 Aug. 1997 | 8 Oct. 1997 |
| 3 | 3 | 12 Aug. 1997 | 6 Nov. 1997 |
| 4 | 4 | 12 Aug. 1997 | 9 Dec. 1997 |
| 5 | 5 | 12 Aug. 1997 | 6 Jan. 1998 |
| 6 | 6 | 12 Aug. 1997 | 10 Feb. 1998 |
| 7 | 7 | 12 Aug. 1997 | 11 Mar. 1998 |
| 8 | 8 | 12 Aug. 1997 | 14 Apr. 1998 |
| 9 | 9 | 12 Aug. 1997 | 14 May 1998 |
| 10 | 10 | 12 Aug. 1997 | 10 June 1998 |
| 11 | 11 | 12 Aug. 1997 | 13 July 1998 |
| 12 | 12 | 12 Aug. 1997 | 14 Aug. 1998 |

sterilised plastic box (19 × 19 × 6 $cm^3$) containing sterile moist tissue paper layered in the bottom. To prevent the test blocks from coming into direct contact with the tissue paper each test block was supported on two plastic lids (6 × 3.5 × 0.5 $cm^3$). Periodically the test blocks were sprayed with sterile distilled water to keep them moist. They were incubated at 20 C in a cabinet with cool white fluorescent light.

### *Examination and identification of the fungi*

Test blocks were examined under the stereomicroscope for the presence of fungi after incubation for one week, 1, 2 and 3 months. Three sides of each test block were selected: top, bottom and one side from both timbers, then each side was divided into 30 equal squares and the number of fungi in each square recorded. Herbarium material and voucher slides were prepared and are kept in the BIOTEC Herbarium, while isolates are maintained in the BIOTEC Culture Collection, Thailand.

## Results

Species diversity was greatest on the *Xylia dolabriformis* test blocks (60) with 62 species (14 ascomycetes, 48 mitosporic fungi), and 53 (15 ascomycetes, 2 basidiomycetes, 36 mitosporic fungi) on *Dipterocarpus alatus* (60) with an overall total of 89 taxa (Table 4). All test blocks were colonised even after 4 weeks of exposure. The number of species per block varied from 3.4-11 (aveage 5.6) on *Dipterocarpus alatus* (Table 2) to 1-9.8 (average 7.1) on *Xylia dolabriformis* (Table 3). The average Shannon Index was 4.8 (4.7 and 4.9 on *Dipterocarpus alatus* and *Xylia dolabriformis* respectively) and the ratio of mitosporic fungi to ascomycetes was 3.4 on *Dipterocarpus alatus* and 2.3 on

**Table 2.** Colonisation and percent frequency of fungi present more than 20% on test blocks of *Dipterocarpus alatus* at km 29.2, Khao Yai National Park.

| Fungi | 1 Sep | 2 Oct | 3 Nov | 4 Dec | 5 Jan | 6 Feb | 7 Mar | 8 Apri | 9 May | 10 Jun | 11 Jul | 12 Aug | Divide N * | Divide Y ♦ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Helicomyces roseus* Link | 100 | 100 | 80 | 80 | 80 | 60 | 60 | 100 | 100 | 60 | 100 | 60 | 81.67 | 81.67 |
| *Trematosphaeria* sp. 2 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 60 | - | - | - | - | 95.00 | 63.33 |
| Coelomycete sp. 1 | - | - | 20 | - | 20 | 60 | 40 | 40 | 60 | 100 | 100 | 100 | 60.00 | 45.00 |
| *Dictyochaeta* sp. 1 | 60 | 80 | 60 | 100 | 60 | 60 | - | 20 | 60 | 20 | 20 | - | 54.00 | 45.00 |
| *Ophioceras dolichostomum* (Berk. and M.A. Curtis.) Sacc. | - | - | - | 60 | 40 | 40 | 20 | 20 | 60 | 20 | 40 | 40 | 37.78 | 28.33 |
| *Bombardia* sp. | 20 | 20 | - | - | 20 | 40 | 20 | 40 | 60 | 40 | - | 40 | 33.33 | 25.00 |
| Teleomorph of coelomycete sp. 1 | - | - | - | - | - | - | 20 | - | 60 | 40 | 100 | 80 | 60.00 | 25.00 |
| Ascomycete sp. 11 (SS576) | - | - | - | - | - | - | - | - | - | 40 | 60 | 100 | 66.67 | 16.67 |
| Conidia in pycnidia sp.1 | - | - | 20 | 20 | 20 | - | - | 40 | - | 40 | 60 | - | 33.33 | 16.67 |
| *Tubeufia cylindrothecia* (Seaver) Höhn. | 20 | - | - | - | - | - | - | 40 | 80 | - | - | - | 46.67 | 16.67 |
| *Ellisembia brachypus* (Ellis and Everh.) Subram. | 20 | - | 20 | 20 | 20 | 80 | - | 20 | - | - | - | - | 30.00 | 15.00 |
| *Helicosporium grisum*-like | 20 | 40 | 20 | 40 | - | 20 | - | 40 | - | - | - | - | 30.00 | 15.00 |
| *Savoryella aquatica* K.D. Hyde | - | 20 | - | - | - | - | 20 | - | 60 | 20 | 20 | 40 | 30.00 | 15.00 |
| *Anthostomella aquatica* K.D. Hyde and Goh | - | - | - | - | - | - | - | - | - | 80 | - | 80 | 80.00 | 13.33 |
| *Thozetella nivea* (Berk. and F. Muell.) O. Kuntze | - | - | 20 | 40 | 20 | 20 | 20 | - | - | 20 | 20 | - | 22.86 | 13.33 |
| *Dactylaria* sp. 4 (SS560) | - | - | - | - | - | - | - | - | 20 | - | 20 | 100 | 46.67 | 11.67 |
| *Sporoschisma uniseptatum* Bhat and W.B. Kendr. | - | - | 20 | 20 | 40 | 20 | - | - | - | 20 | - | - | 24.00 | 10.00 |
| No. of species per 5 blocks | 10 | 11 | 11 | 10 | 14 | 13 | 10 | 14 | 23 | 16 | 18 | 11 | X = 13.42 | |
| No. of species per block | 4.2 | 4.6 | 4 | 5.2 | 5 | 5.6 | 3.4 | 5 | 11 | 5 | 7.8 | 7 | X = 5.65 | |
| Total no. of species on *D. alatus* | 53 spp. | | | | | | | | | | | | | |

* = Percent frequency of fungi present divided by number of months with fungi present; ♦ = Percent frequency of occurrence.

**Table 3.** Colonisation and percent frequency of fungi present on 20% or more on the test blocks of *Xylia dolabriformis* at km.29.2, Khao Yai National Park.

| Fungi | 1 Sep | 2 Oct | 3 Nov | 4 Dec | 5 Jan | 6 Feb | 7 Mar | 8 Apr | 9 May | 10 Jun | 11 Jul | 12 Aug | Divide N * | Divide Y ♦ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Savoryella aquatica* | - | 20 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 90.91 | 83.33 |
| *Helicomyces roseus* | - | 20 | 80 | 40 | 60 | 100 | 80 | 60 | 100 | 60 | 40 | 60 | 63.64 | 58.33 |
| *Ellisembia opaca* (Cooke and Harkn.) Subram. | - | 20 | 20 | 40 | 80 | 60 | 40 | 100 | 100 | 80 | 60 | 80 | 61.82 | 56.67 |
| *Dictyochaeta* sp. 1 | 20 | - | 20 | 40 | 80 | 80 | 60 | 100 | 80 | 20 | 40 | 20 | 50.91 | 46.67 |
| *Sporidesmium*-like sp. 1 (SS419) | - | - | 60 | 80 | 40 | 80 | 20 | 20 | 20 | 40 | 80 | 80 | 52.00 | 43.33 |
| *Scutisporus brunneus* Ando and Tubaki. | - | - | 80 | 80 | 20 | 80 | 40 | 40 | 20 | 60 | 40 | 40 | 50.00 | 41.67 |
| *Biflagellospora siamensis* Sivichai and Hywel-Jones | - | 40 | 100 | 60 | 60 | 60 | 20 | 40 | - | - | - | - | 54.29 | 31.67 |
| *Biflagellospora gracilis* Sivichai and Hywel-Jones | - | - | 60 | 80 | 60 | 80 | 40 | 40 | 20 | - | - | - | 54.29 | 31.67 |
| *Canalisporium pulchrum* (Hol.-Jech. and Mercado) Nawawi and Kuthub. | - | 20 | 60 | - | - | 20 | - | 40 | 60 | 60 | 80 | 20 | 45.00 | 30.00 |
| *Biflagellospora papillata* Sivichai and Hywel-Jones | - | - | - | - | 40 | 20 | 40 | 60 | 40 | 60 | 60 | 20 | 42.50 | 28.33 |
| *Canalisporium elegans* Nawawi and Kuthub. | - | 20 | 20 | - | 40 | 20 | - | 60 | 40 | 60 | 20 | 60 | 37.78 | 28.33 |
| *Berkleasmium* sp. 1 | - | - | 40 | 60 | - | - | - | - | 80 | - | 20 | - | 50.00 | 16.67 |
| *Thozetella nivea* (Berk. and F. Muell.) O. Kuntze | - | - | - | - | 40 | 20 | 20 | 20 | 40 | - | 20 | - | 26.67 | 13.33 |
| *Chaetopsina fluva* Rambelli | - | - | - | 60 | 40 | 20 | - | - | 20 | - | - | - | 35.00 | 11.67 |
| Hyphomycete sp. 9 (SS447) | - | - | - | 80 | 60 | - | - | - | - | - | - | - | 70.00 | 11.67 |
| *Chaetopsina polyblastiae* Samuels | - | - | - | - | - | 40 | - | 40 | 40 | - | - | - | 40.00 | 10.00 |
| *Acrogenospora sphaerocephala* (Berk. and Broome) Ellis | - | - | - | - | 20 | 20 | 20 | 20 | 20 | - | 20 | - | 20.00 | 10.00 |
| No. of species per 5 blocks | 2 | 14 | 19 | 18 | 22 | 18 | 13 | 21 | 25 | 9 | 20 | 17 | X = 16.5 | |
| No. of species per block | 1 | 3.8 | 8.6 | 8.6 | 9.2 | 9 | 5.2 | 9.6 | 9.8 | 5.4 | 8.8 | 6.8 | X = 7.15 | |
| Total no. species on *X. dolabriformis* | 62 spp. | | | | | | | | | | | | | |

* = Percent frequency of fungi present divided by number of months with fungi present; ♦ = Percent frequency of occurrence.

**Table 4.** Perecntage frequency of occurrence of fungi on *Dipterocarpus alatus* and *Xylia dolabriformis* exposed test blocks at km.29.2, Khao Yai National Park.

| Fungi | *D. alatus* | | | *X. dolabriformis* | | |
|---|---|---|---|---|---|---|
| | # | Divide N* | Divide Y ♦ | # | Divide N* | Divide Y ♦ |
| *Acrogenospora sphaerocephala* (Berk. and Broome) Ellis | - | - | - | 6 | 20.00 | 10.00 |
| ***Annulatascus* sp. 1** (SS622) [1] | 2 | 30.00 | 5.00 | 2 | 20.00 | 3.33 |
| *Anthostomella aquatica* K. D. Hyde and Goh | 2 | 80.00 | 13.33 | - | - | - |
| *Aquaphila albicans* Goh, K.D. Hyde and W. H. Ho | 2 | 30.00 | 5.00 | - | - | - |
| Basidiomycete conidia (SS557) | 1 | 60.00 | 5.00 | - | - | - |
| Basidiomycete sp. 7 (mycelium) | 1 | 20.00 | 1.67 | - | - | - |
| ***Berkleasmium* sp. 1** | 1 | 20.00 | 1.67 | 4 | 50.00 | 16.67 |
| *Biflagellospora japonica* Matsush. | - | - | - | 1 | 20.00 | 1.67 |
| *Biflagellospora papillata* Sivichai and Hywel-Jones | - | - | - | 8 | 42.50 | 28.33 |
| *Biflagellospora siamensis* Sivichai and Hywel-Jones | - | - | - | 7 | 54.29 | 31.67 |
| *Biflagellospora gracilis* Sivichai and Hywel-Jones | - | - | - | 7 | 54.29 | 31.67 |
| *Boerlagiomyces* sp. 1 (Brown) | - | - | - | 2 | 20.00 | 3.33 |
| *Bombardia* sp. | 9 | 33.33 | 25.00 | - | - | - |
| *Brachydesmiella caudata* Rao and de Hoog | 2 | 20.00 | 3.33 | - | - | - |
| *Campylospora* sp. | - | - | - | 1 | 20.00 | 1.67 |
| *Canalisporium caribense* (Hol.-Jech. and Mercado) Nawawi and Kuthub. | - | - | - | 4 | 25.00 | 8.33 |
| ***Canalisporium elegans*** Nawawi and Kuthub. | 2 | 30.00 | 5.00 | 9 | 37.78 | 28.33 |
| *Canalisporium exiguum* Goh and K.D. Hyde | - | - | - | 2 | 20.00 | 3.33 |
| *Canalisporium pallidum* Goh, W.H. Ho and K.D. Hyde | - | - | - | 3 | 20.00 | 5.00 |
| ***Canalisporium pulchrum*** (Hol.-Jech. and Mercado) Nawawi and Kuthub. | 1 | 20.00 | 1.67 | 8 | 45.00 | 30.00 |
| ***Candelabrum brocchiatum*** Tubaki | 3 | 33.33 | 8.33 | 2 | 20.00 | 3.33 |

# = Number of month that fungus occur; * = Percent frequency of fungi present divided by number of months with fungi present;
♦ = Percent frequency of occurrence; [1] = Species in bold refer to those present on both timbers.

**Table 4.** (continued).

| Fungi | *D. alatus* | | | *X. dolabriformis* | | |
|---|---|---|---|---|---|---|
| | # | Divide N* | Divide Y ♦ | # | Divide N* | Divide Y ♦ |
| *Chaetopsina fluva* Rambelli | - | - | - | 4 | 35.00 | 11.67 |
| *Chaetopsina penicillata* Samuels | - | - | - | 1 | 20.00 | 1.67 |
| *Chaetopsina polyblastiae* Samuels | - | - | - | 3 | 40.00 | 10.00 |
| **Conidia in pycnidia sp. 1** | 6 | 33.33 | 16.67 | 2 | 30.00 | 5.00 |
| *Cryptophialoidea unilateralis* | 1 | 20.00 | 1.67 | - | - | - |
| *Cylindrocarpon* sp. 1 | 1 | 20.00 | 1.67 | - | - | - |
| *Dactylaria lakebarrinensis* Goh and K.D. Hyde | 1 | 20.00 | 1.67 | - | - | - |
| *Dactylaria* sp. 1 (SS270) | 1 | 20.00 | 1.67 | - | - | - |
| *Dactylaria* sp. 4 (SS560) | 3 | 46.67 | 11.67 | - | - | - |
| *Dactylaria* sp. 5 (SS593) | - | - | - | 1 | 60.00 | 5.00 |
| *Dendrosporium lobatum* Plakidas and Edgerton ex Crane | 1 | 20.00 | 1.67 | - | - | - |
| *Dictyochaeta gylosetula* Kuthub., Nawawi and G.M. Liew | - | - | - | 1 | 60.00 | 5.00 |
| ***Dictyochaeta* sp. 1** | 10 | 54.00 | 45.00 | 11 | 50.91 | 46.67 |
| *Dictyochaeta* sp. 2 | - | - | - | 1 | 20.00 | 1.67 |
| *Dictyochaeta* sp. 3 | 1 | 20.00 | 1.67 | - | - | - |
| ***Dinemasporium* sp. 1** (SS571) | 2 | 20.00 | 3.33 | 1 | 20.00 | 1.67 |
| **Discomycete sp. 7** (SS466) | 1 | 20.00 | 1.67 | 2 | 20.00 | 3.33 |
| *Elegantimyces siamensis* Sivichai, Hywel-Jones and Goh | 1 | 40.00 | 3.33 | - | - | - |
| ***Ellisembia brachypus*** (Ellis and Everh.) Subram. | 6 | 30.00 | 15.00 | 2 | 20.00 | 3.33 |
| ***Ellisembia opaca*** (Cooke and Harkn.) Subram. | 2 | 20.00 | 3.33 | 11 | 61.82 | 56.67 |
| *Ellisembia* sp. 1 (SS357) | - | - | - | 3 | 26.67 | 6.67 |
| *Ellisembia* sp. 2 (SS493) | - | - | - | 1 | 20.00 | 1.67 |
| ***Gonytrichum* sp. 1** | 1 | 20.00 | 1.67 | - | - | - |
| *Halosarpheia aquadulcis* S.Y. Hsieh, H.S. Chang and E.B.G. Jones | - | - | - | 1 | 20.00 | 1.67 |

**Table 4.** (continued).

| Fungi | *D. alatus* | | | *X. dolabriformis* | | |
|---|---|---|---|---|---|---|
| | # | Divide N* | Divide Y ♦ | # | Divide N* | Divide Y ♦ |
| *Helicoma* sp. 2 (SS424) | - | - | - | 1 | 20.00 | 1.67 |
| ***Helicomyces roseus*** Link | 12 | 81.67 | 81.67 | 11 | 63.64 | 58.33 |
| *Helicoon* sp. 1 | - | - | - | 1 | 20.00 | 1.67 |
| *Helicosporium griseum*-like | 6 | 30.00 | 15.00 | - | - | - |
| *Helicosporium* sp. 1 (SS559) | 1 | 20.00 | 1.67 | - | - | - |
| ***Helicosporium vegetum*-like** | 3 | 20.00 | 5.00 | 3 | 20.00 | 5.00 |
| *Helminthosporium* sp. 1(SS524) | - | - | - | 1 | 20.00 | 1.67 |
| *Jaculispora submersa* Hudson and Ingold | 1 | 40.00 | 3.33 | - | - | - |
| *Massarina bipolaris* K.D. Hyde | 1 | 40.00 | 3.33 | - | - | - |
| **Coelomycete sp. 1** | 9 | 60.00 | 45.00 | 3 | 33.33 | 8.33 |
| *Monodictys* sp. 1 | - | - | - | 1 | 20.00 | 1.67 |
| *Monotosporella setosa* var. *macrospora* S. Hughes | - | - | - | 1 | 20.00 | 1.67 |
| *Nectria chaetopsinae* Samuels | - | - | - | 1 | 20.00 | 1.67 |
| *Nectria chaetopsinae-polyblastia* Samuels | - | - | - | 2 | 30.00 | 5.00 |
| *Nectria* sp. 1 | - | - | - | 3 | 33.33 | 8.33 |
| ***Ophioceras dolichostomum*** (Berk. and Curt.) Sacc. | 9 | 37.78 | 28.33 | 2 | 20.00 | 3.33 |
| ***Phaeoisaria clemantidis*** (Fuckel) Hughes | 2 | 20.00 | 3.33 | 2 | 20.00 | 3.33 |
| ***Savoryella aquatica*** K. D. Hyde | 6 | 30.00 | 15.00 | 11 | 90.91 | 83.33 |
| *Scutisporus brunneus* Ando and Tubaki | - | - | - | 10 | 50.00 | 41.67 |
| ***Sporodesmium*-like sp. 1** | 1 | 20.00 | 1.67 | 10 | 52.00 | 43.33 |
| *Sporoschisma saccardoi* E. W. Mason and S. Hughes | 1 | 20.00 | 1.67 | - | - | - |
| ***Sporoschisma uniseptatum*** Bhat and W.B. Kendr. | 5 | 24.00 | 10.00 | 1 | 40.00 | 3.33 |
| Teleomorph of *Ellisembia brachypus* | 2 | 20.00 | 3.33 | - | - | - |
| **Teleomorph of coelomycete sp. 1** | 5 | 60.00 | 25.00 | 1 | 20.00 | 1.67 |
| ***Thozetella nivea*** (Berk. and F. Muell.) O. Kuntze | 7 | 22.86 | 13.33 | 6 | 26.67 | 13.33 |
| ***Trematosphaeria* sp. 2** | 8 | 95.00 | 63.33 | 1 | 80.00 | 6.67 |
| *Tubeufia cylindrothecia* (Seaver) Höhn. | 3 | 46.67 | 11.67 | - | - | - |
| Ascomycete sp. 4 (SS459) | - | - | - | 1 | 20.00 | 1.67 |

**Table 4.** (continued).

| Fungi | *D. alatus* | | | *X. dolabriformis* | | |
|---|---|---|---|---|---|---|
| | # | Divide N* | Divide Y ♦ | # | Divide N* | Divide Y ♦ |
| **Ascomycete sp. 11** (SS576) | 3 | 66.67 | 16.67 | 1 | 20.00 | 1.67 |
| Ascomycete sp. 25 (SS489) | 2 | 20.00 | 3.33 | - | - | - |
| **Ascomycete sp. 28** (SS574) | 2 | 40.00 | 6.67 | 1 | 20.00 | 1.67 |
| Ascomycete sp. 30 (SS606) | 1 | 20.00 | 1.67 | - | - | - |
| Hyphomycete sp. 5 (SS361) | 1 | 40.00 | 3.33 | - | - | - |
| Hyphomycete sp. 18 (SS605) | 1 | 20.00 | 1.67 | - | - | - |
| Hyphomycete sp. 7 (SS425) | - | - | - | 1 | 20.00 | 1.67 |
| Hyphomycete sp. 9 (SS447) | - | - | - | 2 | 70.00 | 11.67 |
| Hyphomycete sp. 13 (SS520) | - | - | - | 2 | 20.00 | 3.33 |
| Hyphomycete sp. 15 (SS547) | - | - | - | 1 | 20.00 | 1.67 |
| Hyphomycete sp. 19 | - | - | - | 1 | 20.00 | 1.67 |
| Hyphomycete sp. 20 | - | - | - | 1 | 20.00 | 1.67 |
| *Volutella* sp. | - | - | - | 2 | 40.00 | 6.67 |
| ***Wiesneriomyces javanicus*** Koorders | 2 | 30.00 | 5.00 | 3 | 33.33 | 8.33 |
| *Xylomyces chlamydosporis* Goos, R.D. Brooks and Lamore | 1 | 20.00 | 1.67 | - | - | - |
| ***Xylomyces elegans*** Goh, W.H. Ho, K.D. Hyde and K.M. Tsui | 4 | 20.00 | 6.67 | 2 | 20.00 | 3.33 |
| No. of species per 5 blocks | 13.42 | | | 16.5 | | |
| No. of species per block | 5.65 | | | 7.15 | | |
| Total no. species on each timber | 53 | | | 62 | | |
| %Similarity between two timbers | 29.21 | | | | | |
| Total no. species overall | 89 | | | | | |

**Table 5.** Percentage cover (after 3 months incubation) of the most common fungi on test blocks of *Dipterocarpus alatus* at km.29.2, Khao Yai National Park.

| Fungi | 1 Sep | 2 Oct | 3 Nov | 4 Dec | 5 Jan | 6 Feb | 7 Mar | 8 April | 9 May | 10 Jun | 11 Jul | 12 Aug | Divide N * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Trematosphaeria* sp. 2 | 83.55 | 100 | 100 | 100 | 35.55 | 68.88 | 21.11 | 9.11 | - | - | - | - | 64.78 |
| Ascomycete sp. 11 (SS576) | - | - | - | - | - | - | - | - | - | 13.33 | 20.22 | 50.22 | 27.92 |
| *Helicomyces roseus* Link | 39.33 | 34.66 | 4.66 | 16.88 | 18.22 | 6.44 | 3.77 | 33.77 | 19.77 | 4.22 | 18 | 2.66 | 16.87 |
| *Anthostomella aquatica* K.D. Hyde and Goh | - | - | - | - | - | - | - | - | - | 21.77 | - | 9.77 | 15.77 |
| Coelomycete sp. 1 | - | - | 1.77 | - | 1.11 | 3.55 | 1.55 | 4.66 | 13.33 | 9.77 | 43.11 | 26.22 | 11.67 |
| *Dactylaria* sp. 4 (SS560) | - | - | - | - | - | - | - | - | 3.55 | - | 3.33 | 15.77 | 7.55 |
| *Ellisembia brachypus* (Ellis and Everh.) Subram. | 2.66 | - | 12.22 | 0.44 | 0.88 | 9.77 | - | 1.33 | - | - | - | - | 4.55 |
| Conidia in pycnidia sp. 1 | - | - | 4.44 | 0.44 | 1.55 | - | - | 2 | - | 7.33 | 10.22 | - | 4.33 |
| Teleomorph of coelomycete sp. 1 | - | - | - | - | - | - | 0.44 | - | 5.11 | 0.66 | 12 | 1.77 | 4.00 |
| *Dictyochaeta* sp. 1 | 3.33 | 5.33 | 1.55 | 5.55 | 2.89 | 2.44 | - | 1.55 | 3.33 | 0.22 | 0.44 | - | 2.66 |
| *Savoryella aquatica* K.D. Hyde | - | 1.55 | - | - | - | - | 0.22 | - | 4.22 | 1.11 | 1.11 | 1.11 | 1.55 |
| *Bombardia* sp. | 0.22 | 0.44 | - | - | 1.33 | 1.11 | 1.11 | 1.77 | 3.77 | 1.55 | - | 2.44 | 1.53 |
| *Tubeufia* sp. 1 (SS440) | 0.66 | - | - | - | - | - | - | 1.11 | 2.66 | - | - | - | 1.48 |
| *Helicosporium griseum*-like | 1.33 | 2.66 | 0.44 | 1.55 | - | 0.44 | - | 1.33 | - | - | - | - | 1.29 |
| *Sporischisma uniseptatum* Bhat and W.B. Kendr. | - | - | 0.66 | 0.44 | 3.77 | 0.66 | - | - | - | 0.44 | - | - | 1.19 |
| *Ophioceras dolichostomum* (Berk. and Curt.) Sacc. | - | - | - | 1.11 | 1.33 | 1.33 | 0.66 | 0.44 | 1.77 | 0.44 | 1.33 | 2.22 | 1.18 |
| *Thozetella nivea* (Berk. and F. Muell.) O. Kuntze | - | - | 0.44 | 1.11 | 0.22 | 0.66 | 0.44 | - | - | 0.22 | 2 | - | 0.73 |

* = Percent frequency of fungi present divided by number of months with fungi present.

**Table 6.** Percentage cover (after 3 months incubation) of the most common fungi on test blocks of *Xylia dolabriformis* at km.29.2, Khao Yai National Park.

| Fungi | 1 Sep | 2 Oct | 3 Nov | 4 Dec | 5 Jan | 6 Feb | 7 Mar | 8 April | 9 May | 10 Jun | 11 Jul | 12 Aug | Divide N * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Savoryella aquatica* K.D. Hyde | - | 2.22 | 58.66 | 57.33 | 61.77 | 73.33 | 48.88 | 72.66 | 47.77 | 92.44 | 71.55 | 98.22 | 62.26 |
| *Biflagellospora gracilis* Sivichai and Hywel-Jones | - | - | 2 | 18.89 | 10.89 | 22 | 7.56 | 4.89 | 1.56 | - | - | - | 9.68 |
| *Helicomyces roseus* Link | - | 3.33 | 2.67 | 0.67 | 33.55 | 6 | 11.33 | 8.89 | 18 | 3.56 | 2.44 | 4.22 | 8.61 |
| *Scutisporus brunneus* Ando and Tubaki | - | - | 6.22 | 20 | 1.11 | 9.56 | 5.56 | 2.89 | 3.78 | 2.89 | 5.78 | 4 | 6.18 |
| *Dictyochaeta* sp. 1 | 0.44 | - | 0.89 | 1.11 | 8.2 | 11.33 | 1.56 | 16 | 4.89 | 0.44 | 2 | 0.67 | 4.32 |
| *Ellisembia opaca* (Cooke and Harkn.) Subram. | - | 0.44 | 0.67 | 1.11 | 2.67 | 1.33 | 1.33 | 6.89 | 11.56 | 8 | 3.78 | 7.78 | 4.14 |
| *Biflagellospora papillata* Sivichai and Hywel-Jones | - | - | - | - | 3.33 | 0.67 | 1.78 | 1.78 | 8.44 | 5.78 | 9.56 | 0.67 | 4.00 |
| *Biflagellospora siamensis* Sivichai and Hywel-Jones | - | 1.56 | 10.89 | 5.56 | 2 | 5.33 | 1.11 | 1.11 | - | - | - | - | 3.94 |
| *Sporidesmium*-like sp. 1 (SS419) | - | - | 2.89 | 1.56 | 1.56 | 4.67 | 0.44 | 0.67 | 0.44 | 2.67 | 6.89 | 8.22 | 3.00 |
| Hyphomycete sp. 9 (SS 447) | - | - | - | 3.78 | 1.33 | - | - | - | - | - | - | - | 2.56 |
| *Chaetopsina polyblastiae* Samuels | - | - | - | - | - | 1.56 | - | 2.22 | 3.11 | - | - | - | 2.30 |
| *Canalisporium pulchrum* (Hol.-Jech. and Mercado) Nawawi and Kuthub. | - | 3.11 | 1.56 | - | - | 0.44 | - | 1.11 | 4 | 1.78 | 4 | 0.88 | 2.11 |
| *Chaetopsina fluva* Rambelli | - | - | - | 3.11 | 2.67 | 0.89 | - | - | 0.67 | - | - | - | 1.84 |
| *Berkleasmium* sp. 1 | - | - | 0.44 | 1.78 | - | - | - | - | 3.78 | - | 0.67 | - | 1.67 |
| *Canalisporium elegans* Nawawi and Kuthub. | - | 0.44 | 0.44 | - | 1.78 | 0.44 | - | 2.44 | 2 | 2.22 | 1.56 | 1.11 | 1.38 |
| *Thozetella nivea* (Berk. and F. Muell.) O. Kuntze | - | - | - | - | 0.89 | 2.22 | 0.22 | 1.56 | 1.78 | - | 0.22 | - | 1.15 |
| *Acrogenospora sphaerocephala* (Berk. and Br.) Ellis | - | - | - | - | 0.22 | 1.11 | 0.67 | 0.67 | 3.11 | - | 0.22 | - | 1.00 |

* = Percent frequency of fungi present divided by number of months with fungi present.

**Table 7.** Comparison of the dominant fungi colonising wood test blocks in four selected studies.

| Khao Yai, km 29.2 | | Hong Kong (Ho, 1998) | | United Kingdom, River Severn (Kane and Jones, unpublished) | | United Kingdom, River Dee (Eaton and Jones, 1971a) | |
|---|---|---|---|---|---|---|---|
| ***Dipterocarpus alatus* 53 species** | | ***Machilus velutina* 59 species** | | ***Fagus sylvatica* 41 species** | | ***Fagus sylvatica* 34 species** | |
| *Trematosphaeria* sp. 2 | 95* | *Savoryella lignicola* | 13.1 | *Camposporium pellucidum* | 95 | *Clasterosporium caricinum* | 11 |
| *Helicomyces roseus* | 81 | *Aniptodera chesapeakensis* | 12.3 | *Codinaea parva* | 85 | *Helicoon sessile* | 10 |
| Ascomycete sp. 11 | 66 | *Sporoschisma nigroseptatum* | 10 | *Pseudohalonectria lignicola* | 85 | *Trematsphaeria pertusa* | 8 |
| Coelomycete sp. 1 | 60 | *Spirosphaera floriformis* | 7.1 | *Trichocladium lignicola* | 80 | *Monodictys putredinis* | 6 |
| Teleomorph of coelomycete sp. 1 | 60 | *Aquaticola rhomboida* | 5.7 | *Fusarium* sp. | 65 | *Tricladium splendens* | 6 |
| *Dictyochaeta* sp. 1 | 54 | *Dictyosporium elegans* | 5.6 | *Ophioceras dolichostomum* | 60 | *Ceratosphaeria lampadophora* | 6 |
| *Ophioceras dolichostomum* | 37 | *Massarina ingoldiana* | 3.4 | *Trematosphaeria pertusa* | 35 | | |
| *Bombardia* sp. | 33 | | | | | | |
| ***Xylia dolabroformis* 62 species** | | ***Pinus massoniana* 60 species** | | ***Pinus sylvestris* 28 species** | | ***Pinus sylvestris* 20 species** | |
| *Savoryella aquatica* | 90 | *Massarina ingoldiana* | 9.6 | *Trichocladium lignicola* | 95 | *Monodictys putredinis* | 10 |
| *Helicomyces roseus* | 63 | *Sporoschisma nigroseptatum* | 9.5 | *Fusarium* sp. | 95 | *Sterigmatobotrys macrocarpa* | 7 |
| *Ellisembia opaca* | 62 | *Spirosphaera floriformis* | 9.5 | *Heliscus lugdunensis* | 35 | *Tricladium alpollonellum* | 2 |
| *Biflagellospora siamensis* | 54 | *Aniptodera chesapeakensis* | 7.8 | *Codinaea parva* | 30 | *Heliscus lugdunensis* | 2 |
| *Biflagellospora gracilis* | 54 | *Massarina bipolaris* | 6.6 | *Alatospora acuminata* | 20 | *Septonema* sp. | 2 |
| *Sporodesmium* sp.-like | 52 | *Aquaticola rhomboida* | 6.6 | *Trichocladium alopallonellum* | 20 | | |
| *Dictyochaeta* sp. 1 | 51 | *Dictyosporium elegans* | 6.1 | *Camposporium pellucidum* | 20 | | |
| *Scutisporus brunneus* | 50 | | | | | | |
| Total species on both timbers: 89 | | Total species on both timbers: 80 | | Total species on both timbers: 60 | | Total species on both timbers: 43 | |

* percentage frequency of occurrence.

*Xylia dolabriformis*. There was little change in the total number of species on the test blocks over different seasons, although numbers did peak on both timbers in the April-May retrievals. However, only 7 out of 53 species occurred on more than 20% on *Dipterocarpus alatus* samples and 11 (with only 4 common to the other timber) out of 62 on *Xylia dolabriformis* samples.

*Helicomyces roseus* and *Trematosphaeria* sp. 2 were present on *Dipterocarpus alatus* at an average frequency of more than 50% throughout the year (Table 2). *Savoryella aquatica*, *Helicomyces roseus* and *Ellisembia opaca* were present on *Xylia dolabriformis* at an average frequency of occurrence of greater than 50% through out the year (Table 3). Of the 89 fungi recorded on the timbers, only 29% were common to both (Table 4). Thus each timber supported a different mycota. This is illustrated with respect to the dominant fungi where only *Helicomyes roseus* was dominant on the two timbers (Tables 2 and 3).

Data on the percentage cover of each fungus on the timbers is presented in Tables 5 and 6. *Trematosphaeria* sp. 2 and *Helicomyes roseus* were not only present on most of the test blocks of *Dipterocarpus alatus*, (Table 2), but the percentage cover on each block was also high (65 and 17% respectively). Ascomycete sp. 11 however, had a high percentage cover on test blocks late in the colonisation period and was present on 67% of the test blocks in months 10-12. *Savoryella aquatica* had the greatest percentage cover on the test blocks of *Xylia dolabriformis* (62%) and was present on 91% of the test blocks. Thus there was good correlation between the frequency of occurrence of fungi on the wood and percentage cover on each test block.

More fungi colonised *Dipterocarpus alatus* than *Xylia dolabriformis* after 4 weeks, with 4.2 and 1 taxa per test block respectively and with an average of 10 and 2 fungi per 5 test blocks. The number of fungi colonising the test blocks were high, 10-23 per 5 blocks (average per test block 3.4-11) on *Dipterocarpus alatus*, and 2-25 per 5 blocks (average 1-9.8 per test block) on *Xylia dolabriformis* (Tables 2, 3).

Fungi colonising test blocks were arbitrarily categorised into 4 groups: (i) Early colonisers which dominated the earlier months and were often present through out the exposure period; (ii) Intermediates were those appearing after 3-4 months exposure; (iii) Late, those appearing months 8-9; and (iv) Transients, those that occurred sporadically and at a low frequency of occurrence.

The low-density timber, *Dipterocarpus alatus*, was colonised by 10 taxa within the first month (Table 2). Of these, *Helicomyces roseus*, *Trematosphaeria* sp. 2, and *Dictyochaeta* sp. 1 were found at a high percentage frequency (≥60%). *Helicomyces roseus* was present at a high level throughout

the twelve months of exposure. *Dictyochaeta* sp. 1 was present throughout the exposure period, but at a decreasing frequency. In contrast, *Trematosphaeria* sp. 2 was present at 100% frequency for the first seven months before decreasing abruptly to 0% after month 9 (Table 2). Coelomycete sp. 1 and *Ophioceras dolichostomum* appeared on the wood after 3 and 4 months respectively and are termed intermediate colonisers, while ascomycete sp. 11 and *Anthostomella aquatica* were late colonisers (Table 2).

The early colonisers on *Xylia dolabriformis* were *Savoryella aquatica*, *Helicomyces roseus*, *Ellesmbia opaca* and slightly later *Sporidesmium*-like sp. 1 and *Scutisporus brunneus*, which persisted thoughout the exposure period. *Biflagellospora siamensis* was also an early coloniser, but was absent from month 10 onwards. Intermediate colonisers included *Biflagellospora gracilis*, *B. papillata* and *Thozetella nivea*, while *Canalisporium pulchrum* and *C. elegans* were more abundant during the latter exposure period (Table 3).

**Discussion**

Species diversity was high on both test blocks, although higher on *Xylia dolabriformis* (62), with 89 species occurring on both timbers. This is in marked contrast to some previous studies: 19 hyphomycetes on oak wood (Sanders and Anderson, 1979), 33 ascomycetes on various baits (Shearer and Bodman, 1983), 59 species on natural and wood baits (Lamore and Goos, 1978) and 40 taxa on various baits (Willoughby and Archer, 1973). However, Gönczöl and Révay (1993) reported 77 fungi on 3 different baits, while Kane (1980) recorded 61 species on two timbers and Ho (1998) collected 178 fungi on natural and two timber baits. Thus species diversity can vary greatly from location to location, and the intensity of the sampling procedure adopted. There is no clear evidence that species diversity is affected by geographical location. However, detailed comparison is difficult due to the different timbers and dimensions of the test blocks used and the variation in sampling time.

The average number of fungal species on the test blocks in the present study was remarkably high: number of species per 5 blocks were 13.4 and 16.5 on *Dipterocarpus alatus* and *Xylia dolabriformis* respectively and 5.6 and 7.1 per timber. Ho (1998) reported 150 species from a total 150 samples on natural submerged, 50 samples of each from Brunei, Hong Kong and Malaysia with an average species occurrence per sample 2.9, 2.9 and 0.7 respectively, while the average number of fungal taxa occurring on baits, *Machilus velutina* and *Pinus massoniana* were 4.3 and 3.8, which was higher than on natural wood. Hyde and Goh (1997) have presented results for aquatic fungi on natural wood submerged at Mt Lewis in north Queensland Australia with a low average of 0.9 species per sample, while Hyde and Goh (1998) reported 1.4 species per

sample from another study at Lake Barrine. Hyde *et al.* (1998) also reported on the species diversity of freshwater fungi from the Palmiet River, Durban, South Africa with an average of 1.7 species per sample.

Fungi colonising woody substrata in the marine environment are largely ascomycetes with few mitosporic fungi (53 ascomycetes/13 mitosporic: Brunei (Hyde, 1989), 82/15 Malaysia (Alias *et al.*, 1995) and 34/11 Denmark (Peterson and Koch, 1997). In the present study however, the mycota on both timbers was dominated by mitosporic fungi 48/14 on *Xylia dolabriformis*, and 36/15 on *Dipterocarpus alatus*. This trend is reflected in the studies of other worker freshwater habitats: 15 ascomycetes/36 mitosporic (Lamore and Goos, 1978), 15/44 (Kane, 1980), 16/43 on *Machilus velutina* and 11/49 on *Pinus massoniana* (Ho, 1998), and 11/23 on *Fagus sylvatica* and 4/16 on *Pinus sylvestris* (Eaton and Jones, 1971a).

A comparison of the fungi colonising different timbers indicates little overlap in species composition of the population. Table 7 lists the dominant fungi on various timbers in 4 studies. While there is some overlap in dominant species colonising *Machilus velutina* and *Pinus massoniana* in Hong Kong (Ho, 1998) (*Anitptodera chesapeakensis*, *Aquaticola rhomboida*, *Dictyosporium elegans*, *Savoryella lignicola*, *Spirosphaera floriformis*, *Sporoschisma nigroseptatum*), there is no such trend in the mycota of the Thai study with only *Helicomyces roseus* common to the two timbers. Furthermore, there is no overlap between the dominant fungi recorded in the Thai study with those in the Hong Kong investigation. Similarly, there is no correlation between the fungi noted by Ho (1998), the present study and those recorded by Kane (1980) on *Fagus sylvatica* and *Pinus sylvestris* test blocks in the River Severn, U.K. However, there was an overlap between the common fungi on *Fagus sylvatica* and *Pinus sylvestris* in the River Severn (Kane and Jones, unpublished) (*Codinaea parva*, *Trichocladium lignicola*, *Fusarium* sp.). Fungi colonising *Fagus sylvatica* and *Pinus sylvestris* test block in the River Dee (Eaton and Jones, 1971) were different from those on the same timbers in the River Severn. Dominant species were: *Monodictys putredinis* (on both timbers), *Ceratosphaeria lampadophora*, *Clasterosporium caricinum*, *Helicoon sessile*, *Trematosphaeria petrusa* and *Tricladium splendens* on *Fagus sylvatica* and *Sterigmatobitrys macrocarpa* on *Pinus sylvestris*. The latter timber supports fewer fungi (34) than the beech wood (20). However, there was no overlap in the fungi dominant on the timber in Rivers Severn and Dee. Fungi colonising the wood in the U.K. study (Eaton and Jones, 1971; Kane and Jones, unpublished) were distinctly different from the tropical species recorded in the studies of Ho (1998) and the present study.

High and low density timbers were selected in this study in order to

compare species diversity and colonisation sequence. More fungi were collected on the high density wood (*Xylia dolabriformis*: 62 species) than on low density timber (*Dipterocarpus alatus*: 53 species). In the studies of Eaton and Jones (1971) and Kane and Jones (unpublished) more species colonised *Fagus sylvatica* test blocks than *Pinus sylvatica* 34/20; 41/28. Ho (1998) however, reported similar number of species on *Machilus velutina* as on *Pinus massoniana*.

This study has demonstrated that lignocellulosic material submerged in a tropical stream is colonised by rich diversity of fungi. Dominant species colonising *Dipterocarpus alatus* were significantly different from those in temperate habitats (Eaton and Jones, 1971) and those reported for a subtropical stream in Hong Kong (Ho, 1998).

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