# A PRELIMINARY SURVEY OF AQUATIC HYPHOMYCETES IN LUNDY STREAMS

by

John N. Hedger[1] and Alan Rowland[2]

[1] 9 Durnamuck, Dundonnell, Wester Ross, Scotland IV23 2QZ.

[2] Mole Cottage, Woodford, Morwenstow, Cornwall EX23 9JR.

*Corresponding author, email: johnnhedger2@gmail.com*

**ABSTRACT**

Aquatic hyphomycetes are fungi which colonise and decompose detritus in freshwater, especially material from terrestrial plants, and are known to be important components of the food web, particularly as a food source for freshwater invertebrates. Microscopy was used to make counts of conidia (spores) of these fungi, which are often trapped in clots of foam, by removing foam samples from selected streams on Lundy to compare the species present and their approximate abundance. A total of 25 taxa were found, most of which are illustrated by micrographs. Many were new records for Lundy. Tentative interpretations of conidium numbers/ species diversity of samples are made and conclude they may be related to three factors: the relative length of the streams; the differences in the quality of the plant litter entering the streams; the time of year the samples were taken.

Keywords: *Lundy*, *fungi*, *aquatic hyphomycetes*, *freshwater streams*, *ecology*, *lotic*

## INTRODUCTION

Aquatic hyphomycetes are fungi found in fresh or brackish water, although they may not be exclusively aquatic and can occur on plant remains away from water bodies. Many form spores with arms, often four in number, termed tetra-radiate, but also less frequently with more branches. Another shape is also common, sigmoid (S-shaped) also termed anguilliform, since it resembles nematode worms. The English mycologist Terence Ingold is credited as the founder of studies of these fungi, which he found growing on decaying alder (*Alnus glutinosa*) leaves in a stream (Ingold, 1942), since when many more 'Ingoldian hyphomycetes' have been described, with several hundred known to date. Plate 1 is a micrograph of a foam sample from the Quarter Wall Copse North Stream showing a mixture of branched and s-shaped spores.

The term hyphomycete is now somewhat redundant and referred to species which produce spores, often termed conidia (singular, conidium), without any 'sexual' process involving meiosis. Many are now known to be forms (anamorphs) of Ascomycota fungi whose 'sexually' produced fruit bodies are termed the teleomorph. In some cases

**Plate 1**. A group of Aquatic Hyphomycete conidia (and a pollen grain) in a foam sample from Quarter Wall Copse North Stream, collected in November 2021.

aquatic hyphomycetes species have been linked to teleomorphs which are species in the Ascomycota, by both observation e.g. Webster (1992) and molecular phylogenetics e.g. Baschien (2006), Johnston & Baschien (2020). Some species are in the order Helotiales (especially family Helotiaceae), forming minute cup or button-shaped fruit bodies (apothecia)on woody debris in or near freshwater, but other taxa are linked to different Ascomycota families and a few have Basidiomycota affinities (Webster, 1992).The relative roles of anamorph and teleomorph spore types in the biology of these fungi may include a differential dispersal strategy, the anamorph conidia being adapted to dispersal in the stream environment, as discussed below, whereas the teleomorph ascospores are air-dispersed and could provide a means of returning the fungi to the headwaters of the stream. The population structure of these fungi is now known to be much more complex than being entirely aquatic and they have now been found in a range of terrestrial environments, both as saprotrophs on plant remains (Bärlocher & Boddy, 2016) but also as endophytes within living roots and leaves ( Sokolski *et al.,* 2006, Lazar *et al.,* 2022).

Both the branched and s-shaped conidia were shown in 'water tunnel' experiments in the 1970's by Webster and his colleagues at the University of Exeter to impact with greater efficiency onto surfaces as compared to rounded spores (Iqbal & Webster, 1973). This gives good retention on debris in streams and the conidia respond quickly to contact by forming appressoria which stick them in place with mucilage, followed by penetration and colonization of the plant materials, including leaves twigs and larger woody debris, that have fallen into the stream or pond (Read *et al.*, 1992) as well as to aquatic plants like *Potamageton* (Bärlocher, 2016).

These fungi are found throughout the world in streams but also in still bodies of water such as ponds and lakes and in very small volumes of water in temporary pools, including ones in tree boles (Bärlocher, 1992) and in cryoconite holes, water-filled depressions on glaciers (Edwards *et al.,* 2013). They also occur and disperse in terrestrial

habitats (Bärlocher & Boddy, 2016). In freshwater they are part of a food web largely based on terrestrial plant remains entering the water, including leaves, fruits, seeds, twigs and wood (termed allochthonous) rather than on the primary production within the water body by algae and aquatic plants (termed autochthonous). As such they act as 'energy intermediates' for stream invertebrates (Bärlocher, 1985 & 2016; Koehn, 2016) by processing the low-quality food resources into a higher quality, at least for a time, by digesting the cellulose and hemicellulose in the material and converting it to fungal mycelium. Experiments have shown that many detritus-feeding invertebrates, especially shredders such as caddis and mayfly larvae, prefer feeding on leaves colonized by these fungi (Suberkropp, 1992) and some can even thrive on pure cultures. However, these experiments show that not all species of these fungi are equally palatable. There are also differences in preferences amongst the fungi: leaves of some broad-leaved tree species like Alder have a more diverse community of hyphomycetes than others such as oak (*Quercus* sp.). Communities on leaves of grasses and sedges are depauperate compared to broad-leaved tree leaves, and streams arising on moorland are thus species-poor compared to those running through deciduous woodland (Shearer & Webster, 1985a).

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## AIMS OF THE STUDY

The identification of these fungi in streams stems from the appreciation by Ingold in the 1940s that their conidia are trapped on small bubbles of air in water and then accumulate in clots of foam, leading him to publish in 1975 a Freshwater Biological Association guide to identification of conidia within foam samples (Ingold, 1975). Microscopy of samples thus gives an idea of species diversity and this has been the approach used in our own study of Lundy streams. Hedger & George (2018) listed four species in their

account of the fungi of Lundy, all of them from foam collected from Pondsbury in October 2003 (Hedger & George, 2004). The current database of Lundy fungi to be found on the Lundy Field Society website (www.lundy.org.uk/index.php/about-lundy/wildlife-on-the-island/fungi) includes these four records. The opportunity to extend the study to Lundy streams came in November 2021 and March 2022 when visits to the island by the authors coincided with many being swollen by recent rains and as a result forming foam clots which could be sampled for conidia.

**METHODS**

Foam from the streams was scooped up with a petri dish bottom and dropped into to a 5 ml plastic vial using a teaspoon. Plate 2 shows sampling in progress next to the Millcombe Pond stream in March 2022. Plate 3 shows a foam raft on the stream in Quarter Wall Copse, also in March 2022. Denatured 100% Ethanol was then gently added with a pipette to dissolve the foam bubbles and fix the conidia, giving a volume of 1-2 ml per tube. Tubes were labelled with site and date and stored at room temperature. To identify the conidia present, the sediment from the bottom of the tube was carefully removed with a needle-pointed 1 ml syringe graduated to 0.01 ml and syringed out into a vial then withdrawn again to mix it. A drop of 0.1 ml was added to a microscope slide and a 2 x 2 cm coverslip dropped onto it. A preliminary examination was made using the x 10 objective (x 100 magnification) of the microscope. If there were many conidia present, then counting/identification was carried out in 10 random microscope fields of the x 40 objective. These counts were converted to approximate numbers in 0.1 ml suspension by measuring the field diameter using a calibration slide and using $\pi r^2$ to calculate the area of the field. The ratio of the field area to the area under the coverslip (400 $mm^2$) was used to calculate numbers of conidia per 0.1 ml of suspension. If there

**Plate 2**. Field sampling of foam.

**Plate 3**. Foam in Quarter Wall Copse North Stream.

were few conidia found in the preliminary scan of the preparation, then the whole of the coverslip area was counted by longitudinal traverses using the x 10 objective, using the x 40 or x 60 objective to identify the conidia, and this was considered to be the approximate number in 0.1 ml.

These counting procedures were only semi-quantitative, one error being the distribution of the conidia under the coverslip, which was not random in spite of attempts to break up clumps. In addition, the field sampling itself was also not standardized since some foam masses were large, others small and the volume removed differed somewhat at each site. Nevertheless, we feel the data do give some indication of relative abundance and diversity of aquatic hyphomycetes in Lundy streams.

## RESULTS

### Location of the streams sampled and their characteristics

**East Side** The streams on the east side have a varied flora of herbaceous and woody plants, except for those which rise and flow north of Halfway Wall which run through unimproved grassland and waved heath. From north to south the streams sampled were:

**Gannets' Combe Complex** (Sample Date: 15 March 2022)

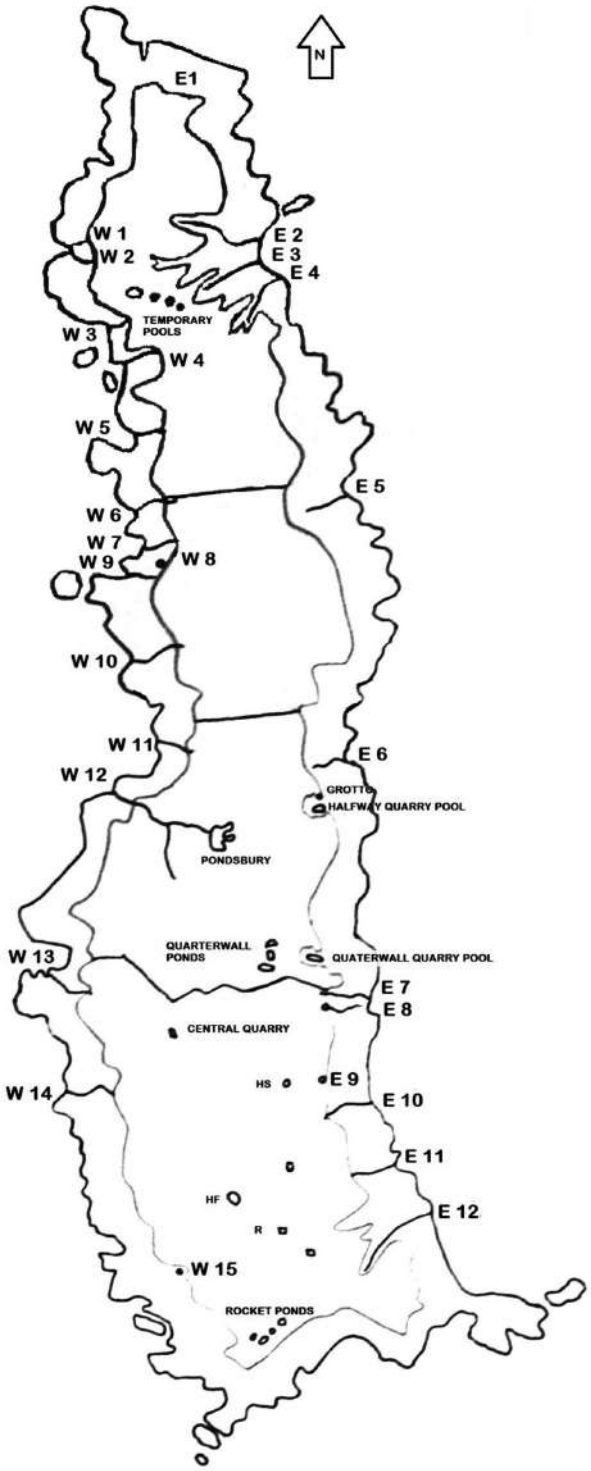
***Gannets' Combe North*** comprises at least three distinct streams, heavily overgrown with bracken and grasses, flowing from around the central footpath eastwards into Gannets' Bay where some converge before falling over the cliff edge into Gannets' Bay.

The northern branch of the main stream rises in the waved heath at SS 13324 47492 and runs for 169 m. The southern branch rises near the central track as SS 13290 47238 and runs for 262 m. They converge at SS 13437 47422 before flowing a further 83 m to the cliff edge at SS 13537 47442 where samples were taken. The vegetation through which they flow is mainly unimproved grassland, bracken (*Pteridium aquilinum*). and tussock sedge (*Carex paniculata*). Longest length is 345 m.

***Gannets' Combe South*** a stream 175 m south of the North Stream rises at SS 13526 47131 within a short grassy valley between two granite outcrops. It flows eastwards for 182 m to the cliff edge where it was sampled at SS 13560 47227. The vegetation through which it flows is also unimproved grassland, bracken and tussock sedge.

**Quarter Wall Stream** (Sample Date: 04 November 2021)

This stream rises on the north side of Quarter Wall which forms the northern boundary of Brick Field by Quarter Wall gate SS 13565 44885. It then flows east to the Upper East Side Path where it is joined by a stream on the south side of Quarter Wall at SS 13788 44887 which drains from Brick Field Pond SS 13706 44900. Quarter Wall is a typical Devon hedge hosting many herbaceous plants and woody plants including bramble *Rubus* sp., bracken and gorse *Ulex* sp. From the Upper East Side Path, they form a braided stream which flows down the steep sidelands through Quarter Wall Copse comprising turkey oak (*Quercus cerris*), alder (*Alnus glutinosa*), birch (*Betula* sp.) and rowan (*Sorbus aucuparia*) before flowing under the Lower East Side Path then over the cliff edge in Quarter Wall Bay SS 13969 44825, a total of 457 m. Samples were taken




Taken from two sketch maps by A.L. Langham (1969) 'Water courses and reservoirs on Lundy' located in Western Studies Library (*Bho sxB/LUN/LAN/836 Box 55*). Streams which were sampled during the survey are in bold.

West Side

W1-3 unnamed
W4 **St Peter's Stone Stream**
W5 unnamed
W6 Threequarter Wall Stream (west side)
W7 unnamed
W8, 9 **St Mark's Bay Stream**
W10 **Pyramid Stream**
W11 Butler's Pantry Stream
W12 **Pondsbury / Punchbowl Stream**
W13 Battery Stream
W14 **Old Light Stream**
W15 **Southwest Field or Pilots Quay Stream**

East Side

E1 Constable Rock Stream
E2–4 **Gannets' Combe Complex**
E5 Threequarter Wall Stream (east side)
E6 Halfway Wall Stream
E7, 8 **Quarter Wall Stream (either side of wall)**
E9 Brickfield Stream
E10 Tillage Field Stream
E11 St Helen's Spring
E12 **St John's & Millcombe Streams**

**Figure 1**. Locations of the streams sampled during the survey.

in the copse from the northern (= **Quarter Wall Copse North)** and southern braids (= **Quarter Wall Copse Central**) at SS 13922 44835.

**St John's Stream** (Sample Dates: 02 & 06 November 2021)
This stream rises in boggy areas in Lighthouse Field SS 1355 4409 which is improved and heavily cropped grassland with outcrops of soft rush (*Juncus effusus*). It then flows through Quarters Pond SS 1364 4403 which is surrounded by dense rushes then via the staff vegetable gardens where the first sample was taken, and under the helipad before emerging at the side of Square Cottage. The stream has been canalised to the top of St John's Valley but has pond water-starwort (*Callitriche stagnalis*) and hemlock water dropwort (*Oenanthe crocata*) in its bed. At the head of St John's Valley SS 1388 4391, it receives runoff from the Golden Well area then flows through unimproved grassland with tussock sedge, soft rush, bracken, bramble and a small, stunted copse of willow (*Salix* sp.) before reaching Brambles Villas SS 1397 4397 where it is culverted under the access road and emerges in a sycamore (*Acer pseudoplatanus* ) copse with ground cover of common nettle (*Urtica dioica*). Emerging from this at Lodore, an animal drinking trough, it runs under the road into Millcombe Gardens where it is joined by Millcombe Stream the bed of which hosts hemlock water dropwort and has been canalised and lined with shale blocks. The combined flow then cascades into Millcombe Pond SS 1404 4403 which is heavily covered with yellow iris (*Iris pseudacorus)* and hemlock water dropwort before emptying into the sea through Smelly Gully a total length of 750 m.

Samples were taken at four locations, below Quarters Pond SS 1364 4403, at the head of St John's Valley SS 1388 4391, adjacent to Brambles Villas SS 1397 4397and below the cascade at Millcombe Pond SS 1404 4403.

**West Side** Most of the streams on the west side flow through unimproved grassland and/or heath with no trees or shrubs on their banks. The exceptions are two streams, one arising from Pondsbury and flowing down the Punchbowl Valley, the other draining the south side of the valley. Both run through the edges of the creeping willow (*Salix repens)* forest. The remainder of the streams contain a limited flora, typically of soft rush, common spike rush (*Eleocharis palustris*), *Potamogeton* sp. and in some cases bog St John's-wort (*Hypericum elodes*) and various *Sphagnum* species. From north to south, the streams sampled were:

**St Peter's Stone Stream** (Sample Date: 15 March 2022)
This stream drains the northern western edge of Widow's Tenement. Rising in marshy ground SS 1345 4696, the stream runs westwards via two dammed pools, one each side of the path crossed by stepping stones SS 1333 4697 with an abundance of bog St John's-wort, *Potamogeton* species and soft rush before flowing through a broad grassy valley between granite outcrops where the sample was taken SS 1324 4700 then over the cliff into the Atlantic, a total of 338 m.

**St Mark's Bay Stream** (Sample Dates: 10 November 2021 & 14 March 2022)
This is a short stream rising south of Threequarter Wall SS 1346 4647 and draining the western side of Middle Park near where the telephone spur ran from the west side of

Lundy to the signal station at Tibbetts. It has been dammed to produce a moderate sized pool with muddy bottom where it was sampled at SS 1332 4643 and hosts sphagnum and bog St John's wort in its 265 m length.

**Pyramid Stream** (Sample Date:10. November 2021 & 15 March 2022)
This is a fair-sized stream which rises in the unimproved grassland and rushes of Middle Park at SS1348 4610. It flows due west and widens into two pools beside the path. There is little vegetation in the stream other than sphagnum and rushes, and the lower pool is practically silted up. It is a short stream of 400 m. Samples were taken at SS1329 4609 west of the western footpath.

**Pondsbury / Punchbowl Stream** (Sample Date: 03 November 2021 & 15 March 2022)
The outflow of Pondsbury SS 1341 4545, and named Pondsbury Stream, is 250m in length and flows down the shallow upper Punchbowl Valley through heathland with tall purple moor grass (*Molinia caerulea)* and large patches of creeping willow (*Salix repens*); the Punchbowl Stream drains the low hills south of Pondsbury, originating in the purple moor grass-dominated heathland at SS 1326 4520 and flows 283 m to their confluence at SS 1317 4548 near the Punchbowl, above which the two streams were separately sampled. The flow below this point consists of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks down Punchbowl Valley into the Atlantic Ocean. The maximum length is 479 m.

**Old Light Stream** (Sample Date: 03 November 2021 & 23 March 2022)
This stream is north of the Old Light and develops from a spring at the western end of the airfield at SS 1325 4446. The spring appears after wet weather and is absent for most of the year. It flows west into Old Light Pond, the marshy pool north of the Old Light below which it was sampled SS 1306 4456. Vegetation consists of unimproved grassland, bracken, sphagnum and rushes. From there it flows steeply down the cliffs into the Western Sidings as alternating areas of rapids, pools and small waterfalls interspersed with larger boulders and smaller rocks, a total of 450 m in length.

**South West Field** or **Pilot's Quay Stream** (Sample Dates: 02 November 2021 & 20 March 2022)
This short stream of 227 m rises in marshy ground in the field south of the Old Light SS 1329 4400 amidst unimproved grassland and rushes. It is dammed by a very substantial wall near the cliff top from where it falls almost vertically into the Atlantic Ocean. There can be much vegetation, mostly water starwort, *Potamogetan* and rushes in the resulting pool, which is near the footpath leading to Montagu Steps. It was sampled where the stream enters the pool at SS 13246 43937.

**Appearance of the foam samples**
The foam samples varied considerably in their size and colour: some were large clots, brown with trapped detritus; others were small and white. The colour was not an indication of spore loading in the foam. Some large brown clots on the west side streams contained very few conidia. The Quarter Wall Copse foam was white and clear (see

Plate 3) but microscopy showed it contained many conidia. The browner clots were always rich in cells of diatoms, including *Tabellaria* and *Navicula* species, probably released from the epiphytic algal communities on the aquatic plants and rocks.

**Identities of conidia found in the foam samples**

Identification of the conidia present was made using Ingold (1975): admittedly out of date but still the best review of the common species of these fungi. In the descriptions below we include some reference to more recent interpretations of the taxonomy and any relationships to ascomycete teleomorphs. Plates 4a–d shows micrographs of some, but not all, of the aquatic hyphomycete conidium-types we found. Spores of terrestrial species of fungi also occurred, the most obvious being the purple ascospores of the dung fungus *Ascobolus* c.f. *immersus.* Multiseptated ascospores of *Pleospora* species and dematiaceous conidia of *Articulospora tetracladia*, *Alternaria*, *Pestalatiopsis* and *Stemphylium* were common in a few samples and were probably from streamside vegetation.

***Alatospora acuminata*** Ingold (Plate 4a top left)

*A. acuminata* was identified as small (5-15 μm long) tetra-radiate conidia with the two curved bluntly-pointed arms arising in the middle of a non-septate, also curved, axis. They resembled a butterfly or bird in form. It is very common in the UK and throughout the world in freshwater habitats and conidia were found in many of the foam samples but were most abundant in those from the Quarter Wall Copse streams. No teleomorph appears to be presently known, though DNA cladistics place the fungus in the Ascomycota Family Leotiaceae**.**

***Anguillospora crassa*** Ingold (Plate 4a top right)

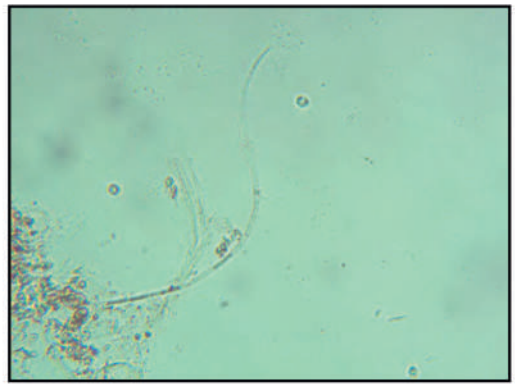
The s-shaped conidia of this species were easy to spot in samples due to their large size (around 75-100 μm long by 5-15 μm wide) and division into cells by 10-12septae. The example in Plate 4a has been stained with Methylene Blue. Most conidia had 10-15 cells, more than quoted in the literature (3-7). *A.crassa* is commonly found in foam samples throughout the UK. Webster (1961) considered its teleomorph was in the Ascomycota genus *Mollisia* (Order Helotiales), characterised by disc-shaped apothecia but more recent interpretations (Baschien, 2006) place it in the Order Pleosporales which have perithecial fruit bodies. On Lundy the conidia were widely distributed but most abundant in the Quarter Wall Copse samples. It was recorded on Lundy in 2003, from Pondsbury (Hedger & George, 2004).

***Anguillospora longissima*** (De Wild) Ingold (Plate 4a middle right)

The very long (100-200 μm) S-shaped conidia of this species were often tangled within clumps of branched conidia of other Hyphomycetes and one can be seen in such a clump in Plate 1. Conidia were much narrower than conidia of *A. crassa* and also differed in the acutely pointed end, although the number of septae was about the same (10-20). *A. longissima* is commonly found in freshwater foam samples in the UK and like *A. crassa* has been placed by cladistics in the Ascomycota order Pleosporales, possibly in the genus *Massarina*. On Lundy it was widely distributed but it was most abundant in the

*Alatospora acuminata*

*Anguillospora crassa*



*Anguillospora longissima*

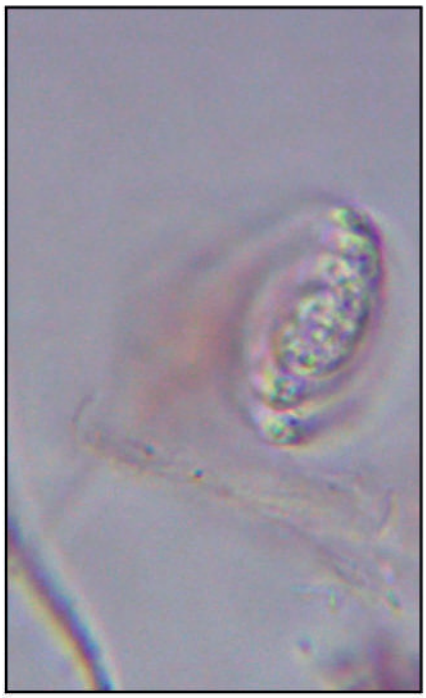
*Articulospora tetracladia*

*Clavariopsis aquatica*

**Plate 4a**. Spore micrographs.

*Dactylella appendiculata*

*Heliscus lugdunensis*



*Gyoeffyella speciosa*

*Dendrospora erecta*

**Plate 4b**. Spore micrographs.

*Lateriramulosa uni-inflata*

*Lemonniera aquatica*

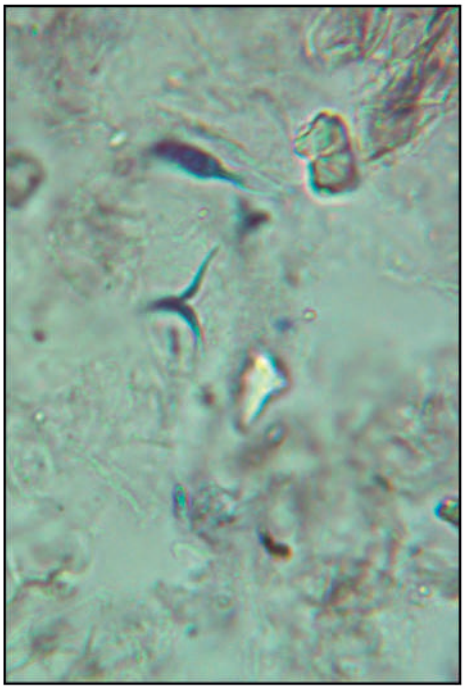
*Tetracladium setigerum*

*Tetracladium marchalianum*

**Plate 4c**. Spore micrographs.

*Varicosporium elodeae*

*Tetrachaetum elegans*



*Volucrispa aurantiaca*

*Tricladium splendens*

**Plate 4d**. Spore micrographs.

November sample of St John's Stream below Quarters Pond where it made up well over half the total count of conidia.

Two other conidia with elongated shapes were also found in the foam samples, *Flagellospora curvula* Ingold and *Lunulospora curvula* Ingold. The S-shaped conidia of *F. curvula* could be mis-identified as *Anguillospora longissima* but were separated by their lack of septae and a narrower diameter. Cladistics have now placed it in the Ascomycota family Nectriaceae. It has a wide distribution in the UK with a cluster of unconfirmed records for Devon (NBN Atlas). On Lundy it was only found in large numbers in the Quarter Wall Copse Streams.

*L. curvula* has a distinctively shaped conidium with a strongly curved crescent moon shape, lacking any septae and around 20-40 μm in length. NBN Atlas does not show it is as widespread in the UK as Ingold's 1975 statement that it is common. There is however a cluster of unconfirmed records for Devon. All of the Lundy records were for November 2021, when it occurred, though not abundantly, in half of the foam samples. No conidia were found in March 2022, perhaps confirming Ingold's view that the fungus prefers warmer conditions, so that the population declines in the winter months. Cladistics place it in the Ascomycotina subdivision Pezizomycotina. *L. curvula* has been previously recorded on Lundy by Hedger & George (2004), from Pondsbury.

***Articulospora tetracladia*** Ingold (Plate 4a bottom left)
The conidia of this species have a distinct main axis with three once septate 'arms' at one end (Plate 2). A clear constriction at the junction of each arm and axis helped identification of this species in the samples, together with the length of the conidia - up to 200μm. The fungus is currently placed by cladistics in the Ascomycota order Helotiales though the teleomorph is not known. It has been widely recorded in the UK. Conidia were most abundant in the Pondsbury and Quarter Wall Copse North stream samples. Conidia of *A.tetracladia* had been previously found in foam samples from Pondsbury lake (Hedger & George, 2004).

***Clavariopsis aquatica*** De Wild (Plate 4a bottom right)
The distinctive shape of this spore type made it easy to identify in samples, with one short wide septate arm with a narrow base and with three long (40-60 μm) non-septate narrow arms attached to the rounded top. The species has been found throughout the UK in freshwater foam. On Lundy conidia seemed to be restricted to the Quarter Wall Copse samples except for one record for Millcombe Pond in March 2022. It was described as early as 1895 by De Wild. Cladistics indicate it is within the Pleosporales order of the Ascomycota though no teleomorph appears to have been found.

***Clavatospora longibrachiata*** (Ingold) Nilsson *and* ***Clavatospora stellata*** (Ingold & Cox) Nilsson
These conidium types were only found a few times, mostly in the Quarter Wall Copse North Stream but also in the St John's Stream at Brambles and in Millcombe Pond. No good images were obtained. The conidia were small, with a tapering main axis about 10 μm in length subtending three branches, around 8 μm long in *C. longibrachiata*. The

conidia attributed to *C. stellata* had a very short main axis and three very short branches, giving a stellate shape. They were very similar in appearance to those of *Heliscus lugdunensis* (described below) which however had a longer septated subtending branch. Both species seem to be placed in the Ascomycota order Sordariales by cladistics.

***Dactylella appendiculata*** Anastasiou (Plate 4b top left)
The large size (60-80 μm long) and odd shape of the conidia of this fungus (Plate 4b) made it easy to identify though it was found infrequently, in the Quarter Wall Copse and the Pondsbury streams. The central part of the conidium consisted of two swollen cells, with a tapering tail cell at one end (the lower part in Plate 4b) and a narrower cell at the other from which three long straight appendages are directed backwards, though in the figure they appear folded (by damage). Ingold (1975) felt that the species should be removed from *Dactylella*, and it is now known as *Monacrosporium tentaculum* Rubner & Gams and placed in the Ascomycota Family Orbiliaceae.

***Dendrospora erecta*** Ingold (Plate 4b lower right)
Large size (2-300 μm in length) and complex branching of the conidia of this species made it easy to identify. The conidia had a straight main axis, projecting to the right in Plate 4b with a cluster of branches arising from the base (to the left in the figure). Both axis and branches were divided into cells by numerous cross walls. It was only found once, in March 2022 in the Old Light Stream. However, in a more recent survey in November 2022 a sample of foam from St John's Stream in Millcombe was found to contain many conidia of the fungus, which is widespread in the UK. A member of the Ascomycota its classification beyond the Pezizomycotina sub-division remains unclear.

***Gyoerffyella speciosa*** (Ingold) Miura (Plate 4b bottom left)
The curious spiral conidia of this species were once thought to be an alga. There is a central axis with a long tail which coils back on itself and encloses two or three tightly curved branches from the central axis which also have long tapering tails. The result is a tight flattened spiral surrounded by long projecting filaments. Lundy conidia were smaller than the description in Ingold (1975), around 20-30μm in diameter. *G. speciosa* is widely distributed in the UK but not common according to the NBN Atlas. Cladistics place it in the Ascomycota Family Discinellaceae. On Lundy we have only found it in the north branch of the Quarter Wall stream, so it seems to need, as it does elsewhere, woodland detritus.

***Heliscus lugdunensis*** Sacc. & Therry (Plate 4b top right)
Ingold (1975) correctly describes the small (10 μm long) conidia of this species as clove-shaped, with a tapering basal cell and three short arms projecting from the sides of the broader apical cell. We only found it to be abundant in one foam sample (Quarter Wall Copse Central Stream in March 2022). The NBN Atlas shows it is widespread in the UK and it is known to be the anamorph of a *Nectria* teleomorph described as *N. lugdunensis* by Webster (1959), now considered to be *Neonectria lugdunensis* (Sacc. & Therry) L. Lombard & Crous. In Quarter Wall Copse the fungus probably colonises twigs of alder forming the conidia (*Heliscus* state) when it flows, but the teleomorph, a minute

rounded reddish perithecium, the *Neonectria* state, may occur on the same twigs when the stream dries out in the summer, a strategy proposed for this wood decomposing fungus by Shearer (1992).

***Lateriramulosa uni-inflata*** Matsushima (Plate 4c top left)
The conidia of this species are very distinctive, with three sharply pointed arms subtended on a round central cell by a narrow neck. The micrograph shows an example from St John's stream at the valley top which was the only site where it was found during the survey. Cladistics place it in the Ascomycota as far as the Pezizomycotina subdivision and no teleomorph seems to be known. The NBN atlas shows very few records for the UK though there is one (unconfirmed) for Devon. The conidia are small (ours measured 5-10 μm) so may well be overlooked in foam samples.

***Lemonniera aquatica*** De Wild (Plate 4c top right)
This species was easily identified in samples due to the length (50-100 μm) of the four straight arms of the tetra-radiate conidia. In the micrograph a conidium stained with Methylene Blue shows how the three arms radiate from a central point from which a fourth projects at 90 degrees. Cladistics show *L. aquatica* is in the Family Discinellaceae of the Ascomycota but no teleomorph has yet been found. Conidia were found the St John's Valley stream, a number of the West Coast streams and in the Quarter Wall Copse North Stream. The NBN Atlas shows it as widely recorded in the UK, including Devon.

***Tetracladium*** species (Plate 4c bottom left and right)
The distinctive conidia of this genus have a main axis up to 20 μm long ending in rounded or finger-like projections and branches. *T. marchalianum* De Wild has one or two rounded central knobs plus two to four longer branches on either side, easily seen in the micrograph. In *T. setigerum* (Grove) Ingold there is a central group of three finger-like lobes bordered by two or three longer branches. Both conidium types were found in foam samples from seven out of the ten streams sampled in November 2021 but *T. setigerum* was much the commoner of the two and it was the only species found in the March 2022 survey. Both are widely distributed in the UK. Some smaller conidia were found in samples from the St. John's Stream at the valley top which corresponded to a third species, *T. maxilliforme* (Rostrup) Ingold, which resemble *T. setigerum* but only have two central lobes and two longer arms. The NBN Atlas shows this has been recorded much less frequently in the UK than the other two *Tetracladium* species. All three have been placed in the Ascomycota, Order Helotiales.

***Tetrachaetum elegans*** Ingold (Plate 4d top right)
The tetra-radiate conidia of this species have a central curved axis with two curved side branches in the middle, making the structure bird-like in shape, clearly seen in the micrograph. Ingold (1975) correctly points out that the narrowness of the curved arms and axis and the length (up to 150 μm) make this species easy to separate from similar conidia such as *Lemonniera aquatica*. The NBN Atlas shows that *T elegans* is widespread in the UK and there are a number of unconfirmed records from S. Devon. Conidia were

not found in the November 2021 survey but were present in the Quarter Wall Copse, Pondsbury and Pyramid stream samples in the March 2022 survey. Cladistics have yet to assign it further than Ascomycota but it is likely to be in the order Helotiales.

***Triscelophorus monosporus*** Ingold
The structure of the conidia of this species is similar to that of *Lemonniera aquatica* with three straight arms radiating from a central cell with another slightly longer arm at 90 degrees to them. However they are much smaller in size (10-20 μm length for each arm). It was found only once, in a sample from the SW Field Stream in November 2021. NBN Atlas data show it to be found infrequently in the UK and Ireland.

***Varicosporium elodeae*** Kegel (Plate 4d top right)
Conidia corresponding to this species were easy to identify due to their large size (100-250 μm in length) and complex but irregular pattern of branching of arms arising from a central axis, sometimes with additional branches arising from the arms. They were often tangled together in small clumps in the foam. The conidium illustrated is relatively simple with one pair of arms and one solitary arm. Cladistics have placed the genus in the Ascomycota Family Helotiaceae. NBN Atlas records show it to be common in the UK. We found it widely in the November 2021 survey, sometimes abundantly, as in St John's stream below Quarters Pond, but conidia were much less frequent in the March 2022 samples. As the name implies, *V. elodeae* was first described on dead shoots of the waterweed *Elodea canadensis* by Kegel in 1906 but most records are from terrestrial plant litter and wood in water, as well as soil and litter well away from water (Bärlocher, 1992). There is one existing record of it for Lundy, from Pondsbury in 2003 (Hedger & George, 2004).

***Varicosporium delicatum*** Iqbal
We identified this species on the basis of branched conidia which were in structure and size like *V. elodeae* but with much narrower axes and branches, which were also curved. Ingold (1975) remarks that the conidia often break up and we often found curved sections, as well as intact structures, making for possible confusion with *Anguillospora longissima*. It seems to have a similar UK wide distribution to *V. elodeae* and NBN lists 69 records. Only one foam sample contained conidia of this species, from the Pondsbury Stream in November 2021.

***Volucrispora aurantiaca*** Haskins (=*Tricellula aurantiaca* (Haskins) Von Arx.) (Plate 4d lower left)
The minute (5-8 μm long) conidia of this species had two short curved and pointed arms in the middle, correctly likened to birds' wings by Ingold 1975. They showed up best in foam samples when the preparation had been stained with Methylene Blue. In practice it was difficult to separate conidia of this species from those of the similar *Volucrispora graminea* Ingold which differed in having only one branch on the main axis, creating a Y shaped structure. The NBN Atlas shows neither species as being widely recorded in the UK. Both species were infrequent in the Lundy stream samples, except for the St John's Stream below Quarters Pond in November 2021.

***Tricladium splendens*** *Ingold* (Plate 4d lower right)
The tetra-radiate conidia of this species were relatively easy to distinguish due to the length of the pointed curved main axis (80-100 μm) and its division into wide (up to 10 μm) cells. Two septate branches were attached to the blunt basal cell and penultimate cell, shown clearly in the micrograph and can arise on either side of the axis or on the same side. A range of morphologies and sizes of conidia were found in the samples, some of which could have been assigned to other species of *Tricladium* described in Ingold (1975) such as *T. attenuatum* Iqbal but were all recorded as *T. splendens*.

The genus *Tricladium* is included in the Ascomycota, Order Helotiales and the NBN Atlas shows *T. splendens* occurring widely in the UK, including a number of localities in Devon. On Lundy it occurred in four out of ten stream samples from November 2021 and six out of the twelve March 2022 samples and was most abundant in the Quarter Wall Copse North Stream in November sample, though absent in March 2022.

A number of *Tricladium*-like conidia were found in the Pondsbury Stream foam samples in which a side branch, usually from the basal cell, subtended a further branch, corresponding to the description of *Pleuropedium tricladoides* Maranova & Iqbal in Ingold (1975) and have been recorded as such, though without complete confidence.

**Abundance of aquatic hyphomycete conidia in the foam samples**
**Numbers of species in stream samples** The data for the numbers of species of Hyphomycete found in each stream in the November 2021 and March 2022 surveys are summarized in Figure 2.

The highest species count in both years was in foam from the Quarter Wall Copse streams. Fourteen taxa were found in November 2021 in the North Stream sample. The March samples of the North Stream were also the most diverse though with a lower species total (nine). The Central Stream foam, only sampled in March 2022, had eight taxa, most being the same as in the North stream. Some of the conidia in the Quarter Wall Copse streams were not found elsewhere on Lundy, such as *Clavatospora longibranchiata*, *C. stellata* and *Gyoerffyella speciosa*. *Tricladium splendens*, *Articulospora tetracladia* and *Alatospora acuminata* had the highest conidium counts.

The other high species counts were from the St John's stream sites in November 2021 (at 750 m the longest stream by far). The greatest numbers of conidia were in the foam below Quarters Pond and there were a lower number downstream at the valley top and at Brambles. A feature of the foam below Quarters Pond was the abundance of two of the conidium-types: *Varicosporium elodeae* and *Anguillospora crassa*. These species were almost absent from foam at the valley top and at Brambles. The count was 960 conidia/ 0.2ml suspension for *Varicosporium elodeae* below Quarters Pond but a zero score at the valley top and just one conidium at Brambles. Although present in foam in some of the other streams conidia of these two species were always in very much lower numbers.

The Pondsbury stream samples were the only ones which approached the diversity of the Quarter Wall Copse and St John's streams with 11 taxa found in November and five in March. There were even a few taxa in common with the Quarter Wall Copse streams, including *Dactylella appendiculata* in November 2021. The Punchbowl stream,

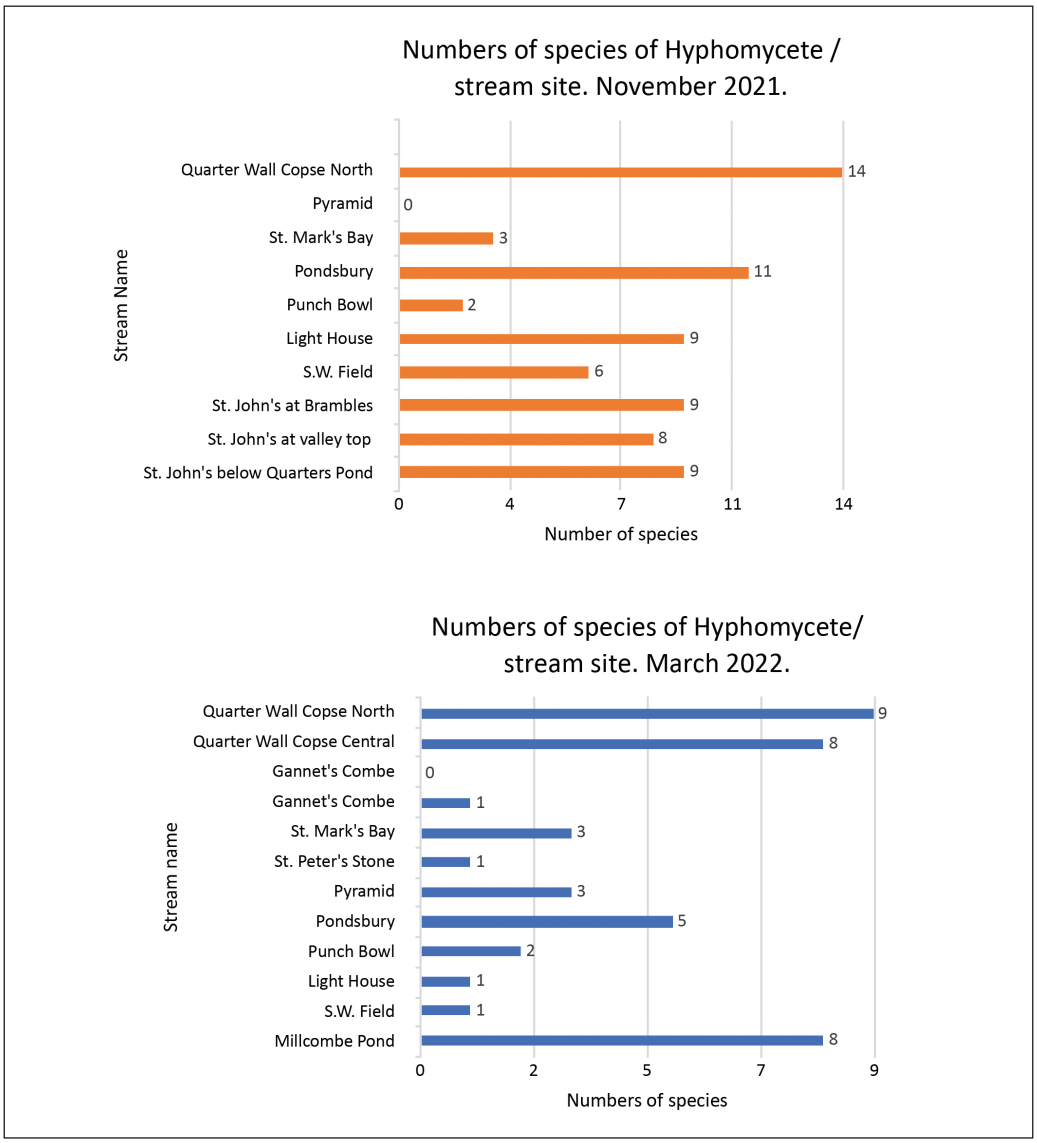



**Figure 2**. Number of Hyphomycete species found in foam samples from Lundy streams. November 2021 (left) and March 2022 (right).

which joins the Pondsbury stream and is about the same length, had, in contrast, very low numbers of just three taxa (*Anguillospora crassa* in the November 2021 sample, *Articulospora tetracladia* and *Varicosporium elodeae* in March 2022). The foam from the other west side streams (St Mark's Bay, St Peter's Stone, Pyramid, South West Field and Old Light) contained more taxa but Pyramid Stream was odd, with no conidia found in the November 2021 sample, though three taxa and 28 conidia were found in the March 2022 sample. The Gannet's Combe streams were only sampled in March 2022 and were really depauperate, no conidia in one sample and one (a *Tricladium splendens* conidium) in the other.

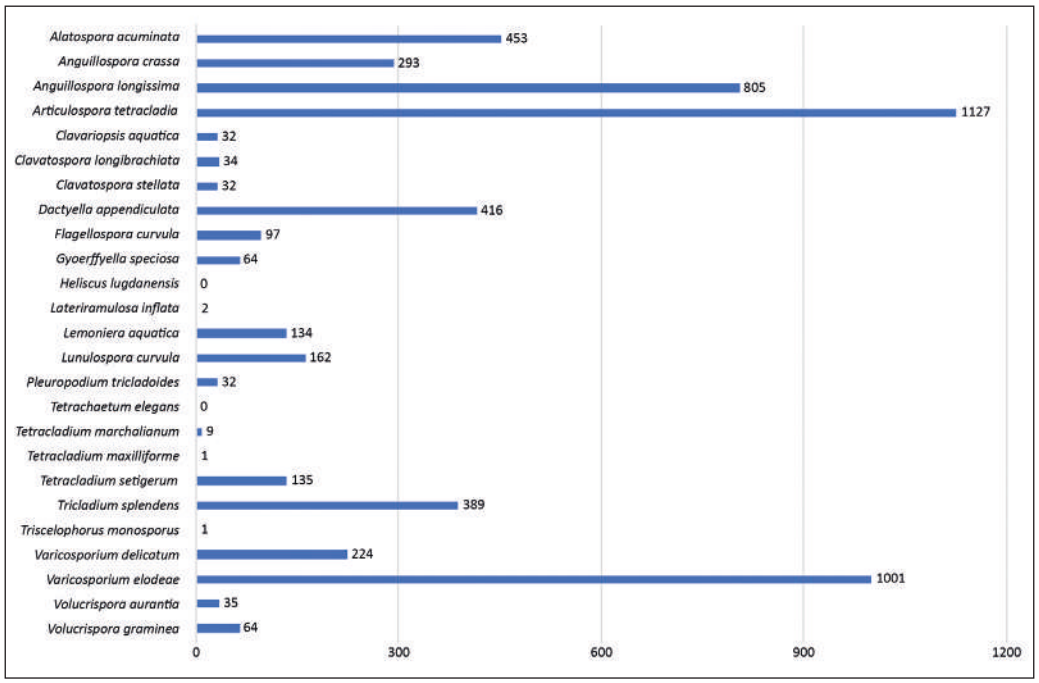



**Figure 3**. Totals counts of conidia of Hyphomycete species in foam samples from all sites (November 2021).

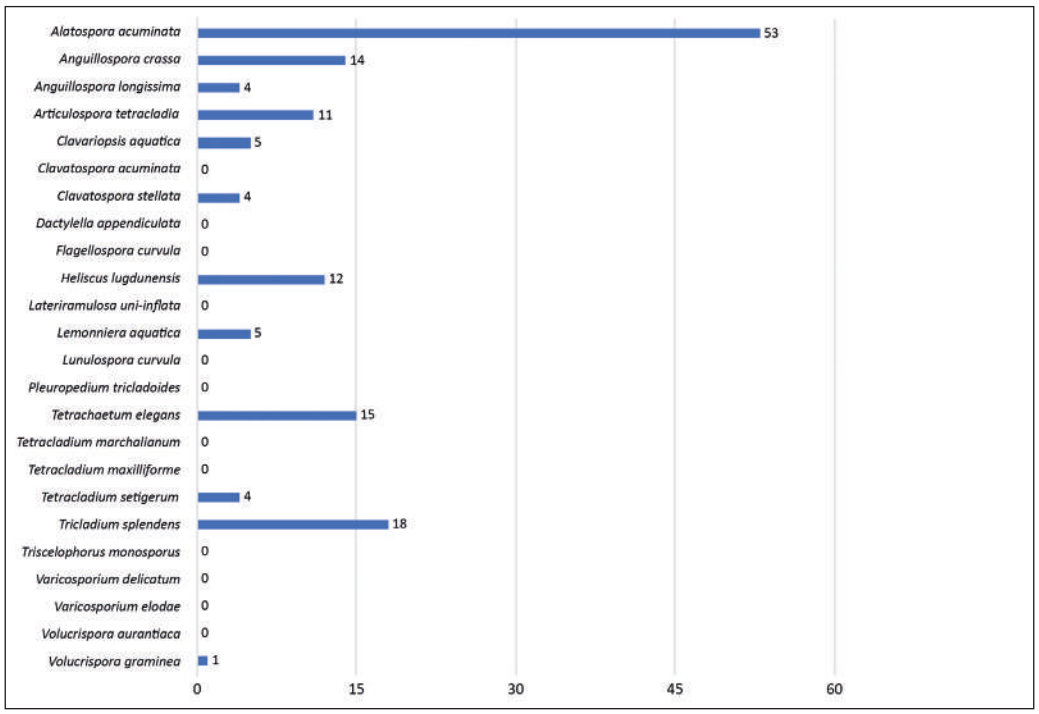



**Figure 4**. Totals counts of conidia of Hyphomycete species in foam samples from all sites (March 2022).

**Numbers of conidia of each species** Counts of the conidia of each species in the samples are shown in Figure 3 (November 2021 survey) and 4 (March 2022 survey). The combined total was much higher in November 2021 (5,542) compared to March 2022 (146) and the bar charts show that most taxa were much more abundant in the November samples. Only a few showed the reverse trend and in one case (*Heliscus lugdunensis*) this was an artifact since the one site where it was found (Quarter Wall Copse Central Stream) was only sampled in March 2022. In both November and March samples the two *Anguillospora* species, *Alatospora acumunita*, *Articulospora tetracladia, Varicosporium elodeae* and *Tricladium splendens* made up a high proportion of the conidium totals.

## DISCUSSION

Our studies were very limited in scope so any conclusions must be tentative. There do seem to be differences in the numbers of aquatic hyphomycete conidia, and by extrapolation populations of the fungi, between Lundy streams. One explanation could be the length of the stream above the point where the foam sample was taken, giving a greater surface area over which conidia can be released into the flow. A second is that they differed in the quality of plant litter they received, which would determine the diversity of fungi which can colonize it. Both aspects of stream dynamics have been shown to influence conidium diversity (Shearer & Webster, 1985b; Bärlocher, 1992; Bärloche, 2016).

Taking the first explanation, the Pondsbury stream is the second longest on the island second only to St John's stream. The stream at Quarter Wall Copse is also comparatively long and partially rises from springs in Brick Field well above the wood. All three had the highest diversity of Hyphomycete species in the foam samples in both November 2021 and March 2022. In contrast the streams with short lengths tended to have lower species diversity and lower conidium counts, especially the very short west side streams: South-West Field, Old Light, Pyramid, St Mark's Bay and St Peter's Stone.

The second explanation reflects the results of many studies of streams and rivers, i.e. that the quality of the plant debris which enter the water body can determine the diversity of aquatic hyphomycetes. Leaves of broad-leaved trees like alder, birch and oak have been shown to support more species than conifer litter or grass litter, which are of poorer quality or contain inhibitory chemicals (Bärlocher & Oertli, 1978). The two Quarter Wall streams had the highest diversity, flowing in their lower sections through alder, turkey oak and other deciduous trees and received higher quality litter, especially in the autumn. St John's stream also passes through stands of Willow in the valley and has an input of sycamore leaves below Brambles.

The relatively high hyphomycete diversity in the Pondsbury stream may be connected to its length. It could also be related to the quality of the resources entering it, including leaves of creeping willow (*Salix repens*) in the Upper Punchbowl valley and to aquatic plants like *Potamageton*. In this respect the difference in numbers and diversity of Hyphomycete conidia counted in November 2021 and March 2022 in foam samples collected from the Pondsbury Stream and the Punchbowl Stream, which join in the Lower Punchbowl Valley, is striking; the Punchbowl Stream samples had much lower

numbers of species and conidia. Both streams are about the same length, but the Punchbowl stream largely flows through dense tussocks of the very silicaceous purple moor grass (*Molinia caerulea*), a difficult substrate for any decomposer fungus. So, the poorer resource quality in the Punchbowl Stream catchment could be the explanation of the difference in Hyphomycete communities. Likewise, the foam samples taken in March 2022 from the two streams in Gannets' Combe were also species-poor (one and zero) and ran though tussocks of the highly silicaceous Tussock Sedge. Past studies, such as those of Iqbal & Webster (1977) on Dartmoor also found low Hyphomycete diversity in streams with moorland catchments.

The species diversity in the foam samples from some of the other West Side streams (South West Field, Old Light, Pyramid (in March 2022), St Mark's Bay, St Peter's Stone) were low but not as low as the Punchbowl Stream Their catchments were mostly grazed grassland but the vegetation was more diverse than on the Punchbowl Stream catchment, perhaps promoting a higher Hyphomycete diversity, in spite of their short lengths.

Finally, the fact that far more Hyphomycete conidia, both in totals and species diversity, were found in the November 2021 than in the March 2022 foam samples of the same streams may be compared to much more detailed studies of streams and rivers throughout the year in Europe. Most have also found that there is an Autumn /early Winter maximum number of conidia in the water bodies and lower populations in the spring. A Devon example, and so climatically similar, is the work of Shearer & Webster (1985b) who in a study of the River Teign catchment found maximum conidium numbers from November to January. Explanations offered include more opportunities for growth of the fungi on the autumnal input of plant debris, especially leaves, which will be progressively removed during the winter and not replenished until late Spring and Summer.

Aquatic hyphomycetes are of importance in the food web in Lundy streams. Future work could include more detailed surveys of Lundy streams by sampling foam, with better replication. Concentrating on the species-rich hyphomycete communities in the Quarter Wall Copse Streams could be a priority and brief sampling of foam from the north stream in November 2022 has already yielded a new record for Lundy, (*Camposporium pellucidum* (Grove) S. Hughes). A closer look at the invertebrate ecology of the streams, especially the shredder communities, is also needed.

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