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AQUATIC HYPHOMYCETE COMMUNITIES IN CLEAR-CUT AND WOODED AREAS OF AN ILLINOIS STREAM

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ABSTRACT

Aquatic hyphomycete communities in wooded and clear-cut areas of Jordan Creek, Vermilion County, Illinois, were compared using leaf pack baits and membrane filtration of stream water. Number of species per unit substrate, species richness, diversity (H'), number of conidia per liter of stream water, and degree of colonization of substrate were all greater in wooded areas and adjacent downstream clear-cut sites than in an up-stream clear-cut site. Wooded patches on clear-cut streams could serve to maintain diversity and inoculum levels of aquatic fungal decomposer communities.

INTRODUCTION

Ingold, in a series of papers initiated in 1942 (Ingold, 1942), described a number of fungi with tetraradiate and sigmoid conidia found in foam and on submerged leaves and twigs in streams in England. A few of these fungi, now generally referred to as the freshwater aquatic hyphomycetes, had been described earlier by de Wildeman (1893, 1894, 1895), Kegel (1906) and Karling (1935). In recent years, many additional species have been described and much information on the taxonomy and geographical distribution of these fungi has accrued (Webster and Descals, 1981). A common substratum for aquatic hyphomycetes in streams is deciduous leaves of riparian origin (Nilsson, 1964; Ingold, 1975; Webster and Descals, 1981).

Leaves of riparian origin comprise a large portion of the total fixed carbon available in streams to heterotrophic organisms at successive trophic levels (Cummins, 1974). Aquatic hyphomycetes play an important role in increasing the palatability and nutritional quality of deciduous leaves for invertebrate grazers (Bärlocher and Kendrick, 1973a and b, 1975), while at the same time enzymatically degrading the leaves (Suberkropp et al., 1983; Chamier and Dixon, 1982). The role of aquatic hyphomycetes is especially important because many aquatic invertebrate grazers which are unable to digest cellulose and lignin are able to use fungal biomass generated by leaf-decomposing fungi.

Although some work has been done on the enzymatic activities of aquatic hyphomycetes (Hewings and Shearer, 1981; Chamier and Dixon, 1982; Suberkropp et al., 1983; Chamier, 1985) and their suitability as a food resource to invertebrates (Bärlocher and Kendrick, 1973a and b), little is known about the factors which regulate the structure of their communities. Environmental factors known thus far to affect aquatic hyphomycete community structure are: seasonality (Nilsson, 1964; Iqbal and Webster, 1973b, 1977; Bärlocher and Rosset, 1981; Shearer and Webster, 1985); pH (Suzuki and Nimura, 1961; Wood-Eggenschwiler and Bärlocher, 1983); temperature (Suberkropp, 1984); and quality of riparian vegetation (Iqbal and Webster, 1977; Bärlocher and Rosset, 1981).

A number of streams and creeks in midwestern agricultural areas have been channelized and have had their riparian vegetation removed (clear-cutting) to facilitate drainage. There has been no effort thus far to investigate the effects of removal of riparian woodland vegetation on aquatic hyphomycete community structure. Jordan Creek, which originates in croplands in Vermilion County, Illinois, is clear-cut at its origin but has subsequent patches of riparian woodland alternating with additional clear-cut areas. This stream afforded the opportunity to investigate the effects of absence of riparian woodland vegetation on leaf-colonizing aquatic hyphomycete communities.

MATERIALS AND METHODS

Description of Study Site

A portion of Jordan Creek near Fairmount, Illinois, with alternately clear-cut and wooded areas was selected for study. The first sampling site was located in the clear-cut portion of the stream above the first wooded area of the stream. The second sampling site was located at the beginning of the first wooded area and sites three through six were within the first wooded area. The seventh and eighth sites were located in the second clear-cut area. During the second filtration experiment, two more stations were added, the ninth within the second clear-cut area and the tenth at the beginning of the second wooded area. The distance between each station was approximately one-quarter mile.

Physical and Chemical Parameters

Physical and chemical parameters measured were: temperature, pH, dissolved oxygen, carbon dioxide, and alkalinity bicarbonates. All parameters were determined with standard techniques (Lind, 1979). Temperature and carbon dioxide were measured in the field. Dissolved oxygen was fixed in the field and samples returned to the laboratory in a cooler for titration. Separate samples were taken in plastic containers and returned to the laboratory in a cooler for determination of pH (Corning pH Meter Model 7) and alkalinity (titration with 0.02 N H_2SO_4).

Aquatic Hyphomycete Community Structure

Submerged plant debris was collected and examined with the compound microscope for aquatic hyphomycete species which were identified. To sample conidia of aquatic hyphomycetes in water, two 500 ml Buchner flasks equipped with 250 ml plastic millipore filtration funnels containing membrane filters of 0.45 um pore size were connected together with a rubber tube (0.5 cm diam.) to a common pressure resistant, rubber tube of the same diameter. A three-way plastic valve was placed at the end of the rubber tube and fitted to a 65 ml syringe, which was used to create a vacuum. Six 250 ml water samples collected with a bucket were filtered directly in the field at each sampling site. Conidia on membrane filters were fixed and stained with cotton blue in lactic acid and quantified according to the procedures of Shearer and Lane (1983).

Leaves of oak (*Quercus macrocarpa* Michx.), collected in November, 1982, from a single tree on the campus of the University of Illinois, were soaked briefly in distilled water, stacked in packs of five, and sewn together by passing nylon fishing line through their centers several times. Packs were tied to bricks (three packs per brick). Three bricks were placed at each station, about 30-50 cm below the water surface on December 7, 1982. Six weeks later, on January 21, 1983, leaf packs were removed from each brick, placed in plastic bags and returned in a cooler to the laboratory, where they were separated and washed in distilled water. Ten leaf disks were cut from each leaf with a paper hole punch, and incubated for 48 hours in Petri dishes with sterilized distilled water at 7 C (stream temperature at time of sample collection). Oak leaves were selected because they are processed fairly slowly (Petersen and Cummins, 1974), and therefore allow the establishment of a fungal community without rapid disintegration of the substratum. Leaf disks were fixed in lactic acid with cotton blue and examined microscopically for loose and developing conidia of aquatic hyphomycetes. Fungi on disks were quantified and colonization estimated subjectively according to the techniques of Shearer and Lane (1983). Quantitative data on occurrences of fungi are reported in two categories: (1) only fungi whose conidia are attached to conidiophores attached to the leaf, and (2) attached conidia as in (1) and loose conidia. The first category reflects those individuals actually growing on the leaf disk and the second category reflects those that are growing on the leaf disk and those that may have been produced on the examined leaf and/or those produced on other leaves and trapped by the examined leaf. Data in the first category will be presented first and without parentheses and data in category 2 will be presented second and within parentheses throughout the paper.

RESULTS

Physical and Chemical Measurements

Physical and chemical measurements are presented in Figure 1. Temperatures ranged from 6 to 8 C, with generally higher temperatures within the wooded area; pH ranged from 6.8 to 7.4, with the lowest pH in the wooded area (Fig. 1A). Alkalinity ranged from 182-240 mg/l and was lower in the wooded area (Fig. 1B). Dissolved oxygen ranged from 11.2 to 12.3 mg/l and was lower in the wooded area (Fig. 1C), while carbon dioxide ranged from 3.7 to 7.0 mg/l with the greatest concentration occurring at the end of the wooded area (Fig. 1D).

Aquatic Hyphomycete Community Analysis

The mean number of conidia per liter increased greatly within the wooded area of the stream and then decreased in the following clear-cut area (Fig. 2A). Differences in conidial numbers between clear-cut and wooded areas were not as great in the March sample (Fig. 2B), but still followed the same general pattern evident in November. In March, samples were taken in a second downstream wooded area (Site 10), and conidial numbers increased as they did in the first wooded area (Fig. 2B).

The mean degree of colonization of leaf disks by aquatic hyphomycetes increased within the wooded area and decreased in the second clear-cut area (Fig. 2C). The mean number of species per disk (Table 1) and per leaf (Table 2) was also greater in wooded than in clear-cut areas. Relative importance values for each species at each site are presented in Table 3 and Shannon and Weaver diversity indices (H') calculated from these data were higher in the wooded than in clear-cut areas (Table 3). More species were detected with leaf pack baits than with membrane filtration and examination of natural substrata (Table 4).

DISCUSSION

The finding that more conidia per liter of aquatic hyphomycete species were found in wooded than clear-cut areas of the same stream suggests that quantity of substrata strongly affects the size of populations of these fungi. In support of this hypothesis is the decrease in number of conidia per liter in the wooded area in March, when amount of deciduous leaf litter is naturally low. Similar seasonal declines in number of conidia per liter have been observed by Iqbal (1973) and Shearer and Webster (1985b).

The greater number of species per leaf and per unit area of leaf (disk) and the higher degree of colonization of leaf disks from oak leaf packs in the wooded area compared to the clear-cut areas probably resulted from the higher inoculum levels present in the wooded area. The greater the number of conidia per liter, the greater the probability for colonization to occur. The same trends were observed for naturally non-wooded and wooded areas of a river in England (Shearer and Webster, 1985a). In the English river, lower number of species per leaf and disk and lower degree of colonization were also linked to lower inoculum levels resulting from the small quantity of substrata and low pH. In Jordan Creek, the greatest difference in pH between any wooded and clear-cut site was approximately ½ unit. Since pH fluctuated around pH 7 and differences between sites were small, pH probably was not responsible for differences between clear-cut and wooded areas and quantity of substrata is probably the most important factor.

Lower temperatures (2 C) in the clear-cut area may have reduced sporulation of some aquatic hyphomycetes. Generally, however, most autumn species of temperate aquatic hyphomycetes grow and sporulate at low temperatures (Webster and Descals, 1981). As a result of greater photosynthesis in clear-cut areas due to the release of light limitation from riparian trees, oxygen levels are higher in clear-cut areas during the day. In addition, during the fall, leaf litter added to the stream in the wooded area is colonized by microorganisms which use oxygen and produce CO_2. Thus during the day, at the time of leaf fall, clear-cut areas of Jordan Creek are higher in oxygen and lower in CO_2 than wooded areas. It is commonly thought that aquatic hyphomycetes are more common in well-aerated streams (Ingold, 1975), but in Jordan Creek, populations of aquatic hyphomycetes are greater in wooded areas with relatively less dissolved oxygen and more CO_2 than in clear-cut areas. It is possible that dissolved oxygen and CO_2 did not reach levels limiting growth and sporulation of aquatic hyphomycetes and the presence of abundant substrata masked any negative effects of low O_2/CO_2 ratios in the wooded area. Further experimental work is needed to determine the effect(s) of dissolved gases on growth and sporulation of aquatic hyphomycetes.

Distinct differences in species composition between wooded and clear-cut areas did not occur, rather the community in the wooded area was richer than in the clear-cut area by four species (*Tricladium angulatum, Alatospora constricta, Lemonniera pseudofloscula* and *L. aquatica*) (Table 4). This contrasts sharply with the distinct species compositional differences between wooded and unwooded areas which occurred in the River Teign in England (Shearer and Webster, 1985a). Differences in the River Teign were attributed to differences in pH and substrata. Since pH can probably be ruled out as a factor in Jordan Creek, quality and/or quantity of substrata may be responsible for differences in species composition and numbers. H' diversity also was greater in the wooded than clear-cut areas, not only because of the addition of new species but also because of the greater equity with which frequencies of occurrence were distributed among species (Table 3).

The overall low number of species of aquatic hyphomycetes found in Jordan Creek contrasts sharply with higher numbers of species found in other streams studied (Barlocher and Rosset, 1981; Iqbal and Webster, 1973b, 1977; Shearer and Webster, 1985a). This suggests that the overall effect of stream channelization and clear-cutting may be harmful to aquatic hyphomycete communities. Since no permanent headwater streams that are not unchannelized and clear-cut exist in this region of East-Central Illinois, we have no idea what species may have comprised aquatic hyphomycete communities prior to land modification for agriculture and drainage. The range and mean number of species per disk and per leaf is lower than that found on sixty randomly sampled leaves in the Sangamon River, Illinois, a river also located in East Central Illinois. All of the species found in Jordan Creek also occur in the Sangamon River (Shearer, Unpubl. data).

Clearly, species diversity, H' diversity, numbers of species per unit resource and species activity (as measured by degree of colonization) were all higher in wooded than in clear-cut areas of Jordan Creek. Establishment of wooded patches on clear-cut streams should be considered as a management option that would improve the biological integrity of agrarian streams. Not only would decomposer fungal diversity and inoculum levels be increased, but leaves and woody debris would serve as a carbon source and habitat for stream heterotrophs other than fungi.

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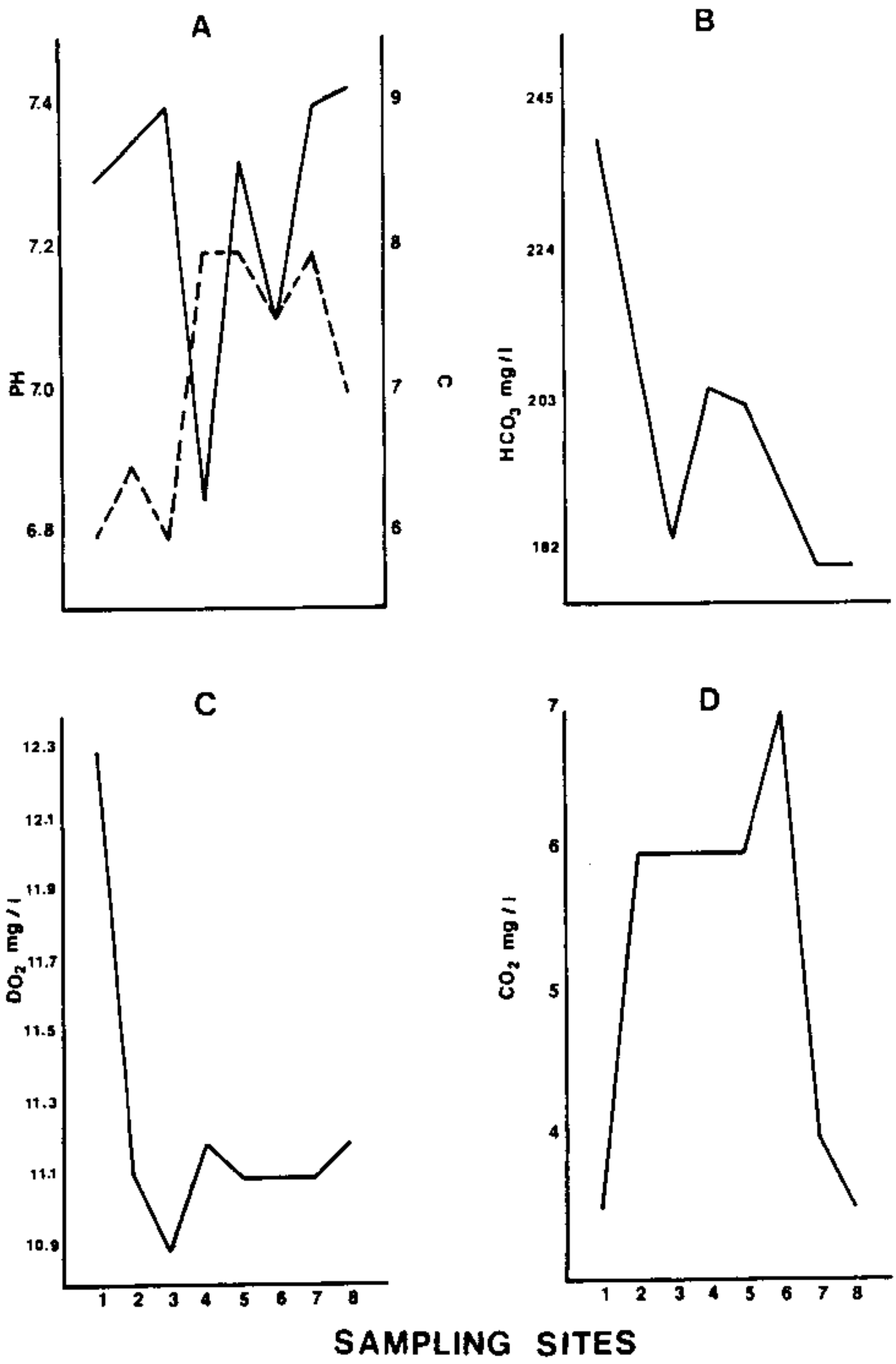

Figure 1. Physical and chemical water-quality measurements at stations 1-8, November 17, 1982: A. temperature (C) (------) and pH (——); B. alkalinity (HCO_3 in mg/l); C. dissolved oxygen (mg/l); and D. carbon dioxide (mg/l).

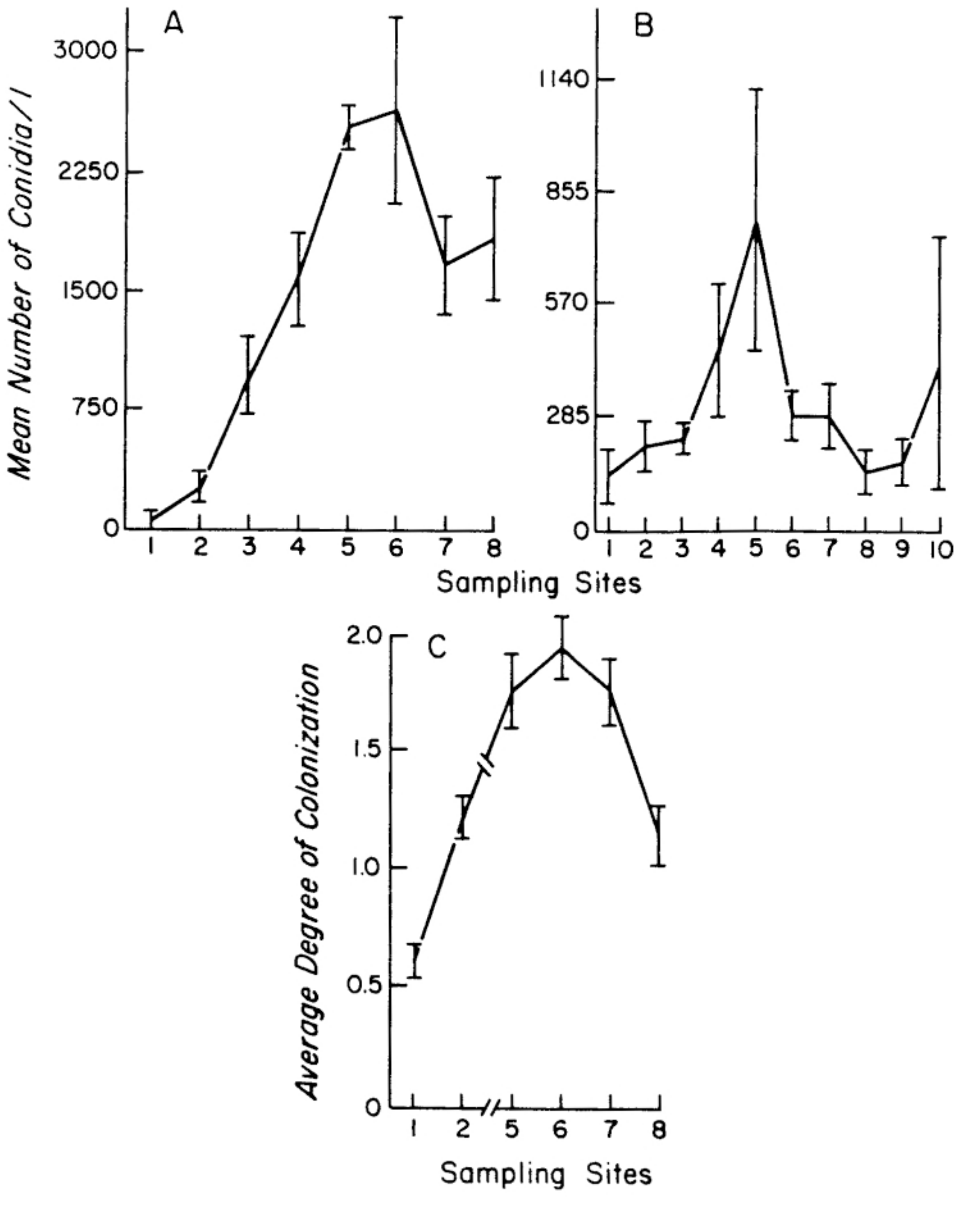

Figure 2. A, B. Mean number of conidia of aquatic hyphomycetes per liter of stream water at each sampling site. (Mean of six 250 ml samples at each sampling site ±95% confidence interval). A. November 17, 1982. B. March 4, 1983. C. Average degree of colonization of leaf disks, subjectively ranked on a scale of 0-5. (Mean of 200 disks/station ±95% confidence interval).

Table 1. The mean number of aquatic hyphomycete species on oak leaf disks from leaf packs submerged from December 7, 1982 to January 21, 1983.

Sampling Site	No. of Disks Colonized n = 200	Mean No. of Species/Disk	
		All Disks	Only Colonized Disks
1	123(191)	1.04 ±0.14 (2.39 ±0.13)	1.69 ±0.10 (2.50 ±0.11)
2	177(199)	0.79 ±0.16 (3.42 ±0.13)	2.03 ±0.14 (3.44 ±0.13)
5	182(193)	1.64 ±0.13 (2.74 ±0.13)	1.80 ±0.12 (2.84 ±0.11)
6	199(200)	2.05 ±0.14 (2.66 ±0.14)	2.06 ±0.14 (2.66 ±0.14)
7	185(190)	1.60 ±0.13 (1.99 ±0.15)	1.71 ±0.12 (2.07 ±0.14)
8	149(189)	1.41 ±0.16 (2.27 ±0.14)	1.89 ±0.13 (2.40 ±0.12)

Table 2. The mean and range in number of aquatic hyphomycete species on oak leaves from packs submerged from December 7, 1982 to January 21, 1983.

Sampling Site	Minimum, Mean and Maximum Number of Species/Leaf	
1	1- 2.75 ±0.34 -4	(1- 3.30 ±0.31 -4)
2	3- 4.25 ±0.43 -6	(4- 5.45 ±0.47 -8)
5	2- 3.45 ±0.42 -5	(2- 4.20 ±0.45 -6)
6	3- 4.25 ±0.45 -7	(3- 4.70 ±0.49 -7)
7	1- 3.45 ±0.56 -5	(2- 4.15 ±0.51 -6)
8	2- 3.10 ±0.40 -5	(3- 3.30 ±0.31 -5)

Table 3. Relative importance values (RIV)* for individual species on leaves in leaf packs and Shannon-Weaver index of diversity (H')** at each sampling site

Species	Sampling Sites					
	1	2	5	6	7	8
Clavariopsis aquatica	0.801 (0.694)	0.558 (0.466)	0.516 (0.581)	0.380 (0.394)	0.480 (0.511)	0.678 (0.662)
Filosporella annelidica	0.645 (0.635)	0.522 (0.460)	0.753 (0.561)	0.546 (0.481)	0.715 (0.594)	0.680 (0.618)
Tetracladium marchalianum	0.484 (0.524)	0.395 (0.401)	0.420 (0.453)	0.373 (0.429)	0.304 (0.365)	0.454 (0.486)
Alatospora acuminata	0.045 (0.045)	0.100 (0.123)	0.017 (0.027)	0.042 (0.041)	0.044 (0.070)	— —
A. constricta	— —	0.109 (0.183)	0.058 (0.150)	0.117 (0.123)	0.086 (0.095)	0.132 (0.174)
Tricladium terrestre	0.022 (0.022)	0.208 (0.195)	0.129 (0.100)	0.154 (0.138)	0.129 (0.126)	0.030 (0.022)
T. angulatum	— —	0.000 (0.012)	— —	0.014 (0.016)	— —	— —
Tripospermum myrti	— —	0.043 (0.101)	0.085 (0.112)	0.370 (0.349)	0.239 (0.206)	0.023 (0.034)
Lemonniera pseudofloscula	— —	0.060 (0.043)	— —	— —	— —	— —
L. aquatica	— —	0.000 (0.012)	0.017 (0.013)	0.000 (0.012)	0.000 (0.014)	— —
Triscelophorus acuminatus	— —	— —	— —	— —	0.000 (0.014)	— —
Unidentified species	— —	— —	— —	0.000 (0.012)	— —	— —
H' Diversity	1.03 (1.10)	2.15 (2.45)	1.69 (1.95)	2.17 (2.28)	1.90 (2.08)	1.35 (1.42)

*Relative Importance Values = A+B where

A = species relative frequency on leaves = leaf frequency of a species ÷ leaf frequency of all other species and

B = species relative frequency on disks = mean disk frequency ÷ mean disk frequency for all other species

**$H' = P_i \ln p_i$ where, $P_i = A+B$

Table 4. Presence of aquatic hyphomycetes on naturally occurring substrata, oak leaf packs, and in filtered water.

	Natural Substratum		Leaf Packs		Filtered Water	
	clear-cut	wooded	clear-cut	wooded	clear-cut	wooded
Clavariopsis aquatica de Wildeman		+	+	+	+	+
Filosporella annelidica (Shearer & Crane) Crane & Shearer		+	+	+	+	+
Tetracladium marchalianum de Wildeman	+	+	+	+	+	+
Alatospora acuminata Ingold	+	+	+	+	+	+
A. constricta Dyko				+		+
Tricladium terrestre Park			+	+		
T. angulatum Ingold		+		+		+
Tripospermum myrti (Lind) Hughes	+	+	+	+		+
L. pseudofloscula Dyko				+		
L. aquatica de Wildeman		+		+		
Triscelophorus acuminatus Nawawi			+		+	+