A PRELIMINARY STUDY

OF

NORTH AMERICAN *SCHIZOPORA* SPECIES

FACULTY OF FORESTRY AND THE FOREST ENVIRONMENT
LAKEHEAD UNIVERSITY
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by

David C.I. Stevenson

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By

David C.I. Stevenson

A Graduate Thesis Submitted

In Partial Fulfilment of the Requirements

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ABSTRACT

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Advisor: Dr. E.C. Setliff

Key Words: *Hyphodontia*, *Schizopora*, taxonomy, cultural growth, phenol oxidase testing, somatic incompatibility, dikaryotic culture pairings.

Macro- and micro-morphological characteristics were examined among specimens of *Schizopora paradoxa*, *Schizopora flavipora*, and *Schizopora apacheriensis* collected from temperate and tropical North America. Characteristics which delineate these species are discussed and clarified. Possible synonymy with recently described poroid species of *Hyphodontia* is discussed. Keys for the identification of North American species and for world wide species are presented. From micro-morphological examinations mitic system and spore size were found to be delineating features of the genus. The use of cultural characteristics, phenol oxidase tests and somatic incompatibility were found to be of little use as definitive tests in separating the three North American species.

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D.C.I.S

January 27, 2007

CHAPTER 1

SCHIZOPORA SPECIES and DESCRIPTIONS

HISTORICAL BACKGROUND AND CURRENT TAXONOMIC PLACEMENT

HISTORICAL BACKGROUND

From the time it was established by Marinus A. Donk (1967) in his revision of European polypores, the genus *Schizopora* has been a difficult genus for fungal taxonomists to define. The genus was typified by the widely found fungus *Polyporus versiporus* Pers. Donk's decision on erecting the new genus was based upon a little known observation made by Velenovsky in 1922 (Donk 1967). Velenovsky wrote in his native Czech of a new genus whose members had "...instead of tubes there are angular nets producing lateral teeth" (Velenovsky 1922, Langer *et al.*1996). Donk felt that the description by Velenovsky, while not in Latin, deserved precedence due to its being the first published description of the genus (Donk 1967). Prior to 1935, Latin descriptions were not required for valid publication of names (Donk 1967, Langer *et al* 1996). Donk wrote:

> It is with some reluctance that I venture to introduce this genus. The name was published somewhat obscurely, but since it was definitely accepted as an alternative name and was accompanied by a description of its own in my opinion it cannot be suppressed. The contents are as yet made up of only a single, but versatile, species that is now currently known as *Poria versipora* (Pers.) Lloyd and for reasons of priority I now call *Schizopora paradoxa* (Schrad. per Fr.) Donk. (Donk 1967)

Donk chose the name *Schizopora paradoxa* as being the best name for the sole member of the genus after rejecting for legitimate reasons several previously published names (Donk 1967). Recognizing that the species is highly variable and had been described under many different names, he settled on the name *Hydnum paradoxum* (Schrad. per Fr.) as the earliest basionym given to the

fungus (Donk 1967). This species was first named by Schrader in 1794 and later incorporated into Fries' *Systema* in 1821 (Donk 1967). Combining the new genus name *Schizopora* with the earliest valid specific name *paradoxa* gave the full specific epithet for the newly named *S. paradoxa* (Schrad.:Fr.) Donk.

Donk recognized that many other species names were synonymous with *S. paradoxa*. The abundance of synonymous fungal names he blamed upon the "hymenophore" or pore surface which "... is notoriously very variable" (Donk 1967). Donk was not the only mycologist to recognise the difficulty of taxonomic placement for this genus. Lowe stated that "...as one of the most common species everywhere [*Poria versipora*] has a confused history" (Lowe 1966). Gilbertson and Ryvarden (1987) stated that "...there are some confusing collections from the Eastern United States. A more extensive investigation is necessary to solve the delimitation of species in this genus" (Gilbertson and Ryvarden 1987). Based upon this challenge, I decided to clarify the delineation of North American species in this genus and to make comparisons with other species described from around the world.

CURRENT TAXONOMIC PLACEMENT

Many authors have discussed the proper placement of the members of *Schizopora* in the overall taxonomy of fungi. Donk (1967) stated: "...I would not be surprised if it proves difficult to draw a clear line of distinction between *Schizopora* and the axially cystidiate species of *Hyphodontia*, although I am optimistic about the possibility". Gilbertson and Ryvarden (1987) commented that

"The microstructure of *Schizopora* species is like that of *Hyphodontia* of the Corticiaceae and the true phylogenetic position of *Schizopora* would be in that family. The morphological variation in the genus [*Schizopora*] is great and specific entities are not clearly understood".

David and Rajchenberg (1992) mentioned that in unpublished cultural work *Schizopora* cultures "...develop drepanocysts as do many *Hyphodontia* species". This observation suggests a close relationship between the polyporoid *Schizopora* and the corticoid *Hyphodontia* as has been pointed out several times". Langer (1994), in his monograph of the genus *Hyphodontia*, describes various species of *Schizopora* but conserves the genus name against that of *Hyphodontia*. Langer's (1998) ribosomal DNA studies "...did not confirm monophyly of *Hyphodontia*, but clearly supported that *Schizopora* species are within a common clade with other *Hyphodontia* species".

A proposal to reject the genus names *Xylodon* and *Schizopora* was made to the Committee for Fungi in 1996 (Langer *et al.*1996). *Xylodon* was an old genus name used by Bondartsev and others for *Poria versipora* (Bondartsev 1971). The proposal was made by the authors because studies "...have shown that it is not possible to clearly distinguish *Schizopora* and *Hyphodontia* on the basis of either macro- or micromorphology" (Langer *et al.*1996). The proposal was accepted by the Committee in 1999 and the current taxonomic position of members of the genus *Schizopora* are as members of the genus *Hyphodontia* (Gams 1999). While it would appear that Donk's optimism was misplaced, it is not strictly true that the genera are inseparable because macroscopically, the members of *Schizopora* are poroid, while the species of *Hyphodontia* are not. Despite this macroscopic observation, Núñez and Ryvarden (2001) state "The

microstructure of *Schizopora* species is similar to that in *Hyphodontia* of the Corticiaceae, and the true phylogenetic position of *Schizopora* would be in that family".

Rather than using the new name *Hyphodontia*, the old name *Schizopora* will be used to describe the various species found worldwide for those that were validly published as such. As there are at least 86 species of *Hyphodontia* described, the study presented here will have the benefit of clarity with respect to those species formerly of the genus *Schizopora* which have not yet been published by their new genus name (Langer *et al* 1996). A recent study on DNA sequences led the latter authors to state "...species of *Schizopora* are now included within the genus *Hyphodontia*, but probably represent a genuine group of closely related species" (Paulus *et al.* 2000). It should be understood for this study however that this does not mean there is priority given to either *Schizopora* or *Hyphodontia* as valid names.

MACRO- AND MICROSCOPIC CHARACTERISTCS OF THE NORTH AMERICAN SPECIES OF *SCHIZOPORA*

The delimitation of specimens within the *S. paradoxa* complex and also among the other *Schizopora* species has been very difficult. From the "confused history" mentioned by Lowe to the "notoriously very variable" basidiocarp discussed by Donk, mycologists have struggled with *Schizopora* specimens (Lowe 1966, Donk 1967). Despite the question of whether the genus belongs to *Hyphodontia* or not, there seems to be a wide interpretation of some of the basic

characteristics found in *Schizopora* species. An examination of these characteristics is warranted and is discussed in the following sections.

HYPHAL SYSTEMS

The study of hyphal construction was introduced by Corner in a series of papers in 1932 (Donk 1964). Up to that point, hyphal types had been neglected as a taxonomic tool (Donk 1964). Corner stressed that to understand the types of hyphae in polypores, it was necessary to tease them apart with needles under a dissecting microscope prior to examination under a compound microscope (Corner 1953, Donk 1964). As the first mycologist to systematically examine hyphal construction, Corner developed a system of classifying hyphae into three main categories (Donk 1964). This system is known as the mitic system (Donk 1964).

The mitic system divides polypores into groups depending upon the types of hyphae encountered in their basidiocarps. The three types of hyphae were called generative, skeletal, and binding (Corner 1953). A trimitic basidiocarp is one in which all three hyphal types are encountered (Corner 1953, Donk 1964). A dimitic basidiocarp is one in which generative and skeletal hyphae or generative and binding hyphae are found (Corner 1953, Donk 1964). A monomitic system contains only generative hyphae (Corner 1953, Donk 1964). Clear separations of the three groups can be difficult to determine.

While dividing the hyphal construction of polypores into three main groups, Corner leaves open the possibility that even in those groups which are monomitic

there can be some room for interpretation. This is definitely the case in the three species of *Schizopora* described in North America. Lowe (1966) considered *Poria versipora* (*S. paradoxa*) to be monomitic with hyphae in the context ranging from 3-4 µm in diameter while being thin- to thick-walled (while in the trama the hyphae are thin-walled and 2-3 µm in diameter). However, Donk (1967) states "...[Lowe] has misunderstood the hyphal structure of *Poria versipora*, which is undoubtedly dimitic with skeletals". Gilbertson and Ryvarden (1987) in their flora *North American Polypores* described *S. paradoxa* and *S. flavipora* as being monomitic with tramal skeletal-like hyphal segments. However, in their flora *European Polypores* they described the same species as dimitic with few skeletal hyphae (Ryvarden and Gilbertson 1994). Ryvarden and Núñez (2001) in their most recent flora, *East Asian Polypores*, describe *S. flavipora* as monomitic and *S. paradoxa* as dimitic. Langer (1994) further complicates the matter by describing the hyphal system of *S. paradoxa* and *S. flavipora* as being pseudodimitic. As the mono- or dimitic nature of a polypore is often one of the first diagnostic features to be encountered when using a key for identification, this leads to considerable confusion and frustration for the student mycologist trying to identify specimens in this group.

A point all the authors seem to agree upon is that there are hyphae in the species *S. paradoxa* and *S. flavipora* which either are, or resemble strongly, skeletal hyphae. Corner (1953) stated that "...typical skeletal hyphae are unbranched, thick-walled, commonly aseptate, longitudinal, constructional hyphae of the first order in the growing region". In all the specimens examined for

this study, only one exhibited a skeletal segment arising from a thin-walled hypha at a clamp connection (FP-70898 *S. paradoxa*). Corner (1953) explains the genesis of skeletal hyphae as arising from the laterals of generative hyphae.

Care must be taken in looking for both skeletal and generative hyphae. Often generative hyphae can have thickened walls which can be mistaken for skeletal hyphae (Corner 1953). The lumen of the hyphae must be quite narrow, and the hyphae must be long unbranched and lacking septation to be considered skeletal. An example of this can be found in Figure 1.1. The wall thickness tends to be much greater than the width of the lumen and, in the specimens examined, skeletal hyphae are generally 3.0-5.0 µm in diameter. This is in contrast to the generative hypha seen in Figure 1.2, which is thin-walled to the point to which the wall thickness is not visible. Corner (1953) notes that generative hyphae are sometimes inconspicuous due to their thin walls. The specimens of all three North American species examined had a typical generative hyphae diameter of 2.0-3.0 µm. Generative hyphae could be encrusted lightly to heavily, sometimes to the point where the hyphae themselves were completely hidden in crystals.

A generative hypha with thickening walls can be seen in Figure 1.3. Corner (1953) states that generative hyphae can range from thin- to thick-walled and the latter can be mistaken for skeletal hyphae. The diameter of these generative hyphae rarely got much larger than the normal range of thin-walled generative hyphae for this genus (2.0-3.0 µm).

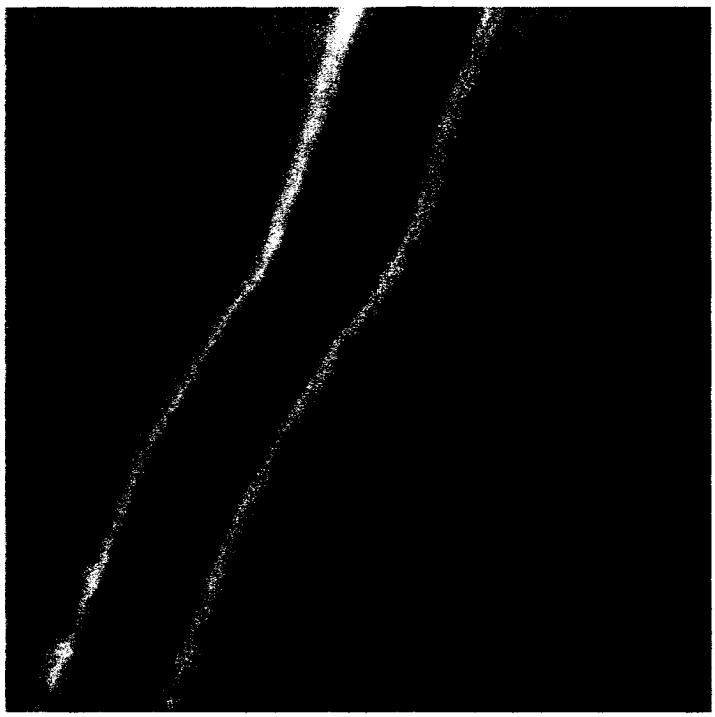

Figure 1.1 Skeletal hypha showing narrow lumen

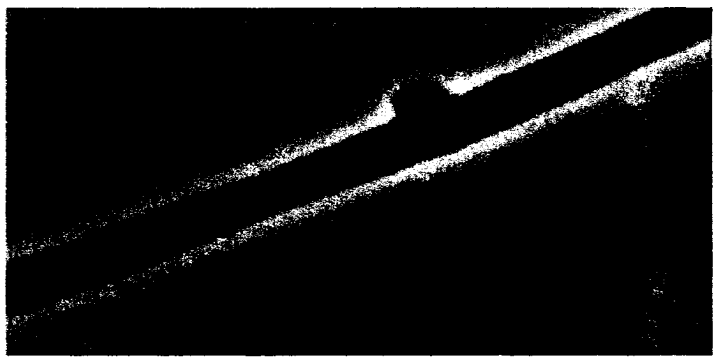

Figure 1.2 Generative hypha with a thin wall and clamp connections

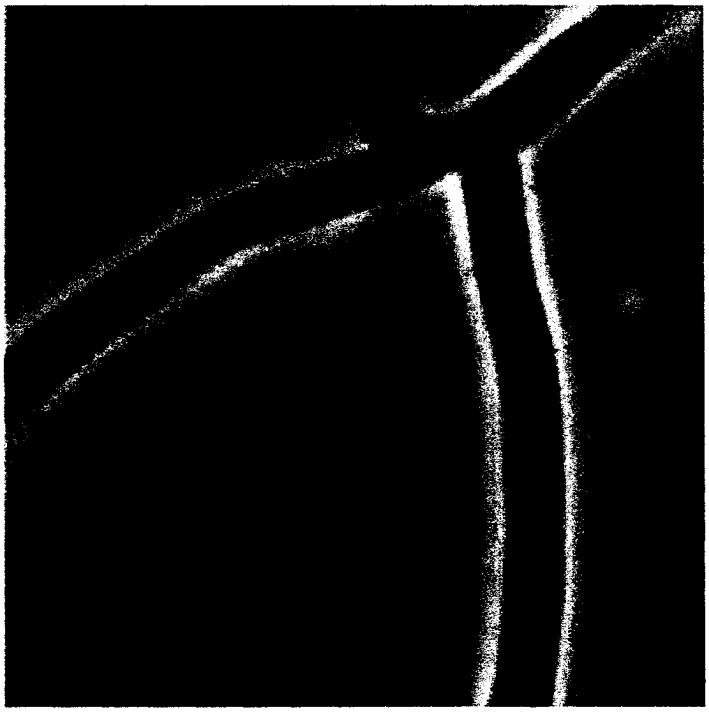

Figure 1.3 Generative hyphae with thickened walls

The North American species of *Schizopora* can be thus described according to their hyphal systems. For the sake of clarity, this study asserts that if skeletal-like hyphae are found along with thin-walled generative hyphae, then this is evidence of dimitism along the lines of Donk's understanding of the subject. *Schizopora paradoxa* and *S. flavipora* are therefore considered dimitic with generative hyphae and skeletal hyphae (Ryvarden and Gilbertson 1994). *Schizopora apacheriensis* is monomitic, having only generative hyphae. As hyphal sizes tend to be the same for all three species and both hyphal types, other microscopic characteristics must be used to delineate between the three species.

BASIDIOSPORES

The most reliable characteristic used to separate the species of *Schizopora* in North America is spore size and shape. While there are some difficulties with these characteristics, especially concerning variability in spore sizes in a species, they are the most diagnostic features for discerning between *S. flavipora* and *S. paradoxa.*

Schizopora paradoxa has spores which are smooth, thin-walled, hyaline, usually with one oil drop (guttulate), IKI-, ellipsoid, and 3.5-4.5 x 5.5-6.5 µm in size (see Figure 5). *Schizopora flavipora* has spores which are smooth, thin-walled, hyaline, ellipsoid, IKI-, and (2.5)3.0-3.5 x 3.5-4.5(5.0) µm in size (see Figure 6*). Schizopora apacheriensis* has spores which are smooth, thin-walled, hyaline, usually with one oil drop (guttulate), broadly ellipsoid to subglobose, and 4.0-5.5 x 5.0-6.5 µm in size (see Figure 1.4).

In this study, all spores were measured by finding spores with the proper lateral orientation with an apiculum. The measurement was taken from the tip of the apiculum to the end of the spore. As the spores are usually floating freely in a mixture of 2% KOH and phloxine, and frequently exhibit Brownian motion, measuring spore size was a time consuming task. Usually only spores which had become stuck to the cover slip or slide, or had become trapped in the hyphae were measurable.

It must be noted that the differences between the spore of *S. apacheriensis* and *S. paradoxa* are slight and differentiation between these two species is based upon the presence of skeletal hyphae (*S. paradoxa* being

dimitic and *S. apacheriensis* being monomitic). *Schizopora flavipora* can be separated from *S. paradoxa* and *S. apacheriensis* by a smaller spore size.

Figure 1.4 Basidiospore of *S. apacheriensis*

Figure 1.5 Basidiospores of *S. paradoxa*

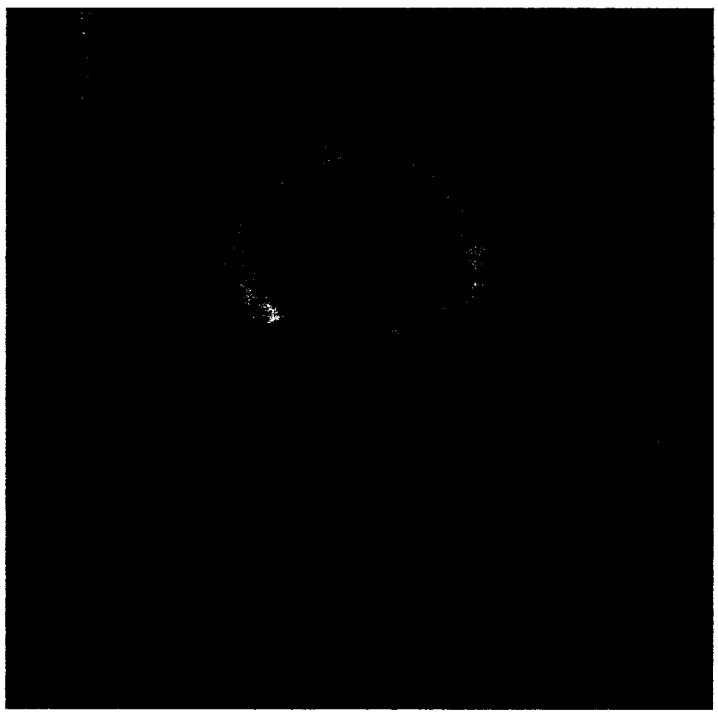

Figure 1.6 Basidiospore of *S. flavipora*

VARIATION IN BASIDIOSPORE SIZE

The present study arose in part from a desire to identify a number of *Schizopora* specimens collected by E.C. Setliff in Puerto Rico during 1991 and 1993. All specimens examined from Puerto Rico (save for ECS-2119 which was markedly different from the others) seemed to belong to a single group which closely resemble *S. flavipora* except for one aspect. The spore sizes of the Puerto Rican specimens were slightly smaller than published spore sizes for the species *S. flavipora*. The question became whether these might be considered a separate species or a variety influenced by genetic isolation on a small island, or just a population of *S. flavipora* with smaller spores. *Schizopora flavipora* has a published spore size range of (2.5)3.0-3.5 x 3.5-4.5(5.0) µm (Gilbertson and Ryvarden 1987). The Puerto Rican specimens had an average spore width of 2.99 µm (±0.10 at a 95% confidence level) and average spore length of 3.96 µm (±0.13 at a 95% confidence level). This puts the Puerto Rican specimens within the published range for *S. flavipora*, albeit towards the lower end of the range. The smaller spores sizes of the Puerto Rican specimens fell within a narrow range and their shapes were uniformly subglobose. Other specimens of *S. flavipora* from other parts of North and South America had an average spore width of 3.26 µm (±0.19 at a 95% confidence level) and average spore length of 4.39 µm (±0.20 at a 95% confidence level). An F-test of the different groups of widths showed that the probability that they are significantly different was 5.54 $x10^{-5}$, while an F-test of the lengths showed that the probability that they are significantly different to be 5.03 $x10^{-3}$. These findings show no statistically

significant difference between Puerto Rican specimens and other specimens from the Americas. A Belgian study of the *Schizopora* species of that country is one of the few studies which examine *Schizopora* spore sizes from a variety of specimens (Marchal 1989). The results show that in Belgium, for *S. flavipora*, spore widths average 2.9 µm (±0.30 at a 99% confidence level) and spore lengths average 3.6 µm (±0.30 at a 99% confidence level) (Marchal 1989). These results also fall within the published European range for *S. flavipora* (Ryvarden and Gilbertson 1994). While discussions of the statistical range of spore sizes has merit for comparison purposes it must be remembered that the theoretical resolution of a light microscope at 1000x magnification is 0.2 µm, while its practical resolution is 0.5 µm.

Discussions of spore sizes in statistical terms is however somewhat moot as what is technically significant in a statistical sense may not be so in a biological one. As an example, Parmasto and Parmasto (1982a) offered the following observation:

> "As a demonstration of such a case we may indicate one pair of basidiocarps of *Phellinus alni* growing on *Padus racemosa*: the difference between the mean spore lengths was insignificant on 3 June, 1969 ($P > 0.20$), but statistically significant on 15 October of the same year ($P \approx 0.30$)."

Spore size variability is of interest as it is relatively unknown what the natural range of spore sizes is for many species. Most published reports of spore size give a range of sizes, but no indication of how many spores were examined from different specimens (Parmasto and Parmasto 1982a). Furthermore, descriptions of new species usually include those spore sizes from the type

specimen only, giving no idea of how spore sizes vary within the population (Parmasto and Parmasto 1982a). The present study confirms the published spore size ranges for *S. flavipora* across a wide geographical range of the Americas.

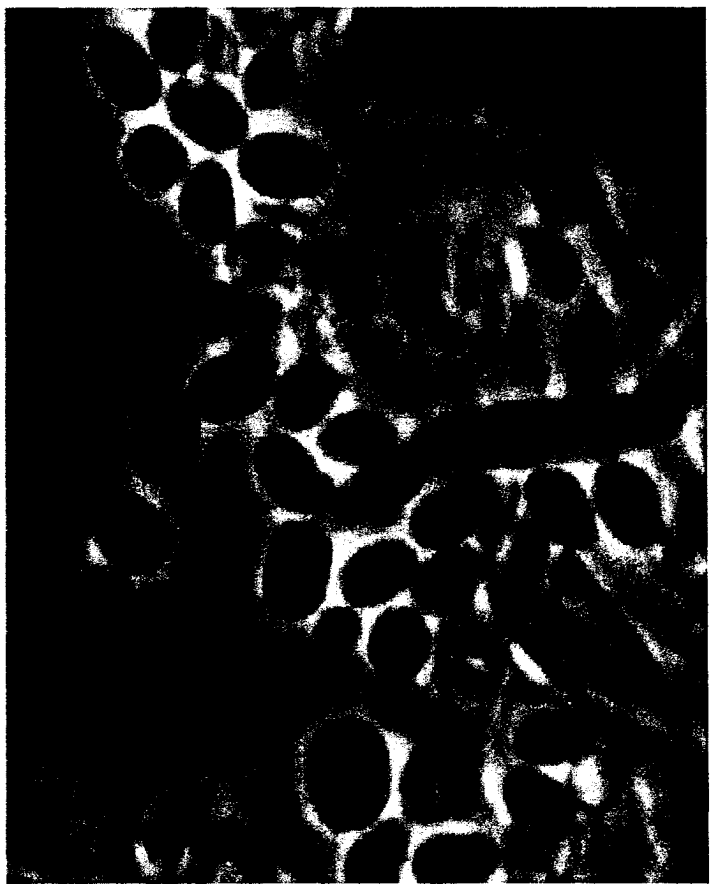

Figure 1.7 Anomalous spore size variation in *S. paradoxa* FP-103756

One exception to the regularity of spore sizes in the specimens examined was specimen FP-103756, collected in Virginia and identified as *S. paradoxa* by Dr. Gilbertson in 1965. As can be seen in Figure 1.7, a wide variation of spore sizes were present and represented an anomalous situation as far as observations of spore size in this study. This specimen is of particular interest and is discussed in further detail later in this chapter.

CYSTIDIAL AND HYMENIAL STRUCTURES

The species which comprise the North American members of the genus *Schizopora* have a variety of hymenial structures and cystidia in common. The most conspicuous of these are the capitate cystidia (see Figure 1.8) (Pegler 1973). While found in the hymenium and thus considered cystidia, these capitate structures can also be found throughout the trama and context in more or less abundance. While Pegler (1973) considered these structures to be cystidia, Bondartsev (1971) described them as "the normal ends of hyphae often terminating with spherical or pear-shaped inflations". Gilbertson and Ryvarden (1987) call these structures either cystidia or "tramal hyphal ends with spherical swellings". While the proper name for these structures is somewhat unclear, the diagnostic presence of them is not (Langer 1994).

Figure 1.8 Capitate cystidia

The swollen hyphal tips (or cystidia) can vary in size and length. Those found in the hymenial layer can be 10.0 x 25.0 µm long with an apical swelling of

4.0-10.0 µm in diameter. Those found in the trama or context can be of indeterminate length (up to at least 50 µm was observed on occasion) and with a larger apical swelling of 6.0-12.0 µm. While apical swellings were not often encrusted, the 'stems' sometimes were either lightly to heavily encrusted, particularly when found in the dissepiments. In addition to the apically swollen hyphae/cystidia more conventional cystidia were found.

Hymenial cystidia of a more conventional type were also found in the hymenial layer. These could take a variety of forms from hyphoid, clavate, lanceolate, or lageniform. While these cystidial forms were found in various degrees in the specimens observed, they are not useful for diagnostic purposes as they are found throughout all the species. One type of cystidia of special interest is that seen in Figure 1.9, an apically encrusted cystidium.

Figure 1.9 Apically encrusted cystidia

It is suspected that the crystals that make up such encrustations on cystidia are made of calcium oxalate (Barron 2002).

The presence of calcium oxalate as a crystalline deposit within the hymenium is interesting in that it is a feature of some variability. Specimens examined in this study exhibited a wide degree of encrustation. The author suspects that the feature is highly variable and dependent on several factors; biochemical activity of the fungus, predation, and the availability of calcium in the environment. Calcium oxalate is precipitated from solution according to the following equilibrium reaction; Ca^{2+} (ac) + $H_2C_2O_4 \leftrightarrow CaC_2O_4$ (s) + $2H^+$ (aq) (Whitehead 2004). This equilibrium between CaC_2O_4, calcium oxalate, and $H_2C_2O_4$, oxalic acid, depends upon several factors. The presence of calcium ions, pH, and the amount of water can shift the reaction to the left or the right (Whitehead 2004). As the amount of free water can be variable from day to day so can the presence of calcium oxalate (Whitehead 2004). It may also be possible that the use of dilute KOH and phloxine in the preparation of microscope slides can affect the amount of encrustation represented by calcium oxalate (Whitehead 2004). This is suggested as possible in diagrams of *Hyphochnicium polonese*, which distinguish between granularly encrusted cystidia when viewed in water and smooth cystidia when viewed in KOH solution (Langer and Oberwinkler 1993). This would suggest that KOH dissolves the crystals by driving the equilibrium reaction to the left side of the equation.

As oxalic acid is used as a defence chemical in other organisms (leaves of rhubarb for example) it is likely that it is used in such a way by fungi (Barron 2002). Not only is calcium oxalate a toxic compound, but on a microscopic level, it is likely a deterrent to feeding by micro-organisms on the hymenium due to the

spiny nature of the crystals (Shimada *et al.* 1997). Perhaps predation by such micro-organisms such as small mites triggers the production of encrustations on cystidia as a means of defending the hymenial layer. It is likely that defence provides part of the explanation for the calcium oxalate encrustations as they are most often found at the dissepiments (the first place a predator would likely have to go to feed on a resupinate basidiocarp). The environment likely also plays a role, as the absence of available calcium may limit the formation of encrustations in the hymenium. While much of this is speculation, further study of fungi in calcium limited environments, or with active predation, may shed some light on the formation and role of crystalline encrustations as a defence mechanism of fungi.

From the variety of specimens examined in this study it was impossible to use encrustations of cystidia as a diagnostic feature for the genus as the species examined showed a wide range of encrustation. Certainly one of the diagnostic features for *S. trichiliae* was encrusted cystidia very much like the one in Figure 1.9) (Ryvarden and Johansen 1980). This species has been deemed as synonymous with *S. flavipora* despite this supposedly diagnostic feature, likely because it shows up regularly in other species (Ryvarden 1985).

PORE SURFACE AND BASIDIOCARP HABIT

The most varied characteristics of the genus *Schizopora* and its species are that of the pore surface and basidiocarp habit. Problems in identification usually stem from this basic taxonomic feature. As there are a wide range of

possibilities that influence the characteristics of the basidiocarp; thus, it is important to keep an open mind during specimen identification.

Some characteristics are common to all the members of the genus. Basidiocarps are primarily resupinate which is defined as "...having the fruiting structure reclining on the substratum and facing outward" (Snell and Dick 1971). While this usually means that the basidiocarp grows in a horizontal fashion on the underside of a log or branch, it can also mean that the basidiocarp grows from surfaces which are reclined or even vertical. Observations made on basidiocarps during this study show that when the basidiocarp is found growing horizontally, the pores tend to be entire (albeit with a variety of shapes). When the basidiocarp grows from anything off the horizontal plane, the pores of *Schizopora* tend to split into lamellae. This is characteristic of the genus, as the name *Schizopora* itself means "with split pores" (Gilbertson and Ryvarden 1987). On the same basidiocarp it is not uncommon, if the growth is from the underside and up the side of a log or branch, to have both poroid and split pored areas. Much of the confusion over the naming of species in the past has come from this "notoriously variable" basidiocarp (Donk 1967).

When fresh, the pore surface is usually white to cream (see Figure 1.10) but dries to a cream-buff-ochreus-tan colour (see Figure 1.11). Pores can be round, angular, irregular, and daedaloid, to split and lamellate. All species tend to have split pores when growing off horizontal. Differences between species can be found in the number of pores per millimetre. *Schizopora apacheriensis* has irregular to daedaloid pores mostly 2-3 per mm but can be as large as 1 mm wide

(Gilbertson and Ryvarden 1987). *Schizopora flavipora* has round to angular or daedaloid pores which can be (3)4-6(7) per mm (Ryvarden and Johansen 1980, Gilbertson and Ryvarden 1987). *Schizopora paradoxa* is similar to *S. apacheriensis* in that there can be 1-3 pores per mm, but the split pores of *S. paradoxa* can develop into "irregular teeth in an irpicoid way" (Gilbertson and Ryvarden 1987).

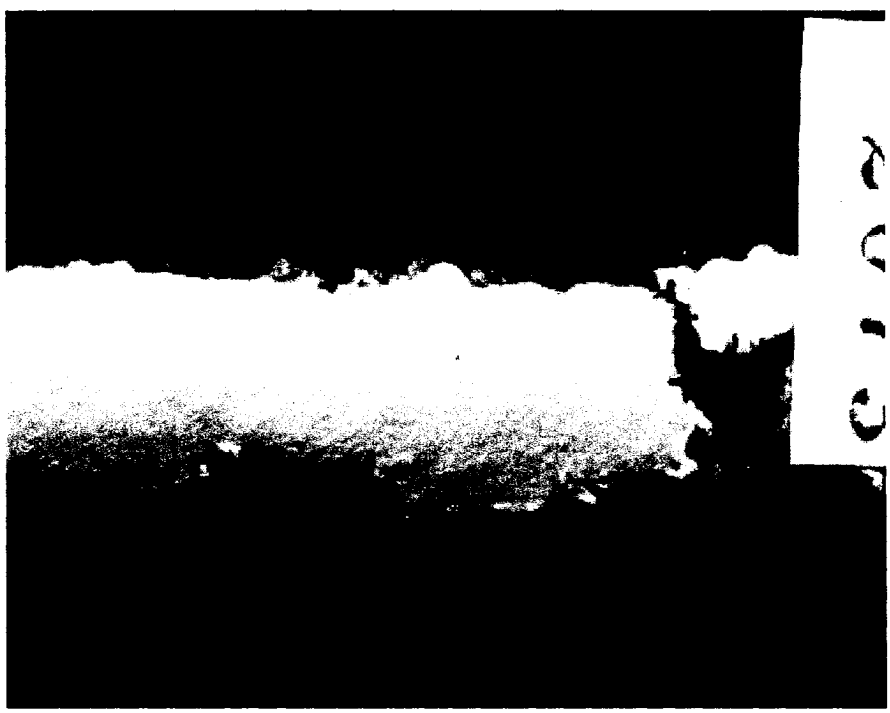

Figure 1.10 Fresh basidiocarp of *S. flavipora* (ECS-2073)

The three species of *Schizopora* commonly found in the Americas typically lack a pileus. Some specimens of *S. paradoxa* examined in this study formed a type of pseudo-pileus (See Figure 1.12). The samples which exhibited this, NYBG-559844 and NYBG-559847, were both growing from a vertical

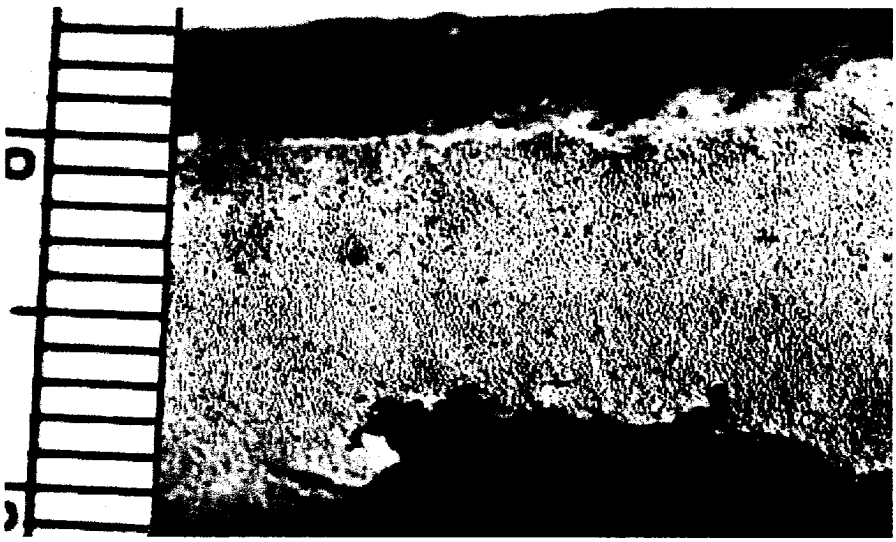

Figure 1.11 Dry basidiocarp of *S. flavipora* (ECS-2073)

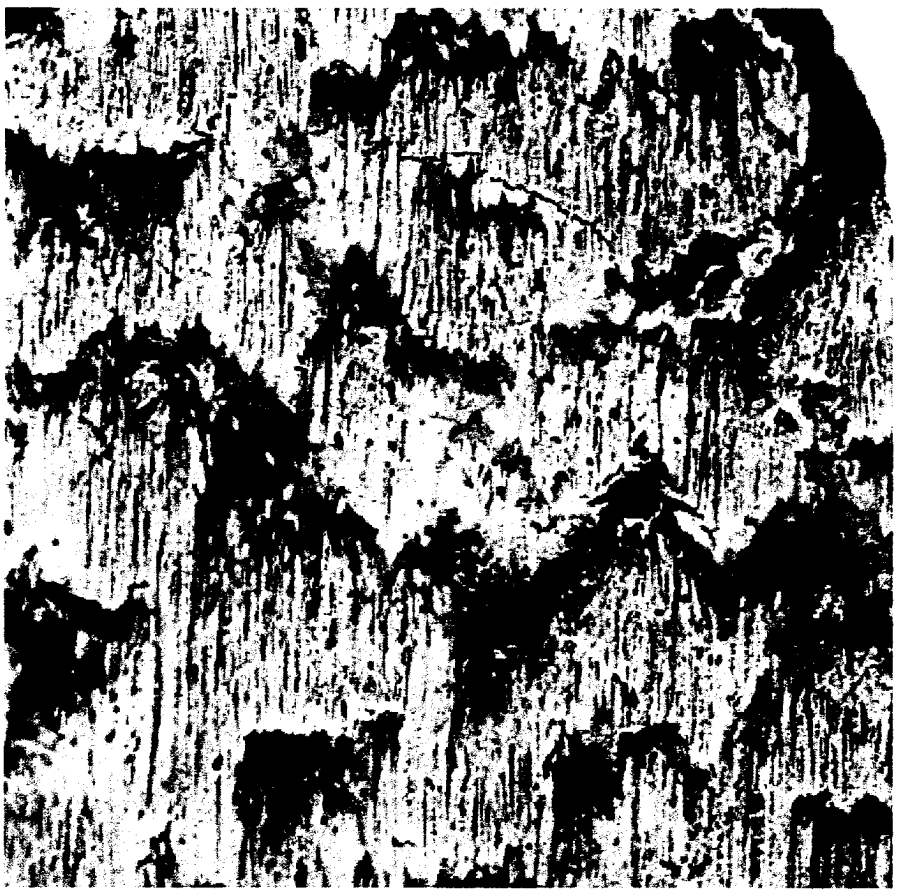

Figure 1.12 *S. paradoxa* showing pseudo-pileus (NYBG-559844)

substrate. It appeared that the fungus had grown on bark of a standing tree and had grown away from the bark surface to form the split tubes. Examination of the pseudo pileus was extremely difficult as it was of miniscule thickness and consisted of agglutinated hyphae of indeterminate type or thickness. It was not clear that the tissue observed was even part of this pseudo-pileus. While species from the Americas do not produce a pileus, there are species of *Schizopora* which do, *viz. S. cystidiata* and *S. trametoides*. It is likely that this pseudo-pileus represents the exposed context as a consequence of the growth habit of the basidiocarp on the vertical substrate. This would allow for tube development without the generation of a true pileus.

KEY TO GENERA OF FUNGI ALLIED WITH *SCHIZOPORA*

Table 1.1 Key to genera of fungi allied with *Schizopora* (adapted with permission from Ryvarden 1991, Núñez and Ryvarden 2001)

This key is a sub-key to the genera of polypore fungi and applies to fungi with the following characteristics: basidiocarps sessile to resupinate, hymenophore poroid, basidiospores smooth and negative in Meltzer's reagent, generative hyphae with clamps, tubes and context light coloured, cystidia present in hymenium and trama

1. Branched brown cystidia present in the hymenium and/or pilear surface ..... ***Echinochaete***
1. Cystidia hyaline and unbranched **2**

2. Hyphal system dimitic with skeletal hyphae, pore surface pinkish, yellow to pale brown, or violet.....**3**
2. Hyphal system Monomitic, pore surface white to sordid ochraceous when dry **5**

3. Basidiocarps pileate, pore surface often with violet shades when fresh.....***Trichaptum***

Table 1.1 Key to genera of fungi allied with *Schizopora* (continued)

3. Basidiocarps resupinate, pore surface cocoa-brown, pink to yellow	**4**
4. Cystidia ventricose, skeletal hyphae few, restricted to the context, causes a brown rot	***Auriporia***
4. Cystidia clavate, arising from skeletal hyphae, skeletal hyphae dominating, causes a white rot	***Junghuhnia***
5. Basidiocarps pileate, up to 4 cm thick, pilear surface hirsute, cystidia ventricose, up to 50 µm long	***Climacocystis***
5. Basidiocarps resupinate to pileate, up to 2 cm thick, pileus (if present) smooth or finely velutinous, cystidia ventricose to tubular	**6**
6. Cystidia tubular, thin-walled and smooth, basidiospores allantoid, 3-4 µm long	***Chaetoporellus***
6. Cystidia different, basidiospores globose to allantoid, longer than 4 µm	**7**
7. Pore surface pale lilac	***Porodontia***
7. Pore surface white to beige	**8**
8. Basidiospores globose, cystidia fusoid to mucronate	***Ceriporiopsis rivulosa***
8. Basidiospores cylindrical to allantoid, cystidia not fusoid to mucronate	**9**
9. Capitate hyphal ends absent, dissepiments not encrusted, brown rot species	***Oligoporus***
9. Capitate hyphal ends present, dissepiments encrusted, white rot species	**10**
10. Arthroconidia arising from hyphae on pileus	***Echinopora***
10. Arthroconidia absent	***Schizopora***

DESCRIPTIONS OF THE NORTH AMERICAN SPECIES OF *SCHIZOPORA*

SPECIMENS EXAMINED

Specimens examined for this study came from a variety of locations world wide, but concentrated on the North American species of *Schizopora*. Specimens from the Center for Forest Mycology Research (CFMR) in Wisconsin are preceded with the letters FP-, HHB-, L-, or PR-. The New York Botanical Gardens Herbarium (NYBG) is organized according to the original name given and the appropriate family. Thus *Schizopora* specimens are found in the Corticiaceae section under the genus heading. For the purposes of this study they have been identified by the letters NYBG- plus the number given to them by their original collectors (many specimens having been donated by collectors over the years). Specimens from the private collection of E.C. Setliff are similarly identified as ECS- along with the collection number given by Setliff. Specimens from A.L. Welden in the private collection of Setliff represent specimens Welden gave Setliff for identification. These specimens are followed by Welden's collection number. These, it should be noted, are not found in the collections of the FDH or the NYBG although other specimens submitted by Welden are. Specimens preceded by the letters CO- or VE- are splits from Kent Dumont, formerly of the NYBG, and are now in the collection of Setliff. Specimens preceded by RLG- are splits graciously provided by R.L. Gilbertson to the author for this study. A number of specimens examined during this study from various herbaria were misidentified and incorrectly labelled. While they play no part in

this study and have been properly annotated in their respective herbaria, they serve as a cautionary note to anyone attempting to use specimens from a collection. Correct identification of specimens is not a certainty, and must always be double checked against the relevant literature.

DESCRIPTION OF *SCHIZOPORA APACHERIENSIS*

Schizopora apacheriensis (Gilbn. and Canf.) Gilbn. and Ryv., North American Polypores, 704-705, 1987.

≡ *Poria apacheriensis* Gilbn. and Canf., Mycologia 65:1117, 1973.

First described as *Poria apacheriensis*, the species was later assigned to the genus *Schizopora* (Gilbertson and Canfield 1973, Gilbertson and Ryvarden 1987). The species seems to be found in the southern US and Gulf Coast. The type specimen is from Arizona while specimens examined for this study were from the Gulf Coast states of Florida and Mississippi.

Macroscopic Characteristics

As described by Gilbertson and Canfield (1973), the basidiocarp is annual, resupinate, and effused up to 10cm, with a soft fibrous texture. The pore surface is white to cream or light buff in colour. The margin can be sterile or fertile and up to 2mm in width. The margin is loosely tomentose. Pores are irregular in shape, sometimes daedaloid, and up to 1mm in diameter but usually 2-3 pores are found per mm. The dissepiments are thick and finely tomentose but become thin and deeply lacerate (Gilbertson and Ryvarden 1987).

Microscopic Characteristics

As described by Gilbertson and Canfield (1973), the hyphal system is monomitic, with both the tramal and subicular hyphae clamped. Subicular and tramal hyphae are 2-4µm in diameter with walls which are thin to somewhat thick

Figure 1.13. *S. apacheriensis* - dried basidiocarp of HHB-6677

and occasional branching. Tramal hyphae are incrusted at the edges of the dissepiments. There are occasional swollen or distorted hyphae imbedded in the tissue. Cystidia are of two types. Acicular or cylindrical hyphae are thin-walled and can be smooth or lightly encrusted (Gilbertson and Ryvarden 1987). These cystidia are 3-5µm in diameter and project up to 40µm. Capitate cystidia have a stalk 3-5µm in diameter and a swollen apex up to 10µm in diameter (Gilbertson and Ryvarden 1987). These cystidia can project up to 45µm. Basidia are basally clamped, have a medial constriction, are four stertigmate, and are 18-21 X 6-7µm in size (Gilbertson and Ryvarden 1987). Basidiospores are broadly ellipsoid to

subglobose, hyaline, smooth, IKI-, and thin-walled. They are 5-6.5 X 4-5.5µm in size (Gilbertson and Ryvarden 1987).

Rot Characteristics

Schizopora apacheriensis causes a white rot which becomes stringy in advanced stages (Gilbertson and Canfield 1973). It occurs as a saprophyte on dead stems and on the roots and root crown of recently killed plants (Gilbertson and Canfield 1973). It can be found on a variety of desert trees and shrubs including Emory oak, desert willow, Arizona walnut, velvet mesquite, turpentine brush, mortonia, agave, and cliffrose (Gilbertson and Canfield 1973).

Cultural Characteristics

As first described by Gilbertson and Canfield (1973), growth can be slow to very slow, covering plates of malt agar in 5-6 or more weeks. The advancing zone is submerged with radiating, branching, and plumose hyphal strands discernable to the limits of growth. The mycelial mat is submerged with a few aerial mycelia appearing after a few weeks at the point of origin. The submerged mat appears dense with radiating plumose strands visible throughout. Microscopically, the hyphae of the advancing zone are clamped, thin-walled, and 2-3µm in diameter. Gloeocystidia are also present with a diameter up to 8µm and often growing from a basal clamp (Gilbertson and Canfield 1973).

Specimens Examined

FP-101821 (Mississippi); HHB-6677 and HHB-4603 (Florida)

DESCRIPTION OF *SCHIZOPORA FLAVIPORA*

Schizopora flavipora (Cke.) Ryv. Mycotaxon 23:186, 1985.

≡ *Poria flavipora* Cke. Grevillea 15:25, 1886.

= *Poria pseudoobductens* Pilát Sborn. Nár. Mus. Praha B9 :1-109, 1953, *fide* Niemala (1987).

= *Schizopora phellinoides* (Pilát) Doms. Acta Soc. Bot. Pol. 38(2):255-269, 1969.

≡*Poria phellinoides* Pilát Bull. Soc. Mycol. Fr. 51:383, 1935.

= *Schizopora carneo-lutea* (Rod. and Cle.) Kotl. and Pouz., Česká Mykol. 33:21, 1979.

≡ *Poria carneo-lutea* Rod. and Clel. Roy. Soc. Tasman. Pap. Proceed. p 18, 1929.

= *Schizopora trichiliae* (Van der Byl) Ryv. *in* A preliminary Polypore flora of East Africa. p 533, 1980.

≡ *Polyporus trichiliae* Van der Byl, S. Afr. J. Sci. 18:262, 1922 (K, isotype).

= *Polystictus subiculoides* Lloyd Mycol. Writ. 7:1331, 1924 (K, isotype).

= *Polyporus acaciae* Van der Byl, S. Afr. J. Sci. 22:168, 1925 (teste Reid 1973:153).

This species represents the small-spored and small-pored taxon in the genus (Ryvarden 1985). First called *Poria flavipora* (Cooke), the species was later placed in the genus *Schizopora* (Ryvarden 1985). This species was previously called *S. trichilae* (van Byl) Ryv. (Ryvarden 1985). Also, *S. carneo-lutea* (Clel. & Rodw.) Pouz. is probably a synonym (Ryvarden 1985).

Macroscopic Characteristics

As described by Ryvarden (1985), basidiocarps are annual, resupinate, coalescing, and become widely effused. The texture is leathery when fresh and cork or tough and fibrous when dried. The margin is usually sterile, whiter than the pore surface, fimbriate, and up to 2mm in width. The pore surface is white to cream when fresh, becoming buff coloured upon drying. Pores are angular to daedaloid, 3-5 per mm, with thin dissepiments which often split to form an irpiciform pore surface. The context is cream to buff, without zones, corky and <1mm thick. Tubes are the same colour and up to 3mm long (Ryvarden 1985).

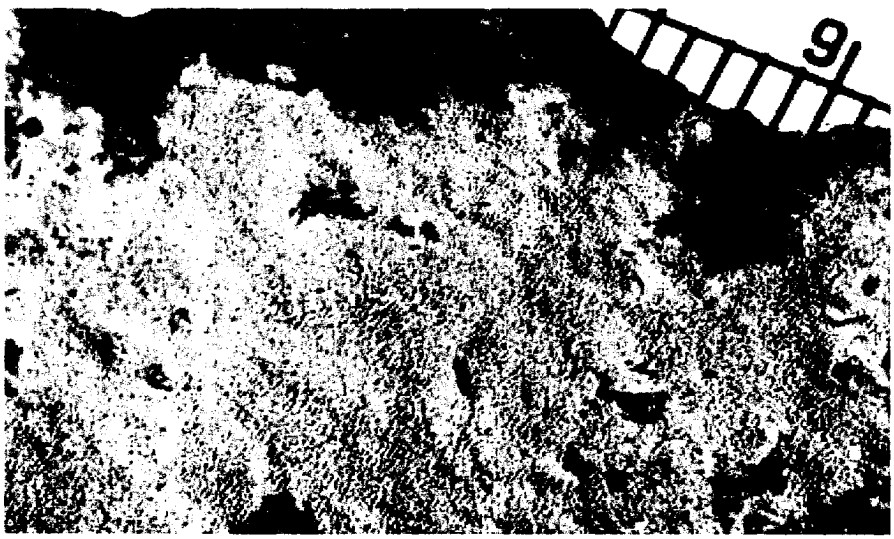

Figure 1.14 Dried basidiocarp of *S. flavipora,* ECS-1938

Microscopic Characteristics

As described by Ryvarden (1985), the hyphal system is dimitic with infrequent skeletal hyphae. Generative hyphae are thin-walled (2-6µm), hyaline with frequent branches. Some hyphae have a bulbous thin-walled apex, up to 12µm in diameter. Skeletal hyphae are thick-walled, unsegmented, and thinner

Figure 1.15 Fresh basidiocarp of *S. flavipora,* ECS-1938

towards their apices. Tramal and subicular hyphae have the same characteristics. Cystidia are absent but fusoid cystidioles 3-4µm in diameter are present. Basidia are basally clamped, clavate, with a median constriction, are four stertigmate, and are 12-15 X 5-6µm in size. Basidiospores are ellipsoid, hyaline, smooth, IKI-, thin-walled, and 3.5-5 X 2.5-3.5µm in size (Ryvarden 1985).

Rot Characteristics

Schizopora flavipora causes a white rot of dead hardwoods, rarely of gymnosperms (Gilbertson and Ryvarden 1986, Wu 2000). It is found worldwide throughout the warm temperate and tropical zones (Gilbertson and Ryvarden 1986).

Cultural Characteristics

Growth is relatively slow and covers the plates in 4-weeks. The advancing zone is even with a white mycelial mat. Aerial mycelia are absent at first, to slightly pellicular to absent later. Hyphae are hyaline, clamped, thin-walled, and 1.5-7µm in diameter. Cystidia are clavate with an occasional medial constriction and 15-30 X 6-10µm in size. Rod-like crystals are present in the medium (Wu 2000).

Specimens Examined

ECS-1938, ECS-2068, ECS-2073, ECS-2082, ECS-2218, ECS-2529, and PR-1257 (Puerto Rico); NYBG-2966, CO-7521, and CO-544 (Columbia); NYBG-5459 NYBG-5586, VE-6409, VE-3758, and VE-5219 (Venezuela); FP-101622 and FP-101628 (Taiwan); FP-102561 (Mississippi); HHB-9460 (Florida); NYBG-559834 (Louisiana); NYBG-197 (Jamaica); NYBG-628 (Tanzania); NYBG-1115 (Kenya); and NYBG-1414 (Peru)

DESCRIPTION OF *SCHIZOPORA PARADOXA*

Schizopora paradoxa (Fr.) Donk. Persoonia 5:76, 1967.

≡ *Hydnum paradoxum* Fr. Syst. Mycol. 1:424, 1821.

≡ *Irpex paradoxus* (Schrad.:Fr.) Fr. Epicr. 1836-1838.

= *Poria versipora* (Pers.) Rom., Svensk Bot. Tidskr. 20:15, 1926

≡ *Polyporus versiporus* Pers., Myc. Europe 2:105, 1825.

= *Poria platensis* Speg., Buenos Aires Mus. Argen. Cien. Nat. Anal. 8 :53, 1902 (isotypes – BPI & S)

= *Poria mucida* var. *irpicoides* Jaap, Fungi Sel. Exs. 233, 1907 (paratypes – BPI & FH)

= *Poria lignicola* Murr., Mycologia 12:307, 1920.

= *Poria jalapensis* Murr. Mycologia 13:177, 1921. (NY; BPI; FH; K; SYRF)

= *Poria ochracea* Murr. Mycologia 13:174, 1921. (NY; BPI; FH; K; SYRF)

First placed in *Schizopora* by Donk, the fungus is based upon *Hydnum paradoxum* Fr. Among the many synonyms for this fungus is the widely described *Poria versipora* (Pers.) Rom. from 1926. The name is derived from the paradox that it provided the author Fries when he originally described it. The paradox Fries faced is likely due to the highly variable character of the pore surface which ranges from poroid to dentate in form. The genus name *Schizopora* (*"schizo"* – split; *"pora"* – pored) also derives from the pore surface habit referring to the split or lacerate pores that the fungus can sometimes exhibit.

Macroscopic Characteristics

As described by Gilbertson and Ryvarden (1987), basidiocarps are small to large, resupinate, and tough. When growing on a vertical surface it can form small nodules with a fertile underside but lacking a real pileus. The colour is whitish cream when fresh darkening to a greyish - ochraceous - brownish colour when aged. Basidiocarps are 1-5mm thick. The pore surface is usually poroid with lacerate to denticulate dissepiments. The pores can be quite irregular to labyrinthine in shape. On sloping surfaces the tubes can be elongated or split

into irregular teeth. Tubes tend to be shallower towards the undifferentiated margins (Gilbertson and Ryvarden 1987).

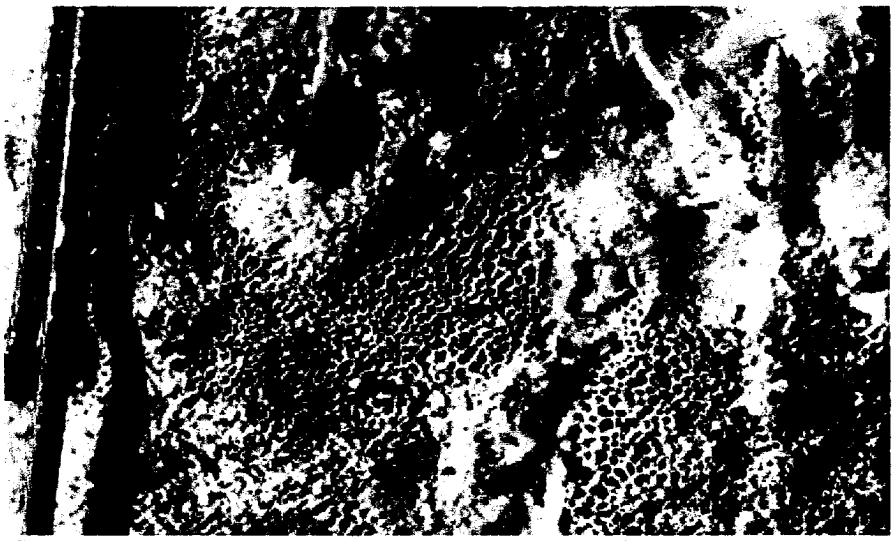

Figure 1.16 *S. paradoxa*: dried basidiocarp of HHB-6507

Microscopic Characteristics

As described by Gilbertson and Ryvarden (1987), the hyphal system is dimitic. Generative hyphae are thin- to somewhat thick-walled, hyaline, clamped, branched, and 2-3µm in diameter. Skeletal hyphae can be infrequent but are 3-4(-5) µm in diameter, hyaline to yellow, and straight to sinuous. Hyphal tips at the ends of the dissepiments are often incrusted with granular crystals. Hyphae with a globose apex 7-12µm in diameter are present throughout the trama. Basidia are suburniform, basally clamped, four stertigmate, and 15-20 X 4-5µm in size. Basidiospores are ellipsoid, hyaline, thin-walled, usually with an oil drop, and 5-6(-6.5) X 3.5-4µm in size (Gilbertson and Ryvarden 1987).

Rot and Cultural Characteristics

Schizopora paradoxa causes a white rot on wood of all kinds. The fungus is widely spread and circumglobal (Gilbertson and Ryvarden 1987). The vegetative growth of *S. paradoxa* in culture is described by Domanski (1969) as follows:

> Growth of the mycelium in culture is moderately quick, covering the plate in two weeks. The mycelial mat was appressed and translucent with a whitish colour. The mat was of a fine cottony-felty to woolly texture. Aerial hyphae are clamped and thin-walled but frequently develop segments with thick, yellowish modified walls. Submerged hyphae clamped, more or less branched and developing swollen vesicles 5-10µm in diameter. (Domanski 1969).

Specimens Examined

ECS-2119 (Puerto Rico); ECS- 3049 (British Columbia); L-15844 (New York); HHB-6700 and HHB-6507 (Florida); FP-103659 and FP-103756 (Virginia); FP-105695 (Georgia); HHB-271 and FP-70898 (Maryland); NYBG-559844 and NYBG-559847 (Mississippi); NYBG-559850 and NYBG-559851 (Louisiana); and NYBG-1413 (California).

KEY TO THE NORTH AMERICAN SPECIES OF *SCHIZOPORA*

Table 1.2 Key to the *Schizopora* species of North America

1. Monomitic (skeletal-like hyphae absent)	*S. apacheriensis*
1. Dimitic (skeletal-like hyphae present)	2
2. Basidiospores >5 µm long and >3.5 µm wide	*S .paradoxa*
2. Basidiospores <5 µm long and <3.5 µm wide	*S. flavipora*

DESCRIPTIONS OF EXTRALIMITAL SPECIES OF *SCHIZOPORA* AND THE POROID *HYPHODONTIA*

The intent of the following descriptions of species is to present a comprehensive look at species of *Schizopora* and the poroid *Hyphodontia* from locations other than North America. The information presented in the following section comes solely from published reports. None of the following extralimital species were examined for this study. Table 1.3 presents a summary of the important characteristics of the North American and extralimital species. The construction of a worldwide key for these species follows.

Schizopora radula (Pers.:Fr.) Hallenb. Mycotaxon 18:308, 1983

≡ *Polyporus radula* Pers.:Fr. Syst. Mycol. 1:383, 1821.

≡ *Poria radula* Pers. Obs,. Mycol. 2:14, 1799.

= *Polyporus versiporus* Pers. *pro parte* Mycol. Europ. 2:105, 1825.

First described as *Poria radula* by Persoon in 1799, this fungus was included in Fries' book *Systema Mycologica* of 1821 as *Polyporus radula* Pers.:Fr. Another synonym is *Polyporus versiporus* Pers. Hallenberg placed it in the genus *Schizopora* in 1985. The species is found throughout Europe but appears to be more prevalent in Central and Southern Europe than *S. paradoxa*. The distribution is unclear as until Hallenberg identified it as a separate species,

it was treated as part of the *S. paradoxa* species complex (Ryvarden & Gilbertson 1994). As regards this species there is a difference in interpretation between North America and Europe (Donk 1967). *Poria radula* (Pers.Fr.) Cooke collections are considered by North American scientists to be *Junghuhnia separabilima* (Pouz.)Ryv. in North America. (Gilbertson and Ryvarden 1986).

Schizopora radula (Pers.:Fr.) Hallenb. causes a white rot of dead hardwoods (and more rarely of conifers) (Hallenberg 1983). It is found on hardwoods of the genera *Alnus, Betula, Carpinus, Castanea, Corylus, Fagus, Fraxinus, Populus, Quercus, Salix*, and *Sorbus*. It is found infrequently on conifers of the genera *Abies, Juniperus, Picea*, and *Pinus* (Ryvarden & Gilbertson 1994).

Table 1.3 Summary of important characteristics of *Schizopora* and poroid *Hyphodontia*

Species	Hyphal System	Basidiocarp Habit	Hyphal Septation	Spore Size & (Shape)	Pore Size & (Shape)	Fresh Pore Surface Colour
S. radula[1]	monomitic	resupinate	clamped	5 X 3-4 µm (ellipsoid)	1-3/mm, (angular)	yellowish-cream to ochraceous with a distinct orange tint.
S. trametoides[2]	trimitic	pileate	clamped	(4)4.5-5 X 2-2.5 µm (subellipsoid)	3/mm (dentate) to 1-2/mm (lacerate)	straw coloured with a weak orange tint.
S. cystidiata[3]	monomitic	resupinate - pileate	clamped	5-6 X 3-4 µm (ovoid to ellipsoid)	2-3/mm	milky-white
H. syringae[4]	monomitic	resupinate	clamped	(7.5)8-9 X (2)3-3.5 µm (suballantoid)	1 mm -3 mm (large & irregular)	white to cream
H. notofagi[5]	monomitic	resupinate	clamped	5-6.5 X 1.5-2 µm (cylindric – suballantoid)	1-4/mm (round to labyrinthine)	chalky white
H. hallenbergii[6]	monomitic	resupinate	clamped	4.2-5 X 4-4.3 µm (subglobose)	3/mm (angular to raduloid)	ivory to cream
H. poroideoefibulata[6]	monomitic	resupinate	simple septate	5-5.7 X 4-4.5 µm (subglobose)	4-5/mm (angular to round)	cream to ivory yellow
H. taiwaniana[6]	monomitic	resupinate	clamped	4.5-5.5 X 2.6-3 µm (ellipsoid)	4-6/mm (angular to round)	cream
H. nongravis[7]	dimitic	resupinate	clamped	4-5.2 X 3.3-4 µm (ellipsoid)	3-4/mm (angular)	cream
H. tropica[7]	dimitic	resupinate	clamped	3.7-4.3 X 2.8-3.3 µm (ellipsoid)	5-9/mm (angular)	cream to pinkish cream or buff
H. niemelaei[8]	monomitic	effused	clamped	6.2 X 3.3-4.0 µm (ellipsoid)	3 per mm (round)	cream
S. apacheriensis[9]	monomitic	resupinate	clamped	5-6.5 X 4-5.5µm (ellipsoid to subglobose)	2-3/mm (irregular to daedaloid)	white to cream or light buff
S. flavipora[9]	dimitic	resupinate	clamped	3.5-5 X 2.5-3.5µm (ellipsoid)	3-5/mm (angular to daedaloid)	white to cream
S. paradoxa[9]	dimitic	resupinate	clamped	5-6(-6.5) X 3.5-4µm (ellipsoid)	irregular to labyrinthine	whitish cream

1-(Hallenberg 1983); 2-(Suhiman and Nùñez 1998); 3-(David and Rajchenberg 1992); 4-(Langer 1997), 5-(Buchanan & Ryvarden 1988); 6-(Wu 2001); 7-(Wu 2000); 8-(Wu 1990); 9-(Gilbertson and Ryvarden 1987)

Schizopora trametoides Nùñez Mycotaxon 68:157-164, 1998.

Schizopora trametoides, first described in 1998 from Sumatra, Indonesia, is very similar to *S. cystidiata* in that it possesses a pileus which is up to 6 cm long (Suhiman and Nùñez 1998). However, *S. trametoides* is described as trimitic (Suhiman and Nùñez 1998). The description of the hyphae of *S. trametoides* leaves a bit of room for speculation however. The generative hyphae are described as thick-walled (up to 2.5 µm) as are the skeletal hyphae (up to 5.0 µm) and the binding hyphae (up to 3.5 µm). Perhaps the binding hyphae are just developing skeletal hyphae (the diagrams given for this species make the binding hyphae look like skeletal hyphae). The authors also suggest that the specimens examined remind them strongly of *Trametes* (thus the name) and possibly there are some evolutionary connections between the two genera (Suhiman and Nùñez 1998).

Schizopora cystidiata David & Rachenb. Mycotaxon 45:131-148, 1992.

Schizopora cystidiata, a monomitic species first described in 1992 from the Reunion Islands, possesses a distinct pileus which is up to 0.7 cm in radius (David and Rajchenberg 1992). Langer (1994) gives specimen records for Italy, Madagascar, and Australia. It is named due to its distinct hymenial cystidia with thickened walls and an apical encrustation. While the authors state that such cystidia are not found in *S. flavipora*, *S. apacheriensis*, and *S. paradoxa*, the

present study shows that they are indeed a feature of other species of the genus (David and Rajchenberg 1992). The cystidia of *S. cystidiata* differ from those of the other species, not in their apical encrustation which is a variable but not uncommon feature, but in the thickness of the cystidial wall (up to 1 µm in thickness).

Hyphodontia syringae Langer Mycotaxon 67:181-190, 1997.

While placed in the genus *Hyphodontia*, this new species, first described by Langer in 1997, is closely related to those described in the genus *Schizopora*. Langer mentions that *H. syringae* is closely related to *S. apacheriensis, H. notofagi,* and *H. neimalaei* (Langer 1997). Langer separates *H. syringae* from *H. notofagi* (the species it most closely resembles) by several characteristics: longer spores, longer basidia, cystidia of different shape, and bigger pore size (Langer 1997). The type species was collected from a montane forest ecotype from "the bark of dead branches of *Syringa reticulata* var. *mandshurica* and deciduous trees(Langer 1997). It is known to cause a white rot (Langer 1997).

Hyphodontia notofagi (G.H. Cunn.) Langer Bybliotheca Mycologia 154:1-298, 1994

≡ *Schizopora nothofagi* (G.H. Cunn.) P.K. Buchanan and Ryv. Mycotaxon 31(1):1-38, 1988.

≡ *Poria nothofagi* G.H. Cunn. Polyporaceae of New Zealand, 47-48, 1965

This species was first described in 1965 from New Zealand as *Poria notofagi* by Cunningham (1965). It was later moved to the genus *Schizopora* by Buchanan and Ryvarden (1988). Ryvarden (1985) separates *H. notofagi* from *S. paradoxa* by two characteristics; spore shape and mitic system. *Hyphodontia notofagi* is monomitic and has "cylindrical to suballantoid spores" (Buchanan & Ryvarden 1988). Langer (1994) placed it in the genus *Hyphodontia*. The fungus causes a white rot of standing dead saplings, fallen branches, and trunks of trees of the genus *Notofagus* (Cunningham 1965).

Hyphodontia hallenbergii Sheng H. Wu Mycologia 93(5):1019-1025, 2001.

This species is one of several which have been recently described from Taiwan (Wu 2001). Wu delineates this species from *H. neimelaei* (the species it most resembles) by three characteristics and by cultural compatibility (Wu 2001). *H. hallenbergii* differs from *H. neimelaei* in that its pores remain intact (instead of splitting, its spores are ellipsoid (instead of subglobose), and its spores are wider and shorter (Wu 2001). Wu found that three different single spore cultures of *H. hallenbergii* were incompatible with a "secondary mycelium" of *H. neimelaei* (Wu 2001). No specific mention of rot type is given by the author. The sole substrate mentioned is that of a branch of *Cryptomeria japonica* (Wu 2001).

Hyphodontia poroideoefibulata Sheng H. Wu Mycologia 93(5):1019-1025, 2001.

This newly described species is remarkable in that it shares many of the characteristics of species of *Schizopora* and also that it is simple septate. Several species of *Hyphodontia* which are non-poroid also share this simple septation (an example being *H. subgobosa*) (Wu 2001). This species closely resembles *Poria terrestris* (DC. ex Fries) Sacc. in most of its features, except that it has slightly larger spores and smaller pores (Lowe 1966, Wu 2001). The type of rot produced by this fungus is not mentioned by the author except that the substrate is an angiosperm. The species is known only from Taiwan (Wu 2001).

Hyphodontia taiwaniana Sheng H. Wu Mycologia 93(5):1019-1025, 2001.

Wu (2001) notes that this species is similar to *H. neimelaei* except that its spores are narrower. The species is also closely related to S. flavipora but has "slightly longer and narrower basidiospores" (Wu 2001). The type of rot this species produces was not mentioned nor its substrate, other than it was found on dead angiosperms and gymnosperms. The species is known only from Taiwan (Wu 2001).

Hyphodontia nongravis (Lloyd) Sheng H. Wu Mycotaxon 76:51-66, 2000.

≡ Polyporus nongravis Lloyd Mycol. Writ. 6: 891, 1919.

Previously described as *Polyporus nongravis* in 1991, Wu has reassigned this species to *Hyphodontia*. Although Ryvarden feels that this species is a synonym of *S. flavipora*, Wu argues that *S. flavipora* lacks encrusted cystidia and separates the species on this basis. Macroscopically, Wu separates the two species in that *H. nongravis* has a much thicker basidiocarp which is reflexed from the margins (Wu 2000). The fungus is described as a saprophyte of angiosperms (Wu 2000). The species is known form Sri Lanka, China, and Taiwan (Wu 2000).

Hyphodontia tropica Sheng H. Wu Mycotaxon 76:51-66, 2000.

Described in 2000 from collections in Taiwan, Wu has delineated this species as separate from *S. flavipora* due to slightly smaller pores and slightly shorter spores (Wu 2001). The fungus is described as a saprophyte of various deciduous species of trees but is found on rare occasions on conifers (Wu 2000). Wu (2000) makes a distinction between *H. tropica* and *S. flavipora* according to ecological adaptation. *Hyphodontia tropica* is found in the subtropical or tropical regions of Taiwan below 850m elevation whereas *S. flavipora* has a wider range on the island and is found at elevations up to 2000m (Wu 2000).

Hyphodontia niemelaei Sheng H. Wu Acta Bot. Fennica 142:1-123, 1990

Described from Taiwan in 1990 by Wu, this fungus is quite similar to *S. apacheriensis* (Gilbertson and Canfield) except for three characteristics that Wu mentions. First, the spores of *H. niemelaei* are narrower than those of *S. apacheriensis* (Wu 1990). Second, the subiculum of *H. niemelaei* contains "capitate cystidial elements instead of fusiform hyphal ends" as found in *S. apacheriensis* (Wu 1990). Finally, Wu mentions that the tubes of *H. niemelaei* are "perhaps" shorter than those of *S. apacheriensis* (Wu 1990).

DESCRIPTIONS OF SPECIMENS EXAMINED WITH SIMPLE SEPTATION

Five specimens examined during this study exhibited many of the features of *Schizopora* / *Hyphodontia*, but were found to have simple septation of hyphal cells. Three specimens (PR-1257, ECS-2129, and ECS-2241) were found in Puerto Rico, while specimen Welden-1911 was found in the Dominican Republic and specimen FP-103756 in Virginia. PR-1257 was determined to be *S. flavipora* by Ryvarden in 1990, while FP-103756 was determined to be *S. paradoxa* by Gilbertson in 1965. Specimen Welden-1911 was undetermined by A.L. Welden and given to E.C. Setliff for further work. Specimens ECS-2129 and ECS-2241 were collected in Puerto Rico in 1990 and provisionally described as an unknown *Schizopora* species by Setliff.

Macroscopically these specimens strongly resemble *S. flavipora* and *S. paradoxa*. Basidiocarps are resupinate and found on the dead wood of

angiosperms. Pores are cream in colour, angular to round, sometimes split, and 3-7 per mm. Margins are white to light cream with no rhizomorphs or arachnoid habit observed.

Microscopically they are also similar to *Schizopora* / *Hyphodontia*. Spores were mainly ellipsoid with the largest examples being subcylindrical and the smallest being subglobose. Spore sizes range from 2.0-5.0 x 3.0-6.0(8.0) µm. While this is a large range of spore sizes, it must be remembered that the specimens were collected over a large geographical area and at very different periods. Spore sizes can range quite a bit due to these factors (Parmasto and Parmasto 1982a).

These specimens differ from *Schizopora* / *Hyphodontia* in a few major ways. All five specimens are monomitic with simple septate hyphae with a size range of (1.5)2.0-6.0 µm. Apically encrusted cystidia are present (Figure 1.17) and lack a basal clamp connection. These cystidia are similar to those found in *S. flavipora* but are not to be confused with the capitate cystidia (or swollen hyphal tips) normally found in the genus *Schizopora* / *Hyphodontia*. Cystidia of this type were not observed in any of the specimens examined. This would appear to be a major difference between these five specimens and the genus *Schizopora*. Capitate cystidia are however found in the genus *Hyphodontia* (Langer 1994). This characteristic and the presence of hyphodontoid branching (Figure 1.[illegible] would lead one to believe that these specimens belong in some way to this genus. If this is indeed the case, then these specimens must be compared with previously described specimens of the same genus. As *H. poroideoefibulata* is

the only species described as monomitic, simple septate and poroid within the genus *Hyphodontia*, an examination of the similarities and differences would be useful.

Figure 1.17 Apically encrusted simple septate cystidia

Most of the features of these simple septate specimens are similar micro- and macroscopically to *H. poroideoefibulata* (Table 1.4). On a microscopic level, the hyphal systems are monomitic and the hyphae are simple septate. They have similar hyphal sizes. They have apically encrusted cystidia which are basally simple septate. Basidia are of the same shape and size. Macroscopically, the basidiocarps are resupinate and of the same colour. Pore sizes are also similar.

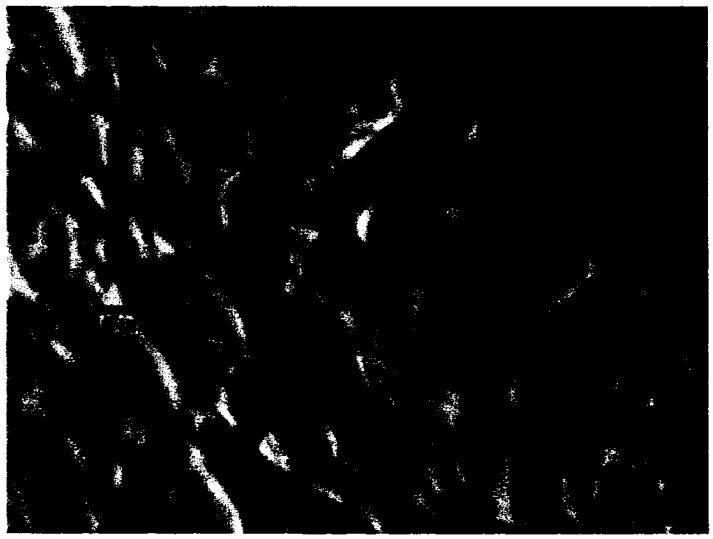

Figure 1.18 Hyphodontoid branching at hymenial layer

The only major difference is in the shape of the spores. Spores for *H. poroideoefibulata* are subglobose and guttulate whereas the spores for these specimens are ellipsoid and non-guttulate. The range of spore sizes for these specimens is also greater but may represent more of the natural range of spore size as *H. poroideoefibulata* is only known from the type specimen. Whether this sole differentiating characteristic is enough to separate these specimens into a species distinct from *H. poroideoefibulata* is a difficult question. While the specimens examined here were initially suspected to be *Poria terrestris*, later comparisons with *bona fide* collections of *Byssoporia (*formerly *Poria) terrestris* showed them to be different. They are indeed very similar to *H. poroideoefibulata* and differ only in spore morphology. As the natural range of *H. poroideoefibulata* is unknown, it must be considered that the morphology of its spores may encompass ellipsoid forms.

Table 1.4 Macroscopic and microscopic characteristic comparisons between *H. poroideoefibulata* Wu and specimens ECS-2241, ECS-2129, FP-103756, PR-1257, and Welden-1911 (Wu 2001).

Characteristics	*H. poroideoefibulata* Wu	Simple Septate Specimens
Basidial Size	5.5-6.5 x 12.0-23.0 µm	4.0-5.0 x 10.0-27.0 µm
Hyphal system	monomitic	monomitic
Hyphal size	2.0-5.0 µm	1.5-6.0 µm
Cystidia	5.0-7.0 x 15.0-30.0 µm	4.0-7.0 x 7.0-20.0 µm
Spore size	4.0-4.5 x 5.0-5.7 µm	2.0-5.0 x 3.0-6.0(8.0) µm
Spore shape	subglobose (guttulate)	ellipsoid (non-guttulate)
Pore size	4-5 per mm.	3-7 per mm (or split pored)
Pore shape	angular to round	angular to round or split
Colour	cream to ivory yellow	cream to light yellow or tan
Habit	resupinate	resupinate

SUMMARY

The genus *Schizopora* has had a tortuous taxonomic life and there is debate as to whether to separate it from the genus *Hyphodontia*. In North America, the variety of forms of the various species of this genus has led to much confusion over the characteristics to be found in its members. Confusion over the proper definition of hyphal systems has not helped to clarify matters. In particular, the presence (or absence) of skeletal hyphae have led to difficulties when using

keys found in many fungal flora. A key for the North American species (Table 1.1) is thus of use. Please note that the presence of skeletal or skeletal-like hyphae denotes a dimitic hyphal system in this key. A key to *Schizopora* and poroid *Hyphodontia* species worldwide is given in Table 1.5. Some biological species can only be reliably separated using incompatibility studies as is noted in Table 1.5.

While the genus *Schizopora* has been reassigned to the genus *Hyphodontia*, the author feels it is important to consider it a separate genus (Gams 1999). Paulus *et al.* (2000) state, "Most species of *Schizopora* are now included in the genus *Hyphodontia*, but probably represent a genuine group of closely related species". Indeed while Langer (1998) supported the reassigning of *Schizopora* to the genus *Hyphodontia,* his own work on the evolution of *Hyphodontia* (as inferred from ribosomal DNA sequencing) led him to state that "the delimitation of *Hyphodontia* and *Schizopora* is well founded when considering the hymenial surface" (Gams 1999, Langer 1998). If the poroid hymenophore is considered to be an evolutionary feature of greater complexity than a smooth hymenophore, then the species of *Schizopora* represent a link between poroid and non-poroid fungi.

Schizopora species can be resupinate to pileate, monomitic to trimitic, as well as simple to nodose septate. The highly variable pore surface and the confusing mitic systems of the genus point to an unstable and evolving complex of species. As such, any division of specimens into discrete species will be

Table 1.5 Key to *Schizopora* and poroid *Hyphodontia* species worldwide

1. Hyphae simple septate..... H. *poroideoefibulata*
1. Hyphae with clamp connections..... 2

2. Basidiocarp pileate..... 3
2. Basidiocarp non-pileate..... 4

3. Hyphal system monomitic..... *S. cystidiata*
3. Hyphal system trimitic ..... *S. trametoides*

4. Hyphal system monomitic..... 5
4. Hyphal system dimitic.....9

5. Spores subglobose..... 6
5. Spores suballantoid..... 7
5. Spores ellipsoid.....8

6. Basidiospores >5 µm long.....*S. apacheriensis*
6. Basidiospores <5 µm long.....*H. hallenbergii*

7. Basidiospores >6.5 µm long..... *H. syringae*
7. Basidiospores <6.5 µm long..... *H. nothofagi*

8. Basidiospores >5.5 µm long.....*H. niemelaei*
8. Basidiospores <5.5 µm long.....*H. taiwaniana*

9. Basidiospores >5 µm long and >3.5 µm wide..... *S. paradoxa**
9. Basidiospores <5 µm long and <3.5 µm wide.....*S. flavipora***

* *S. paradoxa* is distinguished from *S. radula* reliably only through cultural incompatibility testing (Hallenberg 1983, Niemala 1987)
** *S. flavipora* is distinguished from *H. tropica* and *H. nongravis* reliably only through cultural incompatibility testing (Wu 2000)

difficult as there is likely a continuum of characteristics to be observed. While new analytical techniques, such as DNA analysis, will likely make this speciation more apparent, it is equally likely to raise additional questions about this fascinating genus.

CHAPTER 2

EXAMINATION OF LIVE CULTURES

INTRODUCTION

The study of live cultures of wood decay fungi for purposes of taxonomic classification is an established practice dating to the last half of the twentieth century. Nobles introduced the concept in 1948 by identifying characteristics found in pure cultures of wood decay fungi and assigning each characteristic a code number (Nobles 1948). This study became the basis for the identification of wood decay fungi in culture and was later refined and expanded upon by Nobles (1965). Modifications to Nobles' characteristics code of 1965 have been made, notably by Stalpers and Nakasone amongst others (Stalpers 1978, Nakasone 1990). The examination of cultures from this study was performed to see whether they confirmed existing cultural descriptions for the species involved. A list of the cultural characteristics and their associated code numbers can be found in Appendix III. The coding system used for this study was that of Nakasone, which differs from Nobles original classification system by expanding categories to include more characteristic features. Nobles' code as well as Nakasone's modified code can also be found in Appendix III for purposes of comparison.

The purpose of performing cultural studies on isolates of *Schizopora* was to determine whether any deviations from the established cultural descriptions would be found for the specimens collected from Puerto Rico. By comparing these Puerto Rican specimens to known descriptions it was hoped that a cultural characterization of the specimens would be possible. Live cultures of specimens collected by E.C. Setliff in Puerto Rico were compared with live cultures of *Schizopora paradoxa*, *S. apacheriensis*, and *S. flavipora*. All live cultures, other

than those preceded with ECS-, were obtained from the Center for Forest Mycology Research (CFMR).

METHODS AND MATERIALS

Live cultures were obtained from the private collection of Dr. Setliff and from CFMR. Puerto Rican cultures were from specimens ECS-1853, ECS-2119, ECS-2129, ECS-2218, and ECS-2241. Cultures from *S. paradoxa* were FP-103659, HHB-6700, FP-103756, HHB-271, FP-105695, HHB-6507, FP-70898, and L-15844. Cultures from *S. apacheriensis* were HHB-4603, HHB-6677, and FP-101821. Cultures from *S. flavipora* were FP-102561, PR-1257, and HHB-9460.

Live cultures from the ECS collection were taken from oil slants. Transfers were made onto 1.25% MEA plates and allowed to grow out. Live cultures from the Forest Disease Herbarium were shipped as fully covered plates.

Transfers of all cultures from these fully grown plates were made on to seven separate plates filled with 1.25% MEA according to Nobles (1965). All transfers were made in a sterile laminar flow hood. Inoculations were made by removing a small piece of live culture and placing it at the edge of the plate. All inoculations were performed on the same day. Inoculated plates were wrapped with Parafilm® and placed in a closed box. The box was stored out of direct sunlight and kept at room temperature (which, it should be noted, is variable in the building in which the box was stored). Examinations of the plates for growth measurements were made weekly over a 6-week period. Examinations of plates

for microscopic examination were made at the 2- and 6-week periods. After examination, plates were sealed with Parafilm® and placed back in the box.

Radial growth measurements were made with a metric ruler. Occasionally, the leading edge of the advancing hyphae was difficult to discern. In these cases, the plate was placed on top of the ruler on a bottom-lit Leica Zoom 2000 dissecting microscope.

Microscopic examinations were performed on a Nikon E400 binocular compound phase contrast microscope with a F-mount camera attachment. All microscopic examinations were made at 1000X magnification. Images were taken with a Fuji FinePix S1 Pro digital SLR camera with resolution of 6.0 mega pixels. Images were obtained remotely by computer and stored on recordable CDs. Images have not been digitally altered except to insert a scale. The scale measurement was obtained by taking images of a micrometer at 1000x. A scale bar of 10 µm was derived through manipulation of this image in Adobe Photoshop 6.0. This scale bar was merged with any images before any size adjustments were made to preserve the relative scales. Some cropping and adjusting of the size of the images for purposes of clarity and placement in the text of this study were performed, again using Adobe Photoshop 6.0.

RESULTS

The cultures examined had a range of characteristics which closely conform to the published descriptions of members of the genus *Schizopora*.

There were, however, some differences and one culture did not seem to be related.

Schizopora paradoxa

Cultures of *S. paradoxa* examined were ECS-2119, FP-103659, HHB-6700, HHB-271, FP-105695, HHB-6507, FP-70898, and L-15844. Culture FP-103756 was described as *S. paradoxa*, but on examination of the specimen for this culture, it was noted that it lacked clamp connections. This culture was considered monomitic and is discussed in the section stating at page 80.

The species code for cultures of *S. paradoxa* examined in this study is: 2. 3c. (11). (12). 15. 31a. 32. 36. (40). 46. 47. 54.

Macroscopically mycelial mats were white and thin with a downy texture of aerial hyphae. Aerial hyphae were sparse at the 2-week period but less so at 6-weeks. Marginal hyphae at the 2-week period were either appressed or submerged. Margins were even to slightly variable in their shape. Plates were covered after 4- or 5-weeks with the exception of HHB-6700 which covered the plate after 3 weeks. Other than the culture of FP-70898, which showed a slight bleaching of the agar, the cultures were unchanged in colour at either 2- or 6-weeks. Odour was unremarkable.

Microscopically, hyphae were clamped and ranged in diameter from (1.5)2.0 - 4.5(6.0) µm (Figure 2.1). Hyphae were sparsely branched and clamps

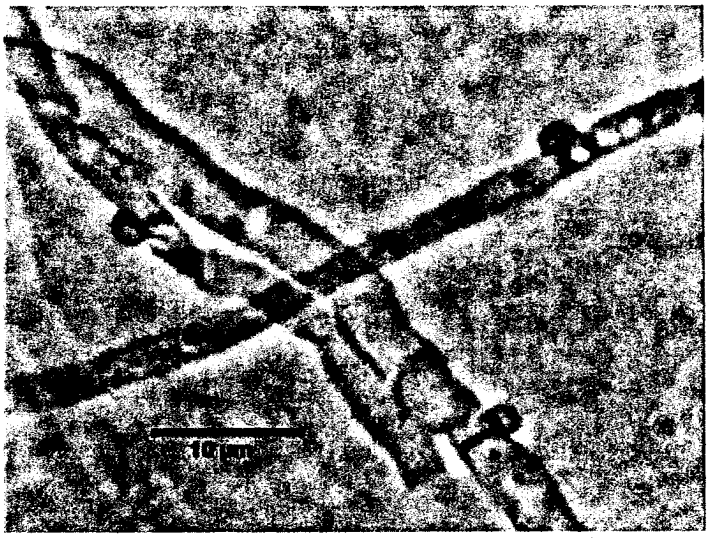

Figure 2.1 *S. paradoxa*: hyphae in culture (L-15844)

were regularly spaced. Two types of cystidia were found; clavate cystidia and gloeocystidia. Clavate cystidia (Figure 2.2) were basally clamped and ranged in size from 4.0-7.0 x 20.0-25.0 µm. Gloeocystidia (Figure 2.3) were of amorphous shape and size. Not all cultures showed signs of these two types of cystidia. Malocysts (Figure 2.4) were also present and were basally clamped and 4.0-5.0 x 6.5-10.0 µm in size. Crystals were found in the agar of all cultures and were either oblong (Figure 2.5) or bipyramidal (Figure 2.13) in shape. Crystals could range in size but were generally larger at 6-weeks than at 2-weeks.

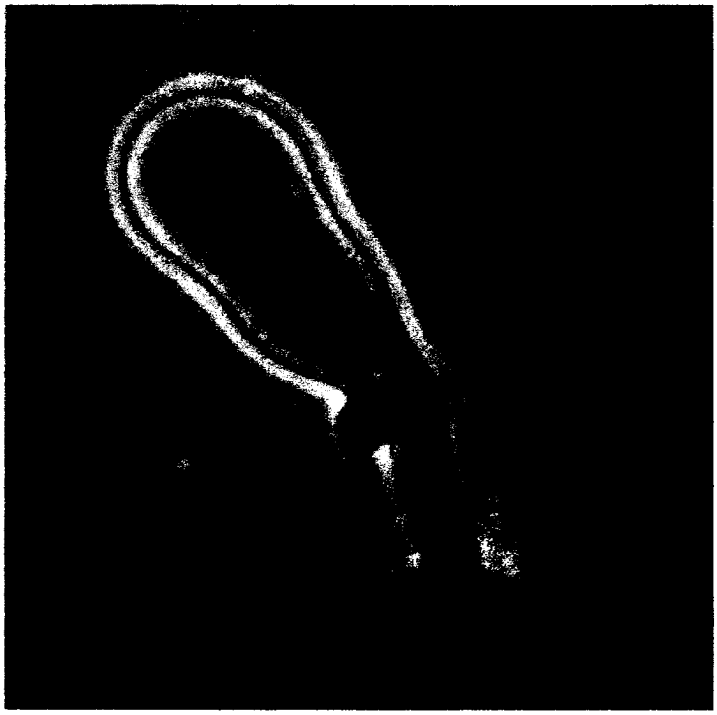

Figure 2.2 *S. paradoxa*: Clavate cystidium (FP-70898)

Figure 2.3 *S. paradoxa*: Gloeocystidia (HHB-6507)

Figure 2.4 *S. paradoxa*: malocyst (FP-103659)

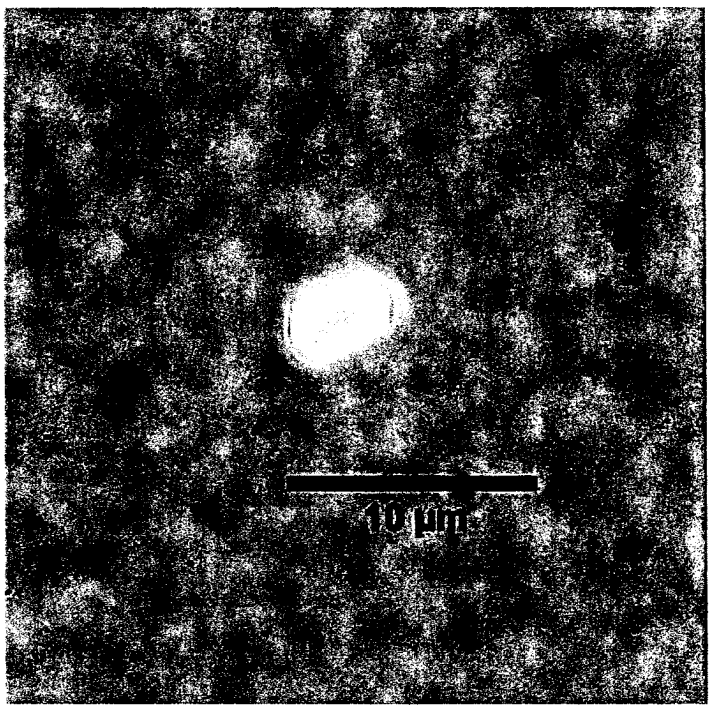

Figure 2.5 Bipyramidal crystal found in agar (L-15844)

Schizopora apacheriensis

Cultures of *S. apacheriensis* examined were HHB-4603 and HHB-6677. Culture FP-101821, although identified as *S. apacheriensis*, was so unlike any other culture examined that it is treated in its own section of this chapter.

The species code for the cultures of *S. apacheriensis* examined was: 2. 3c. 11. (16). 31a. 32. 36. (40). 44. 45. 54.

Macroscopically, mycelial mats were white, thin, with a slight downy texture. This changed little between the 2-week and 6-week periods. Aerial mycelia were sparse at both time periods. Marginal hyphae were appressed or submerged at the 2-week period. Margins were even to slightly bayed at the 2-week period and plates were covered after 4-5 weeks. HHB-4603 showed no change in colour of the agar while HHB-6677 showed slight bleaching of the agar after two weeks. Odour was unremarkable.

Microscopically, hyphae were thin-walled, clamped and 1.5-4.0 µm in diameter. Sections of hyphae appeared to be thick-walled, skeletal-like, and clamped at both ends (Figure 2.6). They would appear as segments within thin-walled hyphae and never were clamped except at the ends. They had similar diameter to thin-walled hyphae and ranged in length from 20 µm to 50 µm. These hyphae were easily identifiable as they refracted a yellow colour under phase contrast at 100x, 400x, and 1000x magnification. Thin-walled hyphae occasionally formed what appeared to be rhizomorphic strands (Figure 2.7).

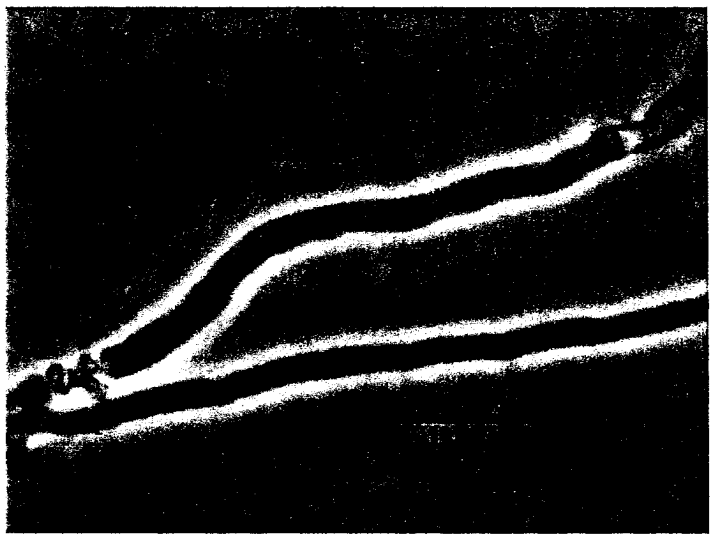

Figure 2.6 *S. apacheriensis*: thick-walled hyphal segment

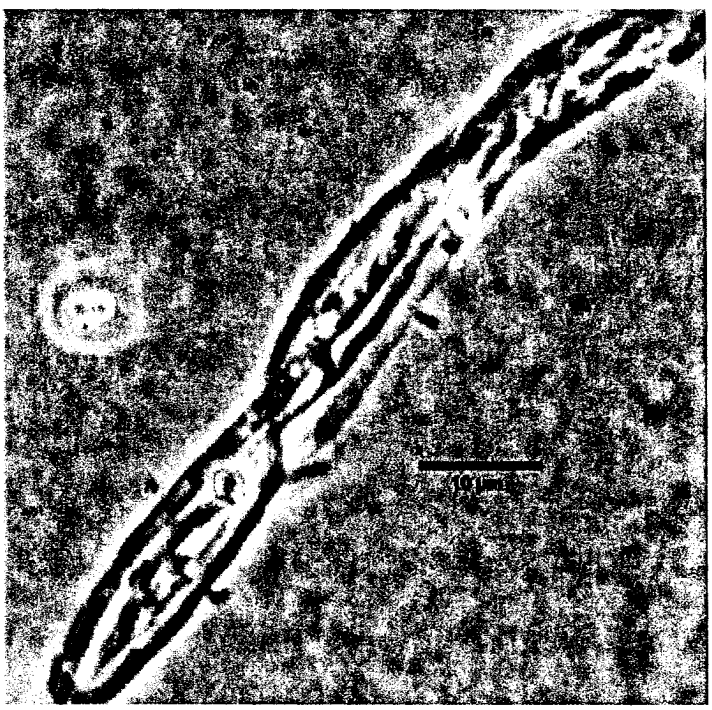

Figure 2.7 *S. apacheriensis*: rhizomorphic strand of hyphae

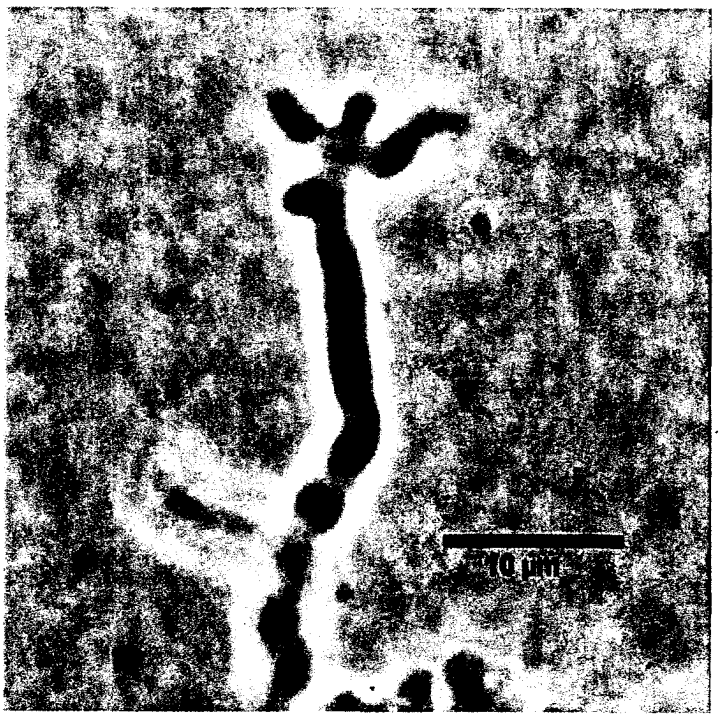

Figure 2.8 *S. apacheriensis*: Staghorn hyphae

Figure 2.9 *S. apacheriensis*: malocysts

While these were not widespread they were distinct from other cultures of *Schizopora*. Staghorn-type hyphae were also evident (Figure 2.8). These were basally clamped and could be of a variety of shapes and sizes. Malocysts (Figure 2.9) were also present and were basally clamped and 3.0-4.0 x 5.5-7.0 µm. Crystals were found in the agar and were similar in size and shape to that found in Figure 2.5. Odour of the cultures was unremarkable at both time periods.

Schizopora flavipora

Cultures of *S. flavipora* examined were ECS-1853, ECS-2218, FP-102561, and HHB-9460. Culture PR-1257 was described as *S. paradoxa*, but on examination of the specimen for this culture, it was noted that it lacked clamp connections. This culture was considered monomitic and is discussed in the section starting at page 80.

The species code for cultures of *S. flavipora* examined was: 2. 3. (15). 31b. 32. 36. 38. (40). 42-44. 54.

Macroscopically mycelial mats were white and thin. Aerial hyphae were either downy or cottony or absent altogether. Cultures differed little between week 2 and week 6. Margins were even and marginal hyphae were appressed to submerged. Plates were covered between the 2-week and 4-week periods. Other than ECS-1853, which showed some bleaching of the agar, the plates were unchanged in colour over the 6-week period. Odour of the cultures was unremarkable.

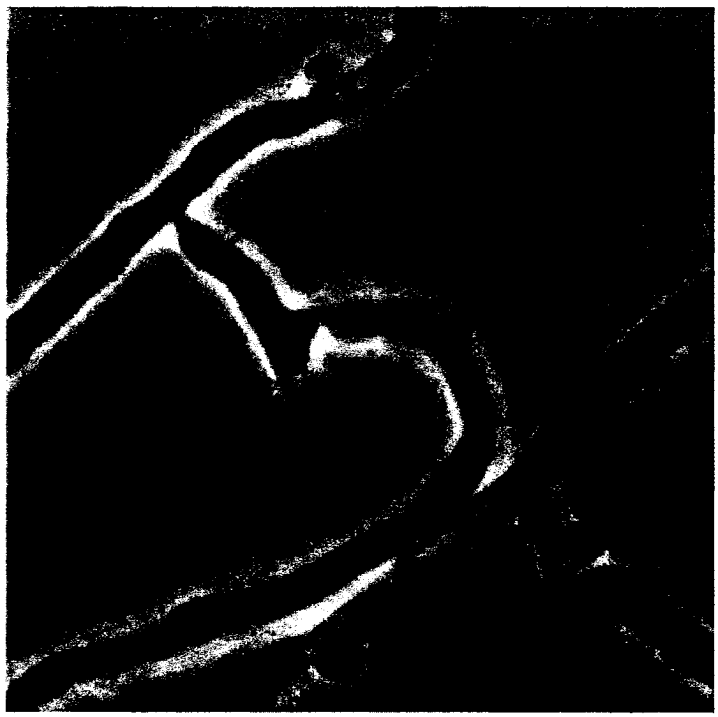

Figure 2.10 *S. flavipora*: Clamped thin-walled hyphae

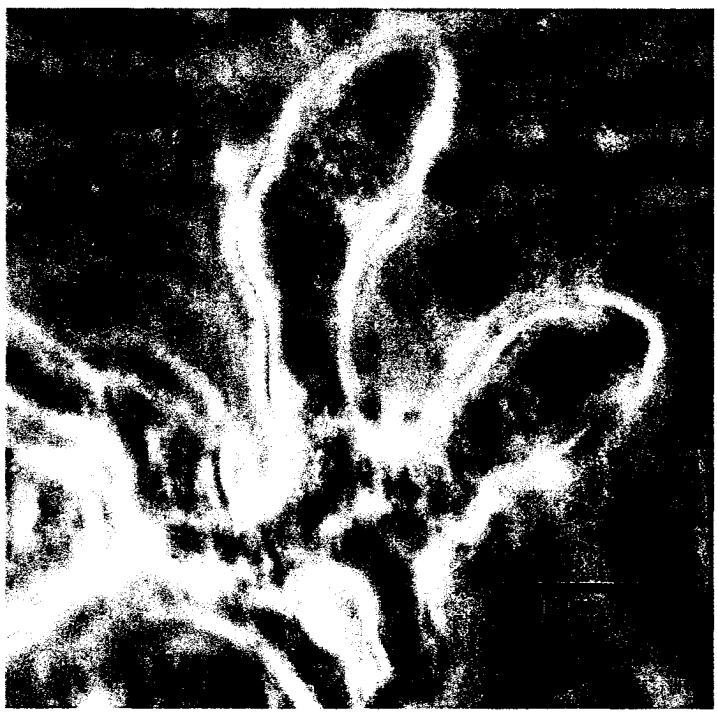

Figure 2.11 *S. flavipora*: gloeocystidia

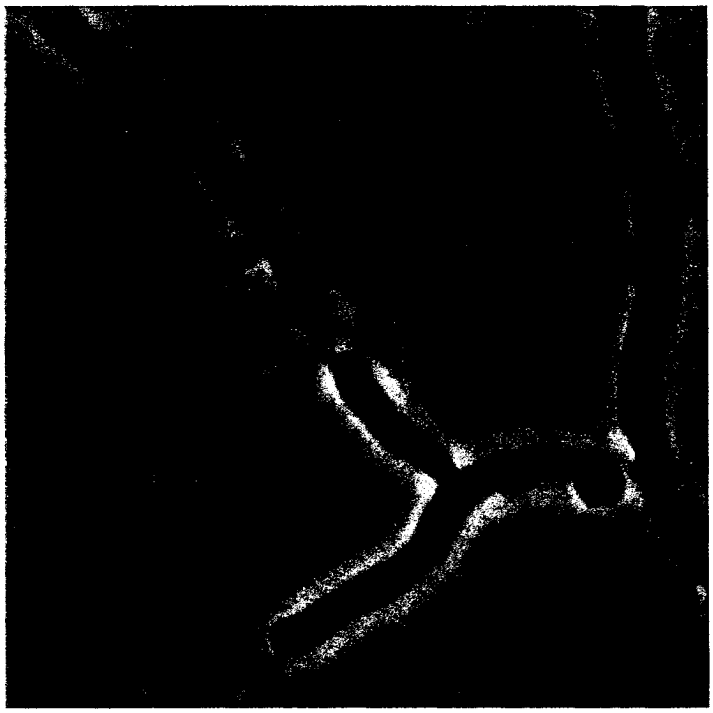

Figure 2.12 *S. flavipora*: drepanocysts

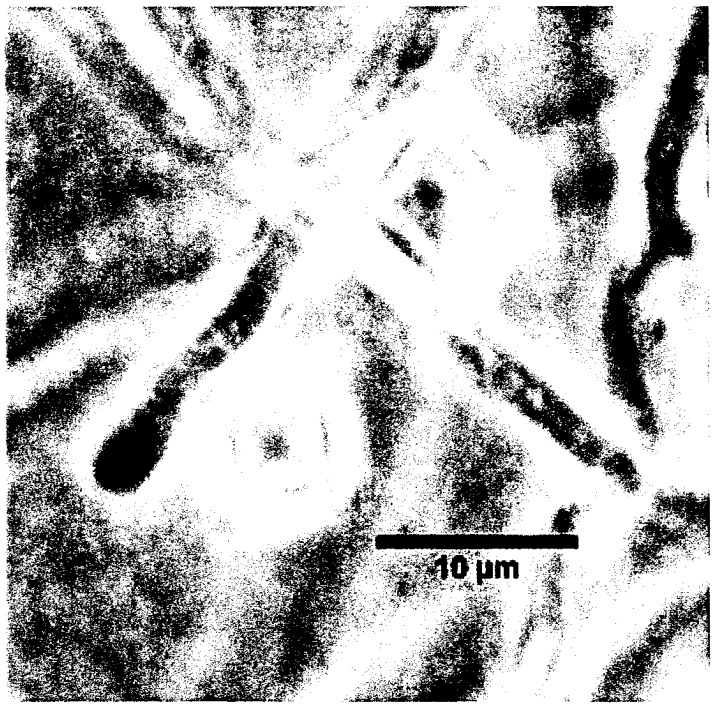

Figure 2.13 *S. flavipora*: bipyramidal crystals in agar

Microscopically hyphae were thin-walled, clamped, and were 2.0-3.5(5.0) µm in diameter (Figure 2.10). Gloeocystidia of amorphous shape and size were observed in several cultures (Figure 2.11). Drepanocysts were also found and were 2.0-3.0 x 4.0-6.0 µm in size. These were invariably basally simple-septate. Crystals of two types were found; large crystals of bipyramidal form (Figure 2.13) and oblong crystals similar in shape and size to those found in *S. paradoxa* (Figure 2.5). Odour of the cultures examined was unremarkable at both time periods.

SIMPLE SEPTATE SPECIMENS

Cultures of simple septate specimens examined were FP-103756, PR-1257, ECS-2241, and ECS-2129. The dry basidiocarps of these specimens revealed an abundance of simple-septate hyphae with only PR-1257 exhibiting rare clamps observed by E.C. Setliff.

The species code for these cultures was: 2. (5). 6. 11. 13. 31a. 31b. 32. 36. 40. 42-43. 47. 54.

Macroscopically these cultures differed little from those of other *Schizopora* cultures. Mycelial mats were thin and white with a cottony or downy texture. Aerial hyphae were sparse at 2-weeks and a little less so at 6-weeks. Marginal hyphae were appressed to submerged at 2-weeks and margins were even to bayed. Plates were covered in 2 to 3 weeks with the exception of FP-103756 which had not covered the plates by week 6.

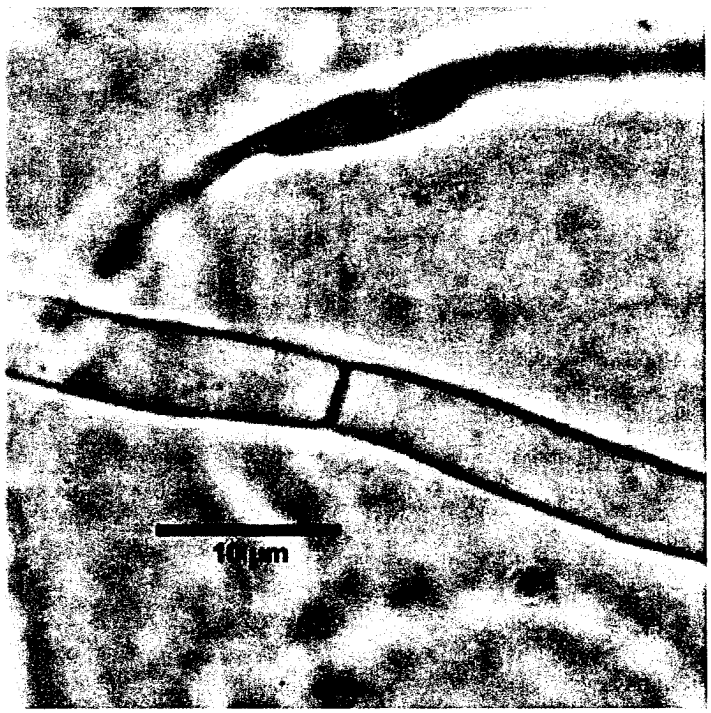

Figure 2.14 Simple septate hyphae

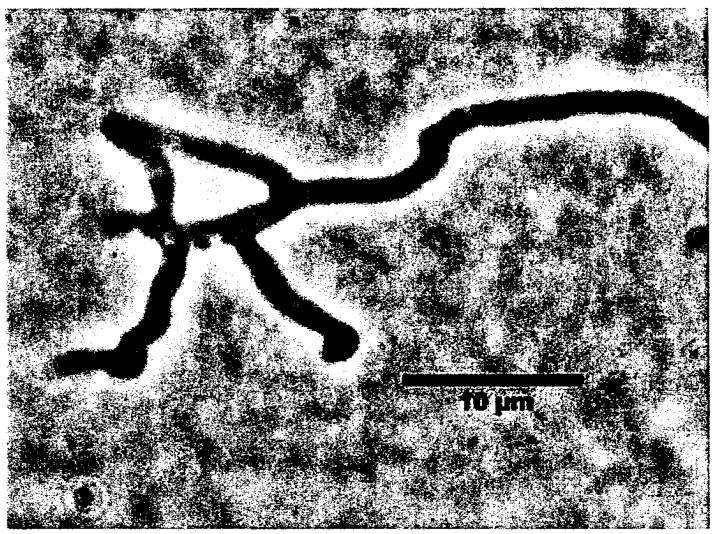

Figure 2.15 Staghorn hyphae

Figure 2.16 Simple septate drepanocysts

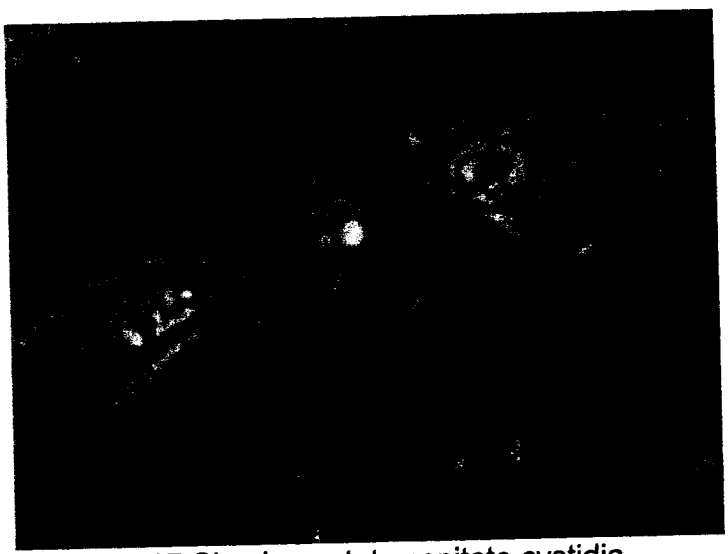

Figure 2.17 Simple septate capitate cystidia

Microscopically hyphae were thin-walled, simple septate, and 2.0-5.0 µm in diameter (Figure 2.14). Culture ECS-2129 additionally exhibited thin-walled hyphae with a diameter of 10.0-13.0 µm. Culture FP-103756 had what might have been thick-walled hyphae but were interpreted to be very long moniliform cystidia, 3.0 µm in diameter and up to 70 µm long with a narrow lumen. These were basally clamped. Also observed in culture FP-103756 were basally clamped malocysts with a size of 6.0 x 14.0 µm. These two structures were the only evidence of the presence of clamps in culture. FP-103756. All other cultures were simple septate in all respects. Staghorn type hyphae were occasionally observed (Figure 2.15), as well as drepanocysts which had sizes of 3.5-4.0 x 8.0-10 µm (Figure 2.16). Simple septate capitate cystidia (Figure 2.17) had a size range of 4.0-8.0 x 10.0-14.0 µm. Crystals similar in shape and sizes to Figure 2.13 were found quite frequently.

CULTURE FP-101821

This culture, identified as *S. apacheriensis*, was very unlike the other cultures of *Schizopora* in its microscopic characteristics. Macroscopically it was indistinguishable from the other cultures of *Schizopora*. The mycelial mat was white and thin with a downy texture. This was also the case at the 2- and 6-week period. The margin was bayed after 1-week and marginal hyphae were appressed and submerged. Plates were covered at week 2 and the reverse of the plates were slightly bleached. The plates smelled slightly of mushrooms but the odour was otherwise unremarkable.

Figure 2.18 FP-101821: Whorled clamps on large hyphae

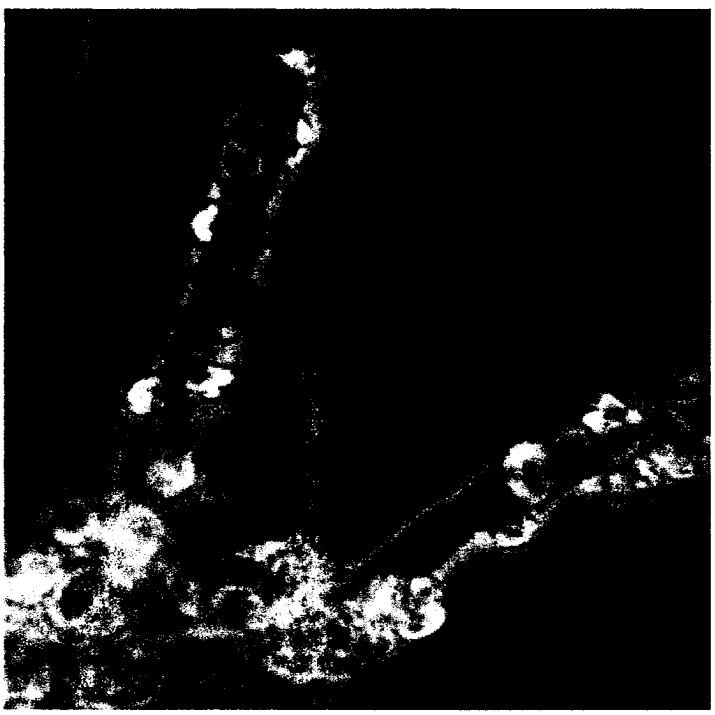

Figure 2.19 FP-101821: Encrusted thin-walled hyphae

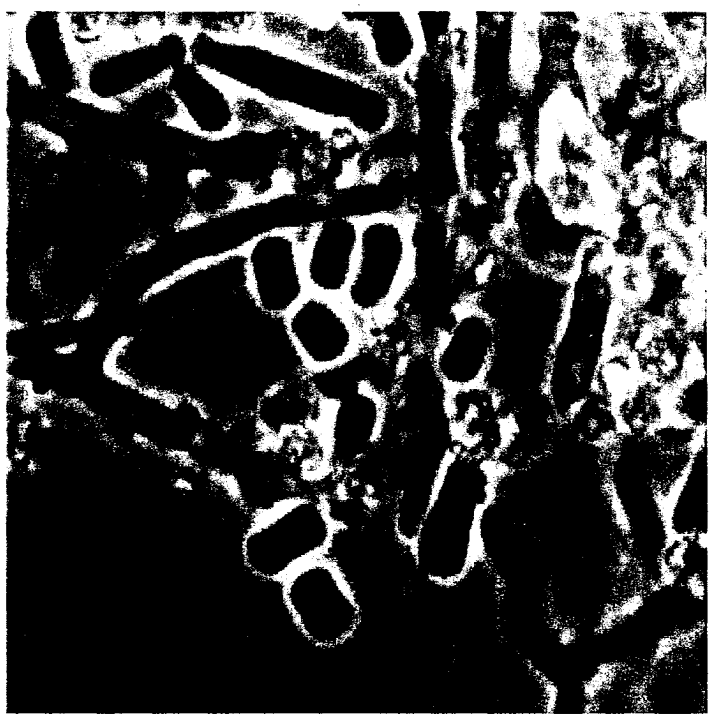

Figure 2.20 FP-101821: Arthroconidia

Microscopically there was no doubt that this culture was not of the same type as the other cultures of *Schizopora*. Hyphae were of two types. Thin-walled hyphae, 10.0-12.0 µm in diameter, had whorls of 2-3 clamps at their septa (Figure 2.20). Occasionally these large diameter hyphae were simple septate as well. Thin-walled hyphae, 2.5-3.5 µm in diameter, were often heavily encrusted (Figure 2.21) These smaller diameter hyphae were never clamped and presumably simple septate. This was hard to discern as there was frequent encrustation and the hyphal contents stained darkly. The most unusual microscopic feature was of small hyphal fragments assumed to be arthroconidia (Figure 2.22). It is likely that this culture was contaminated with an unknown species.

DISCUSSION

Cultures examined for this study exhibited most of the characteristics seen in previously published cultural descriptions of species of *Schizopora*. For most cultures examined there was very little difference whatsoever. Some differences are, however, present and a comparison of published accounts with what was observed during this study is warranted.

COMPARISON OF *Schizopora paradoxa* CULTURES

Cultural studies of *S. paradoxa* exist from four sources. Domanski (1969a) studied cultures of *S. paradoxa* from Poland. Stalpers (1978) refers to this study in listing *S. paradoxa* in a key based upon cultural characteristics. Stalpers (1978) does not list any culture specimens in his key. As this is likely an adaptation of Domanski's study to Stalpers code, no new information is given and this description will not be used for comparison purposes here. Hallenberg (1983) describes cultures of both *S. paradoxa* and *S. radula* in his study on the differences between the two species. Most relevant is Nakasone's (1990) study of many of the same cultures of *S. paradoxa* used here.

Cultures of *S. paradoxa* used in Nakasone's study and the present study were FP-105695, HHB-271, FP-70898, L-15844, FP-103659, and FP-103756. (Nakasone 1990). A complete description of species codes and their numerical representations of characteristics found in culture can be found in Appendix III. Nakasone (1990) gives a species code of 2. 3c.(11).13. 15.31a.32.36.38. (40)

44-47.(53).54.60. This can be compared with that given by Domanski (1969a); 2.3.7.26.32.36.38.46-47.54.55.60. Hallenberg's (1983) code was 2a.3c.(7).(26).32.36.38.45.54.60.61. Some differences must be noted between these three codes as Domanski (1969a) used Nobles (1965) version, Hallenberg (1983) used Boidin's (1966) adaptation of Nobles code, and Nakasone (1990) uses her own adaptation of Nobles' code.

Observations made in this study that differ from these three published descriptions are the occasional presence of staghorn-type hyphae, the occasional presence of encrusted hyphae, and the presence of gloeocystidia. All other characteristics are the same as previous studies. Nakasone (1990) considers *S. paradoxa* as a species complex with varying characteristics which may or may not appear depending on the isolates studied. Thus it is not surprising that some characteristics may have been observed here that are not observed elsewhere in other studies. Hallenberg (1983) also noted in comparing *S. paradoxa* with *S. radula*, that "it is, however, difficult to estimate the constancy of certain cultural characters". Hallenberg (1983) notes the presence of gloeocystidia in cultures of *S. radula*. Nakasone (1990) further states that she "cannot with confidence distinguish between the two species [*S. paradoxa* and *S. radula*]". Thus it may be the case that some of the cultures studied are examples of either species, so the characteristics of both must be considered in describing the observations made here. With this in mind, the cultural characteristics of *S. paradoxa* observed here differ little from previously published accounts and serve to confirm previous observations. A collective code for *S. paradoxa* isolates

observed in this study is as follows: 2.3c.(11).13.15.31a.32.36.(38)(40).44.46-47.(53)54. (Please refer to Appendix III for an explanation of the species codes).

COMPARISON OF *Schizopora flavipora* CULTURES

Cultural studies of *Schizopora flavipora* exist from two studies. Domanski (1969b) studied cultures of *S. phellinoides* (Pilát) Domanski from Poland. Ryvarden considers this species name to be synonymous with *S. flavipora* and lists this study as a reference for cultural characteristics of *S. flavipora* (Gilbertson and Ryvarden 1987, Ryvarden and Gilbertson 1994). Wu (2000) examined cultures of *S. flavipora* found in Taiwan.

Domanski (1969b) reported a cultural code of 2.3.7.26.32.36.38. 40.45. 54.60. again based upon Nobles (1965) coding scheme. Wu (2000) reports a cultural code of 2a.3.13.32.36.38.44.54.60.61 based on Nakasone's (1990) coding scheme. The only differences between these two descriptions is that Domanski (1969b) notes thin-walled undifferentiated hyphae (code 7) and noteworthy swellings on hyphae (code 26), while Wu (2000) notes cystidia on the vegetative mycelia (code 13). It might be argued that noteworthy swellings (code 26) are indeed cystidia (code 13). The thin-walled undifferentiated hyphae (code 7) mentioned by Domanski (1969b) is not supported by his own description of the hyphae found in culture. He describes hyphae which can be straight, arboriform, thin or thick often with vesicular or pyriform branches. These are obviously descriptions of differentiated hyphae which would lead one to a coding of 10 or 11 depending on what was seen.

Observations made are also very close to those of Domanski and Wu. The only observed difference was the presence of gloeocystidia and drepanocysts. These may be interpreted as the noteworthy swellings (code 7) mentioned by Domanski (1969b) or even the cystidia (code 13) observed by Wu (2000). It is difficult to say whether this is reliable, as neither author provides diagrams or photographs of these cultural characteristics (Domanski 1969b, Wu 2000). The published descriptions of *S. flavipora* thus match the observations of this study and serve to confirm the previous work with cultures from North America. A collective code for *S. flavipora* isolates observed in this study is as follows: 2.3.(15).31b.32.36.38.40.42-44.54. (Please refer to Appendix III for an explanation of the species codes).

COMPARISON OF *Schizopora apacheriensis* CULTURES

The only published cultural study of *S. apacheriensis* comes from the paper originally describing it as *Poria apacheriensis* (Gilbertson and Canfield 1973). The authors give a cultural code based upon Nobles' coding scheme as: 2.3.15.32.36.38.46.50.54.(55). The observations made in this published study differ from the observations in the present study in a few aspects. Gilbertson and Canfield (1973) observed gloeocystidia which were not observed in cultures of *S. apacheriensis* in this study. Staghorn hyphae, rhizomorphic-like strands, and malocysts were characteristics uniquely observed in this study. Gilbertson and Canfield (1973) do mention hyphae with "frequent branching and often ending in

profusely branched terminal complexes" which may correspond to the staghorn hyphae observed here. Furthermore they observed "radiating plumose strands throughout" when commenting on the macroscopic features of *S. apacheriensis* in culture (Gilbertson and Canfield 1973). These strands likely are similar to the strands shown in Figure 2.7. The presence of malocysts would be the only characteristic which was observed in the present study and not in the published account (Gilbertson and Canfield 1973). Malocysts are considered a feature common to all members of *Schizopora* and *Hyphodontia* (Langer 1994). These features may be variable however and may not always be expressed in culture. Thus the observations of the cultural characteristics of *S. apacheriensis* in this study differ in this one important but apparently variable respect from the previously published study (Gilbertson and Canfield 1973). A collective code for *S. apacheriensis* isolates observed in this study is as follows: 2.3c.11.(16).31a. 32.36.(40).45-46.54. (Please refer to Appendix III for an explanation of the species codes).

SIMPLE SEPTATE CULTURES EXAMINED

As the exact species of *Schizopora*-like fungi representing the simple septate cultures observed in this study is unknown, comparisons of characteristics are not possible. These specimens include cultures of FP-103756, PR-1257, ECS-2241, and ECS-2129. A cultural characteristics code for these cultures would be: 2a.6.11.13. 31a.31b.32.36.40.42-43.47.54. Unfortunately, this code does not key out in either Nakasone's or Nobles' studies (Nobles 1965,

Nakasone 1990). Identification of these specimens cannot be accomplished on cultural characteristics alone. They are remarkably similar to cultures of *Schizopora* in that all characteristics except for simple septation are found in common. It may be that the septation characteristic is also a variable one found in this genus.

Specimen PR-1257, identified as *S. flavipora*, is an example of this possibility. The author was unable to find clamps in the basidiocarp, although clamps were rarely observed by Setliff. The culture showed no signs of clamps either. That a fungus could exhibit all the characteristics of *S. flavipora* but lack one major one may not be enough of a reason to exclude it from the genus. It may be that in a species complex such as that of *S. flavipora* or *S. paradoxa* that such features are variable, or that the expression of such a characteristic has somehow been suppressed or become dysfunctional. On the other hand, the presence of clamps has been used to delineate species and this specimen might belong to a new species.

Specimen FP-103756, identified as *S. paradoxa*, is another example. This basidiocarp showed no evidence of clamps, but the culture exhibited clamps at a specific location. Clamps were only found in culture at the base of malocysts and cystidia. Perhaps it is true that absence of evidence is not the same as evidence of absence (Rumsfeld 2001).

CHAPTER 3

PHENOL OXIDASE TESTS OF CULTURES

INTRODUCTION

The first study to characterize fungi by their morphological cultural characteristics was written over half a century ago (Davidson 1938). Since that starting point, the procedure has been refined to include many more characteristics including the reactions of fungi in culture to various chemical tests (Nobles 1948, Nobles 1958, Nobles 1965, Kaarik 1965, Taylor 1974, Stalpers 1978, Nakasone 1990). Phenolic and other chemical tests are able to determine whether or not various biochemical processes are active within the fungal culture (Nobles 1965, Stalpers 1978). The intent of this section of the study was to characterize through the use of various chemical tests whether the unknown *Schizopora* species collected in Puerto Rico reacted similarly to known cultures of various *Schizopora* species. Cultures of the unknown species were compared with cultures of *S. paradoxa, S. apacheriensis,* and *S. flavipora* obtained from CFMR.

The tests for extracellular oxidases performed here are used to determine the presence of different enzymes that cause white rot decay. The phenol α-naphthol is used to determine whether laccase is active (Stalpers 1978). Similarly, ρ-cresol is used to determine whether tyrosinase is active (Stalpers 1978). Pyrogallol with hydrogen peroxide (H_2O_2) is used to test for the activity of peroxidase (Stalpers 1978). In addition, potassium hydroxide, (KOH), was used to test for non-enzymatic colour changes in culture of some species.

MATERIALS AND METHODS

Cultures listed in Table 3.1 were obtained either from the Herbarium of the Center for Forest Mycology Research or from Puerto Rican collection of Setliff. The Puerto Rican collections were recovered from oil covered slants. Culture collection information can be found in Table AII.2.

Table 3.1 Cultures used for testing *Schizopora* species

Culture Letter Code	Culture Collection #	Species Binomial
A	FP-103659	*Schizopora paradoxa*
B	HHB-6700	*Schizopora paradoxa*
C	FP-103756	*Schizopora paradoxa*
D	HHB-271	*Schizopora paradoxa*
E	FP-105695	*Schizopora paradoxa*
F	HHB-6507	*Schizopora paradoxa*
G	FP-70898	*Schizopora paradoxa*
H	L-15844	*Schizopora paradoxa*
I	HHB-4603	*Schizopora apacheriensis*
J	HHB-6677	*Schizopora apacheriensis*
K	FP-101821	*Schizopora apacheriensis*
L	FP-102561	*Schizopora flavipora*
M	PR-1257	*Schizopora flavipora*
N	HHB-9460	*Schizopora flavipora*
O	ECS-1853	*Schizopora* unknown
P	ECS-2119	*Schizopora* unknown
Q	ECS-2129	*Schizopora* unknown
S	ECS-2218	*Schizopora* unknown
T	ECS-2241	*Schizopora* unknown

Eighty petri dishes were prepared with 1% ME plus 1.5% agar. Each culture was transferred in a laminar flow hood onto eight Petri dishes with a sterile loop or needle. Cultures were allowed to grow in the dark at room temperature for 2 weeks for the first series of tests and 6 weeks for the second series of tests. Most cultures covered the plates by 2 weeks but FP-103756 *Schizopora paradoxa* and HHB-4603 *S. apacheriensis* had not grown out sufficiently for the first test. All cultures were tested at the sixth week. Each culture was assigned a code letter from A through T to reduce bias in observations of the colour reactions. A list of the cultures and their code letters can be found in Table 3.1.

After examining all the sporocarps associated with each culture it was determined that one of the *Schizopora* samples was in fact *Aporpium caryae* (Schw.) Teix. and Rogers. This culture (culture letter code R) was dropped from consideration and tests were performed on the remaining 76 plates.

Reagents to be used were prepared in advance of the test periods and stored in eye dropper bottles. For the laccase enzyme test 0.1M α-naphthol was prepared in 96% ethanol by dissolution. The tyrosinase reagent used was 0.1M p-cresol prepared in 96% ethanol by dissolution. A 1% solution of pyrogallol was prepared in distilled water as were a 0.4% solution of hydrogen peroxide and a 4% solution of potassium hydroxide. Solutions were prepared according to standards used in previous studies (Nobles 1965, Kaarik 1965, Taylor 1974,

Stalpers 1978). The pyrogallol solution was prepared fresh for each test period as it has a short shelf life (Staplers 1978).

For each test period, two plates of each culture were placed on a white background (blank sheets of paper) and phenolic reagents applied. On one of the two plates, a drop of 0.1M α-naphthol was placed to the left of center and a drop of 0.1M p-cresol was placed to the right of center. The second of the two plates had a drop of 4%KOH placed left of center and single drops of 1% pyrogallol and 0.4% H_2O_2 were placed on top of each other to the right of center. Replicates were not used as the intent was more of an exploratory confirmation of the published cultural studies. Similarly, negative controls were not included. The plates were observed after 30 min, 3 hr, 24 hr, and 72 hr periods. 0.1M α-naphthol produces a blue colour in the presence of laccase (Nobles 1965). 0.1M p-cresol produces a yellow to brown colour in the presence of tyrosinase (Taylor 1974). KOH produces a yellow or brown colour in the presence of certain types of hyphae (Nobles 1965). 1% pyrogallol in conjunction with 0.4% H_2O_2 produces a brown colour in the presence of peroxidase (Taylor 1974). Colour reactions were scored as either negative (no colour change visible), weakly positive (faint or light colour change visible), or positive (distinct colour change visible). Visible colour reactions were recorded at each time period for both 2- and 6-week old cultures. Digital photographs of the cultures and their reactions were taken at the 24 hr period for each age group of plates. Selected examples can be found in Figures 3.1 and 3.2.

RESULTS

The scored colour reactions observed for the 2-week-old cultures can be found in Table 3.2, while those for the 6-week-old cultures can be found in Table 3.3. The actual observations of colour reactions can be found in Table AI.1 through to Table AI.8. An example of the colour changes can be found for culture B (*S. paradoxa*) in Figure 3.1 for the phenol test after 2 weeks and in Figure 3.2 for the phenol tests after 6 weeks.

Table 3.2 Polyphenolic oxidase test results after 2 weeks

Culture Code	Species	α-naphthol	p-cresol	KOH	Pyrogallol
A	*S. paradoxa*	+	+	-	++
B	*S. paradoxa*	++	-	-	++
C	*S. paradoxa*	Too small to test			
D	*S. paradoxa*	+	+	-	++
E	*S. paradoxa*	++	+	-	++
F	*S. paradoxa*	+	-	-	+
G	*S. paradoxa*	++	-	+	++
H	*S. paradoxa*	++	+	+	++
I	*S. apacheriensis*	Too small to test			
J	*S. apacheriensis*	++	-	+	++
K	*S. apacheriensis*	++	++	+	+
L	*S. flavipora*	++	-	+	++
M	*S. flavipora*	++	+	+	++
N	*S. flavipora*	+	-	-	++
O	*Schizopora* unknown	+	++	+	+
P	*Schizopora* unknown	-	++	-	++
Q	*Schizopora* unknown	++	+	-	++
S	*Schizopora* unknown	++	+	+	++
T	*Schizopora* unknown	++	++	+	++

Note: (-)= no reaction, (+)= faint reaction, and (++)= strong reaction

Table 3.3. Polyphenolic oxidase test results after 6 weeks

Culture Code	Species	α-naphthol	p-cresol	KOH	Pyrogallol
A	*S. paradoxa*	++	-	+	++
B	*S. paradoxa*	+	-	+	++
C	*S. paradoxa*	++	-	+	++
D	*S. paradoxa*	++	-	-	++
E	*S. paradoxa*	++	-	+	++
F	*S. paradoxa*	++	-	-	++
G	*S. paradoxa*	++	-	+	++
H	*S. paradoxa*	+	-	++	++
I	*S. apacheriensis*	+	-	-	++
J	*S. apacheriensis*	++	-	+	++
K	*S. apacheriensis*	+	-	+	+
L	*S. flavipora*	++	-	+	++
M	*S. flavipora*	++	++	-	++
N	*S. flavipora*	++	-	-	++
O	*Schizopora* unknown	-	++	-	++
P	*Schizopora* unknown	++	+	+	++
Q	*Schizopora* unknown	++	+	+	++
S	*Schizopora* unknown	++	-	+	++
T	*Schizopora* unknown	++	+	+	++

Note: (-)= no reaction, (+)= faint reaction, and (++)= strong reaction

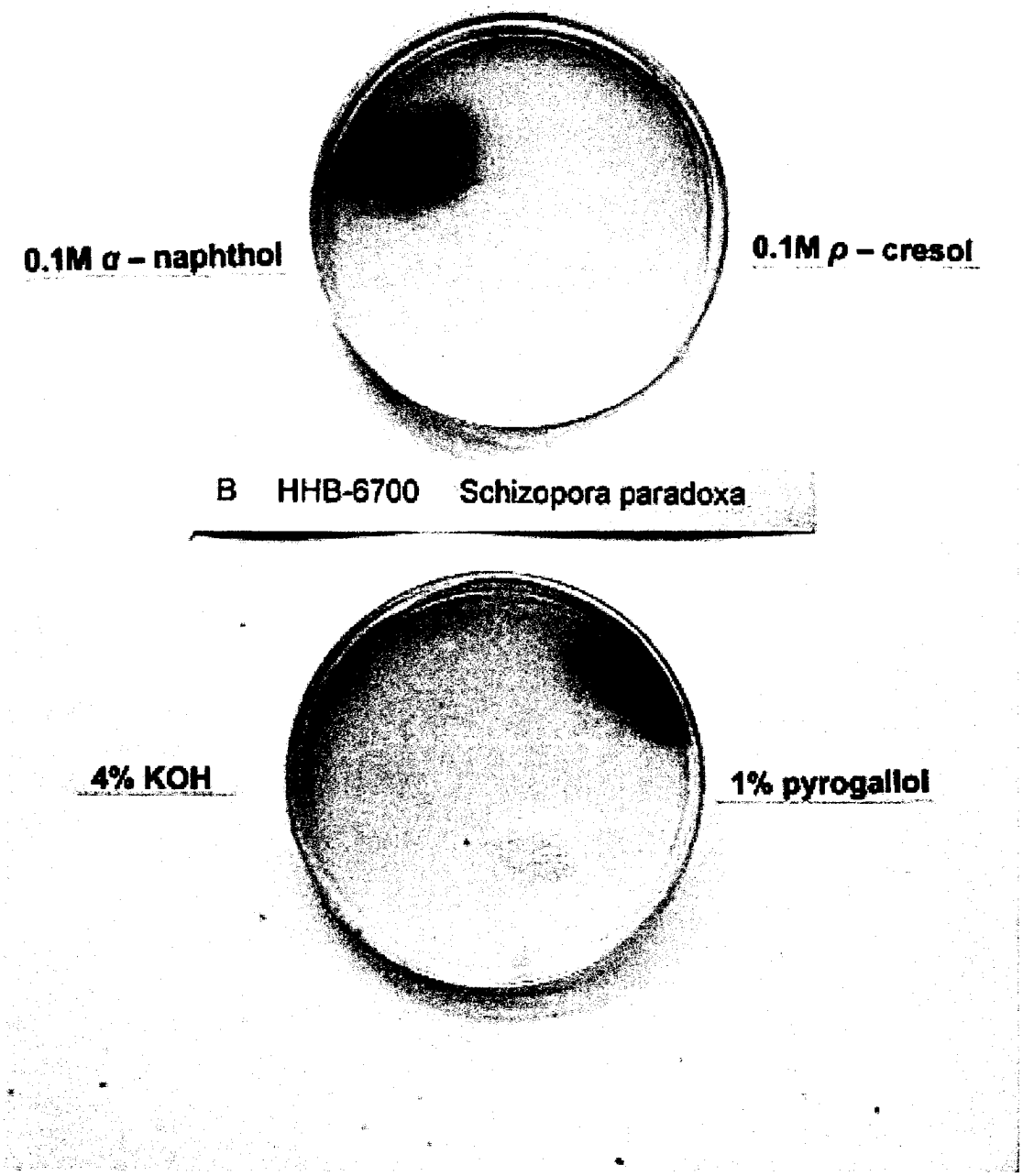

Figure 3.1 Example of phenol test after 24 hours on 2 week old culture

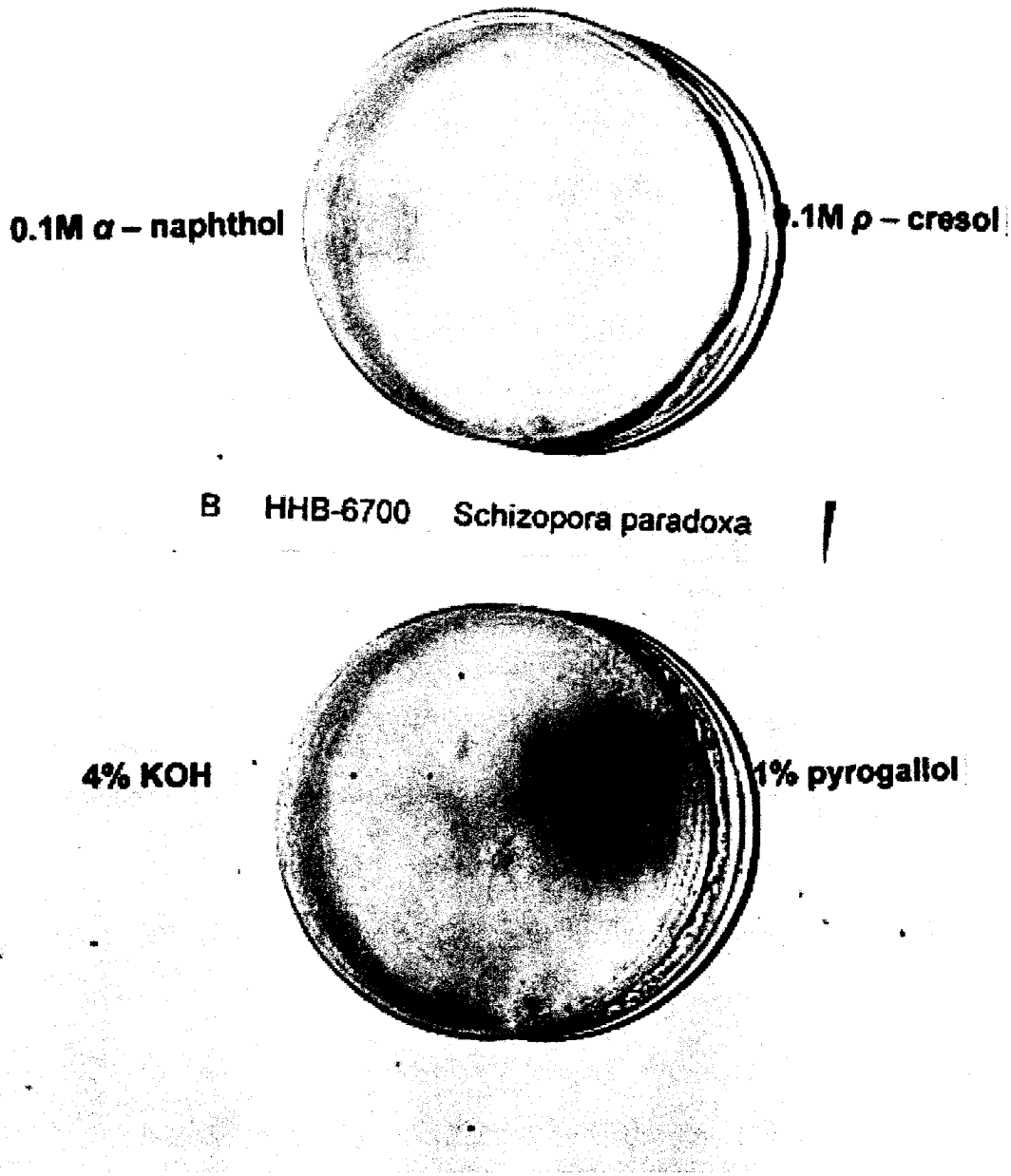

Figure 3.2 Example of phenol test after 24 hours on 6 week old culture

DISCUSSION

The results of the phenol tests for the various species of *Schizopora* were quite varied and difficult to interpret. If it can be assumed that species will exhibit the same reactions to phenols, then the test gives relatively reliable results for two enzymes; laccase (α-naphthol test) and peroxidase (pyrogallol with H_2O_2 test). All of the cultures showed some positive sign of laccase activity at the 2-week period (save for one culture, ECS-2119) and at the 6-week period (save for one culture, ECS-1853). All cultures showed some positive sign of peroxidase activity at both the 2- and 6-week periods. This is expected as all species of the genus in North America are recognized as white rot decay fungi (Gilbertson and Ryvarden 1987a). That peroxidase and laccase activity is present in the fungal cultures indicates they have the enzymic ability to degrade lignin (Nobles 1965, Kaarik 1965, Stalpers 1978). It is also known that peroxidase activity is almost always associated with laccase activity (Kaarik 1965).

Literature review of the cultural studies performed on these three species shows that they all have extracellular oxidase activity. (Domanski 1969, Gilbertson and Canfield 1973, Hallenberg 1983, Wu 2000). Most studies do not specify more than a culture code of 2 (according to Nobles Code System of 1965). As this is not very specific as to which tests were performed or which enzymes were tested for, the literature is lacking in specific enzyme information on oxidase testing.

Wu (2000) tested *S. flavipora* from Taiwan and found it positive for laccase in gallic acid agar (GAA). Using tyrosine agar (TYA) he found a negative result for tyrosinase activity. No test was made for peroxidase.

Hallenberg (1983) tested *S. paradoxa* from Sweden and found that it was positive for laccase using α-naphthol. Similarly, p-cresol gave a negative test for tyrosinase. No test was made for peroxidase. The most comprehensive set of phenolic tests of *S. paradoxa* are found in Stalpers (1978). He found that both laccase and peroxidase were present, while tyrosinase was a variable characteristic of the fungus in culture (Stalpers 1978). Unfortunately the cultures used were not listed in this study, and it is unknown where they may have come from.

Gilbertson and Canfield (1973) tested *S. apacheriensis* from Arizona for extracellular oxidase using GAA for which a positive result was obtained. No tests were made for tyrosinase and peroxidase.

This study confirms what has been found in other studies regarding the presence of laccase. Laccase activity was found in all cultures at the 6-week period using the α-naphthol phenol test. The presence of peroxidase (determined through the pyrogallol test) in all cultures confirms Stalpers work with *S. paradoxa* and adds to the knowledge about *S. flavipora* and *S. apacheriensis*. The variable presence of tyrosinase in the three species is a bit of a puzzle but is alluded to in Stalpers work on *S. paradoxa*. It is of interest to note that the p-cresol test for tyrosinase activity was more pronounced after the 2 week period than after the 6 week period. As tyrosinase is a suspected endoenzymye,

perhaps the activity is restricted to the growth of the culture on a plate (which at 2-weeks would be ongoing, whereas after 6-weeks would be more or less complete) (Kaarik 1965). Alternatively, the pH of the medium might be changing as this also influences the activity of the enzyme.

Tyrosinase is an oxidase which overlaps the function of laccase to some degree (Thurston 1994). While both are oxidases, tyrosinase is a monophenol mono-oxygenase, which would exclude it from the primary attack on the polyphenolic lignin (Thurston 1994). Laccase is a polyphenol oxidase which is part of the biochemical arsenal wood decay fungi use in the degradation of lignin (Blanchette 1991, Thurston 1994). While the exact biochemical pathway used by white rot fungi, of which the *Schizopora* group is a member, is not completely understood, laccase and peroxidase are involved in the biochemical degradation of the lignin-cellulose complex in wood (Blanchette 1995, Leonowicz *et al* 1999).

As a diagnostic feature for separation of species, phenolic tests are not of great use. The three species studied exhibited a great similarity of reactions and the results seen in this study would not allow for any separation of species based on these tests. This does not come as a great surprise as morphologically these species are difficult to separate. As they all perform the same role in degradation of lignin in wood it is understood that they would contain similar enzymes. The tyrosinase activity exhibited by *S. flavipora* and *S. apacheriensis*, while variable, is a new finding. As a diagnostic tool for separation of fungi to genus level, phenolic compounds such as these used here are of great use in fungal systematics.

FINAL THESIS CONCLUSIONS

The species that make up the genus *Schizopora* and related poroid species from the genus *Hyphodontia* represent a challenge in fungal taxonomy. Using a variety of classification techniques, from classical analysis of morphological characteristics to the study of cultural behaviour, it is hoped that this study will aid the taxonomist in delineating amongst the various species of *Schizopora*. While further work in molecular analysis may yield a clearer picture of the place these species occupy relative to their variability in nature, the present study should suffice for accurate descriptions of this genus and its member species.

From its obscure first description in 1922, *S. paradoxa*, as its name suggests, has been difficult to classify due to the extreme variability of its macro- and microscopic characteristics. As other species were added to the genus, the difficulties in delineating the species of this genus increased. After looking at a wide variety of specimens from throughout North and Central America, the most useful morphological characteristics would appear to be related to the basidiospores and hyphal system. Basidiospore shapes and sizes tend to be characteristic for the species examined. While there is uncertainty about the actual range of basidiospore sizes to be found in nature, the study of specimens has provided a range of spore size for the North American species. Basidiospore shape seems similarly to be a feature that varies but to a limited degree and can be used for taxonomic purposes. Hyphal types and systems also provide a good

basis for taxonomic separation of species. While it may be convenient to ignore arguments about whether species are dimitic or pseudodimitic, the fact remains that the presence of skeletal hyphae is a characteristic of use in describing these species. Whether these hyphae are "true" skeletals or not is beside the point for someone trying to identify a specimen. What is important is whether they are present or not as it would take an expert in skeletal hyphal genesis to differentiate their actual "trueness". The highly variable presence of encrustations on cystidia should not be used as a diagnostic characteristic as the vary nature of the calcium oxalate crystals is in itself highly variable due to a variety of reasons. The swollen hyphal tips or capitate cystidia which are typical for members of both *Schizopora* and *Hyphodontia* similarly cannot be used to identify species but rather as a clue to whether they belong to these two genera in the first place. With these ideas in mind the synonymy of newly described species of *Hyphodontia* with previously described species of *Schizopora* must be considered seriously. Only a large study using incompatibility testing between monokaryotic cultures will truly reveal their biological species status. Molecular analysis would also be of use in a taxonomic study of new species.

Cultural studies are of limited use in the examination of differences between these three species. Cultural characteristics are too similar for differentiation as are phenolic test results. Pairing of species for compatibility testing would be of use if cultures available were monosporus. As they were not, all pairings resulted in some form of antagonism. While this reveals something

about the sibling rivalry to be found amongst wood decay fungi, it is of little use in characterising these species.

The hope of the author is that this study will be of use to both amateur and expert mycologists alike in the description of the North American species of *Schizopora.*

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APPENDIX I

PHENOL OXIDASE TEST DATA

Table AI.1 Naphthol test after two weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	-	faint blue	faint blue	faint blue
B	-	light blue	light blue	blue
C				
D	-	faint blue	light blue	light blue
E	faint blue	light blue	blue	blue
F	-	-	faint blue	light blue
G	light blue	blue	blue	blue
H	light blue	blue	blue	blue
I				
J	blue	blue	blue	blue
K	light vinaceous	faint blue	blue	blue
L	light blue	blue	blue	blue
M	blue	blue	blue	blue
N	-	-	-	faint blue
O	-	-	faint blue	light blue
P	-	-	-	-
Q	-	-	blue	blue
S	blue	blue	blue	blue
T	-	-	blue	blue

Table AI.2 Cresol test after 2 weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	-	-	faint orange	faint orange
B	-	-	-	-
C				
D	-	-	light orange	light orange
E	-	-	faint orange	faint orange
F	-	-	-	-
G	-	-	-	-
H	-	-	faint orange	faint orange
I				
J	-	-	-	-
K	-	yellow	orange	orange-brown
L	-	-	-	-
M	-	-	faint yellow	faint yellow
N	-	-	-	-
O	-	-	orange	orange
P	faint yellow	orange-brown	orange	orange
Q	-	-	-	faint yellow
S	-	-	faint yellow	faint yellow
T	orange-brown	orange-brown	orange-brown	orange-brown

Table AI.3 KOH test after two weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	-	-	-	-
B	-	-	-	-
C				
D	-	-	-	-
E	-	-	-	-
F	-	-	-	-
G	faint yellow	-	-	-
H	faint yellow	-	-	-
I				
J	faint yellow	-	-	-
K	-	-	-	faint yellow
L	faint yellow	-	-	-
M	light yellow	-	-	-
N	-	-	-	-
O	light yellow	light yellow	-	-
P	-	-	-	-
Q	-	-	-	-
S	faint yellow	-	-	-
T	faint yellow	faint yellow	faint yellow	-

Table AI.4 Pyrogallol test after two weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	faint yellow	faint yellow	brown	brown
B	yellow	yellow-brown	yellow-brown	yellow-brown
C				
D	faint yellow	faint yellow	light brown	light brown
E	yellow	yellow-brown	brown	brown
F	faint yellow	faint yellow	faint brown	faint brown
G	yellow	yellow-brown	brown	brown
H	faint yellow	yellow-brown	brown	brown
I				
J	yellow	yellow-brown	brown	brown
K	light yellow	light yellow	yellow	yellow
L	light yellow	yellow-brown	brown	brown
M	yellow-brown	yellow-brown	brown	brown
N	faint yellow	yellow	brown	brown
O	-	-	light yellow	light yellow
P	faint yellow	yellow-brown	brown	brown
Q	-	-	light yellow	yellow-brown
S	light yellow	yellow-brown	yellow-brown	yellow-brown

T	yellow	yellow	yellow	yellow

Table AI.5 Naphthol tests after six weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	light blue	spotty blue	blue	blue
B	-	-	-	very faint blue
C	-	blue	blue	blue
D	-	light blue	blue	blue
E	-	faint blue	blue	blue
F	very faint blue	light blue	blue	blue
G	-	-	-	blue
H	-	-	-	very faint blue
I	-	-	-	very faint blue
J	blue	blue	blue	blue
K	-	-	-	faint blue
L	-	very faint blue	blue	blue
M	light blue	blue	blue	blue
N	-	-	faint blue	blue
O	-	-	-	-
P	faint blue	light blue	blue	blue
Q	-	-	light blue	blue
S	light blue	blue	blue	blue
T	-	-	-	blue

Table AI.6 Cresol tests after six weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	-	-	-	-
B	-	-	-	-
C	-	-	-	-
D	-	-	-	-
E	-	-	-	-
F	-	-	-	-
G	-	-	-	-
H	-	-	-	-
I	-	-	-	-
J	-	-	-	-
K	-	-	-	-
L	-	-	-	-
M	-	-	faint yellow	orange-brown
N	-	-	-	-
O	-	-	-	orange-yellow
P	-	-	-	faint yellow
Q	-	-	faint yellow	faint yellow
S	-	-	-	-
T	-	-	faint brown	light brown

Table AI.7 KOH tests after six weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	-	light yellow	-	-
B	faint yellow	faint yellow	-	-
C	faint yellow	faint yellow	-	-
D	-	-	-	-
E	light yellow	light yellow	-	-
F	-	-	-	-
G	very faint yellow	very faint yellow	-	-
H	yellow	yellow	yellow	yellow
I	-	-	-	-
J	faint yellow	faint yellow	faint yellow	-
K	faint yellow	faint yellow	-	-
L	faint yellow	faint yellow	-	-
M	-	-	-	-
N	-	-	-	-
O	-	-	-	-
P	very faint yellow	very faint yellow	-	-
Q	faint yellow	faint yellow	faint yellow	-
S	faint yellow	faint yellow	faint yellow	-
T	faint yellow	faint yellow	faint yellow	-

Table AI.8 Pyrogallol tests after six weeks

Culture	30MIN	3HRS	24HRS	72HRS
A	light brown	spotty brown	brown	brown
B	light brown	light brown	brown	brown
C	light brown	brown	brown	brown
D	faint yellow	light brown	brown	brown
E	faint brown	light brown	brown	brown
F	-	faint yellow	brown	brown
G	-	faint yellow	brown	light brown
H	-	light yellow	yellow	brown
I	-	-	faint yellow	brown
J	light brown	brown	brown	brown
K	-	faint yellow	-	-
L	brown	brown	brown	brown
M	-	-	yellow	brown
N	faint yellow	light yellow	brown	brown
O	-	-	-	brown
P	faint yellow	light brown	brown	brown
Q	-	-	yellow	yellow
S	-	faint brown	brown	brown
T	-	faint brown	brown	brown

APPENDIX II

CULTURAL INFORMATION

Table AII.1 Culture code information

Culture Letter Code	Culture Collection #	Species Binomial
A	FP-103659	*Schizopora paradoxa*
B	HHB-6700	*Schizopora paradoxa*
C	FP-103756	*Schizopora paradoxa*
D	HHB-271	*Schizopora paradoxa*
E	FP-105695	*Schizopora paradoxa*
F	HHB-6507	*Schizopora paradoxa*
G	FP-70898	*Schizopora paradoxa*
H	L-15844	*Schizopora paradoxa*
I	HHB-4603	*Schizopora apacheriensis*
J	HHB-6677	*Schizopora apacheriensis*
K	FP-101821	*Schizopora apacheriensis*
L	FP-102561	*Schizopora flavipora*
M	PR-1257	*Schizopora flavipora*
N	HHB-9460	*Schizopora flavipora*
O	ECS-1853	*Schizopora* unknown
P	ECS-2119	*Schizopora* unknown
Q	ECS-2129	*Schizopora* unknown
S	ECS-2218	*Schizopora* unknown
T	ECS-2241	*Schizopora* unknown

Table AII.2 Culture collection information

Collection #	Species Binomial	Substrate	Locality	Collection Date
FP-103659	*S. paradoxa*	fallen *Salix*	Great Dismal Swamp, Wallacetown, VA	Dec.7, 1952
HHB-6700	*S. paradoxa*	*Pinus elliottii*	Austin Corey Forest, Florida	Jul.20, 1972
FP-103756	*S. paradoxa*	*Salix* trunk	Great Dismal Swamp, Wallacetown, VA	Dec.28,1952
HHB-271	*S. paradoxa*	*Quercus*	Cornell Road, Beltsville Forest, Laurel, MD	Nov.1, 1967
FP-105695	*S. paradoxa*	bark of *Quercus* log	Southlands Expt. Forest, Bainbridge, GA	Apr.13, 1961
HHB-6507	*S. paradoxa*	*Quercus nigra*	Upper Sugarfoot Prairie, FL	Jul.12, 1972
FP-70898	*S. paradoxa*	fallen hardwood	Patuxent Wildlife Research Refuge, Laurel, MD	Jun.10, 1965
L-15844	*S. paradoxa*	*Acer*	Bridgeport, NY	Sept.29, 1978
HHB-4603	*S. apacheriensis*	*Quercus*	Gainesville, FL	Jul.20, 1970
HHB-6677	*S. apacheriensis*	*Quercus*	Gainesville, FL	Jul.19, 1970
FP-101821	*S. apacheriensis*	*Pinus palustris* bark	Harrison Expt. Station, MI	Nov.03, 1981
FP-102561	*S. flavipora*	hardwood branch	NASA Stennis Space Center, MI	Dec.03, 1990
PR-1257	*S. flavipora*	log	El Verde Research Area, Puerto Rico	Aug.27, 1993
HHB-9460	*S. flavipora*	Liquidambar	Tall Timbers Research Station, FL	Aug.23, 1977
ECS-1853	*Schizopora* unknown	trunk of tree fern	Tabonuco, El Verde, Puerto Rico	Apr.30, 1991
ECS-2119	*Schizopora* unknown	dead branch	El Verde Station, Puerto Rico	May 15, 1991
ECS-2129	*Schizopora* unknown	on hanging branch	El Verde, Puerto Rico	May 15, 1991
ECS-2218	*Schizopora* unknown	rotten stem of *Prestoea montana*	El Yunque, Puerto Rico	May 20, 1991
ECS-2241	*Schizopora* unknown	burnt wood slash	Conte National Forest, Puerto Rico	May 21, 1991

APPENDIX III

CULTURAL CHARACTERISTICS

AND

ASSOCIATED CODES

STALPERS CULTURAL CODES

For any given code characteristic there were three optional answers; absent, variable or always. For some characteristics the three options were different and are indicated in this list surrounded by square brackets.

Table AIII.1 Cultural characteristics and associated codes (Stalpers 1978)

Code	Characteristic
1	laccase (naphthol)
2	tyrosinase (cresol)
3	peroxidase (pyrogallol)
4	KOH
5	Growth rate> 70mm in 7 days
6	Growth rate> 70mm in 14 days
7	Growth rate 40-70 in 14 days
8	Growth rate 25-40 in 14 days
9	Growth rate 10-25 in 14 days
10	Growth rate <10mm in 14 days
11	Growth rate ratio MEA:ChA [>1.2, 0.8-1.2, or <0.8]
12	Marginal hyphae raised
13	Marginal hyphae appressed or submerged
14	Distance of marginal hyphal tips [dense, variable, distant]
15	Outline of colony [even, variable, bayed or fringed]
16	Aerial mycelium absent after 2 weeks
17	Aerial mycelium downy
18	Aerial mycelium farinaceous/granulose
19	Aerial mycelium floccose
20	Aerial mycelium silky
21	Aerial mycelium cottony
22	Aerial mycelium woolly
23	Aerial mycelium plumose
24	Aerial mycelium pellicular/sub-felty
25	Aerial mycelium felty
26	Aerial mycelium velvety
27	Aerial mycelium lacunose
28	Aerial mycelium forming crustose layer
29	Aerial mycelium zonate
30	Colony white
31	Colony cream
32	Colony orange/reddish

Table AIII.1. continued...

Code	Characteristic
33	Colony pink, pale lilac, vinaceous, blue
34	Colony brown
35	Colony yellow or ochraceous
36	Odour distinct, definable
37	Reverse bleached
38	Reverse darkened
39	Clamps [absent, inconsistent, at all septa]
40	Clamps if inconsistent [- , always rare, absent in margin]
41	Clamps in whorls
42	Sprouting clamps
43	(not in use in key)
44	Ratio of diameter of hypha to clamp >1
45	Ratio of diameter of hypha to clamp ~1
46	Skeletal hyphae not or rarely branched
47	Skeletal hyphae much branched
48	Thick walled generative hyphae
49	Hyphae with meandering lumen
50	Inequivalent branching
51	Width of hyphae <1.5um
52	Width of hyphae 1.5-3
53	Width of hyphae 3-5
54	Width of hyphae 5-7.5
55	Width of hyphae >7.5
56	Hyphae with encrusted contorted tips
57	Hyphae encrusted
58	Hyphae covered with oil drops/ resin
59	Hyphae covered with minute projections
60	Aerial hyphae with oil drops/ resin
61	Stag-horn, witches broom hyphae
62	(not in use in key)
63	Cuticular cells
64	Interlocking hyphae
65	Hyphal knots or bulbils
66	Sclerotia
67	Hyphae pigmented
68	Asterosetae
69	Setal hyphae
70	Setae
71	Acanthohyphidia
72	Cystidia
73	Gloeocystidia

Table AIII.1. continued...

Code	Characteristic
74	(not in use in key)
75	Terminal swellings
76	(not in use in key)
77	Stephanocysts
78	Ampullate or constricted septa
79	Monilioid hyphae
80	other remarkable swellings
81	Rhizomorphs or hyphal strands
82	Crystals in aerial mycelia
83	Crystals in agar
84	Arthroconidia (oidia)
85	Chlamydospores
86	Blastoconidia
87	Conidiophores
88	Basidia formed within 6 weeks
89	Substrate: angiosperms
90	Substrate: gymnosperms
91	Other substrate (debris, soil)
92	Homothallic [- or+]
93	Heterothallic bipolar [- or+]
94	Heterothallic tetrapolar [- or+]
95	Cells of secondary mycelium binucleate
96	Cells of secondary mycelium multinucleate
97	Number of nuclei per basidiospore [-, variable, 1]
98	Number of nuclei per basidiospore [-, variable, 2 or more]
99	# of nuclei in cells of primary mycelium [-, variable, 1]
100	# of nuclei in cells of primary mycelium [-, var. , 2 or more]

NOBLES CULTURAL CODES

This list of diagnostic characters and their code numbers is taken from Nobles revision of 1965. It is less inclusive of characteristics than that of Stalpers and is not used for this study, but presented here for purposes of comparison of the two codes.

Table AIII.2 Cultural characteristics and associated codes (Nobles 1965)

Code	Characteristic
1	Results negative in tests for extracellular oxidase
2	Results positive in tests for extracellular oxidase
3	Thin walled hyphae clamped
4	Advancing hyphae simple septate, older hyphae clamped
5	Thin walled hyphae simple septate, occasional clamps
6	Thin walled hyphae simple septate
7	Hyphae thin walled and undifferentiated
8	Hyphae differentiated to form fibre hyphae
9	Hyphae with clamps and scattered irregular thickenings
10	Hyphae forming cuticular cells or pseudo-parenchyma
11	Hyphae with numerous short branches, hooked or re-curved, or thick walled nodules
12	Hyphae with contorted encrusted tips
13	Cystidia present on vegetative mycelium
14	Cystidia present on fruiting areas of mycelium only
15	Gloeocystidia present
16	Hyphae forming strands or rhizomorphs
17	Setae on aerial mycelia or in fruiting areas
18	Setal hyphae on aerial mycelium
19	(not in use in key)
20	Hyphae with minute projections on walls
21	Hyphae with resinous masses on walls
22	Bulbils or knots of hyphae
23	Sclerotia
24	Hyphae with walls slightly thickened and empty lumen
25	Hyphae with walls somewhat thickened and empty lumen
26	Noteworthy swellings on hyphae
27	(not in use in key)
28	(not in use in key)
29	(not in use in key)

Table AIII.2. continued...

Code	Characteristic
30	(not in use in key)
31	(not in use in key)
32	Lacking conidia, chlamydospores, and oidia
33	Conidia present
34	Chlamydospores present
35	Oidia present
36	Hyphae hyaline, mats white or pale
37	Hyphae yellow or brown in KOH, mats yellow or brown
38	Reverse of colony unchanged in colour
39	Reverse brown, at least in part
40	Reverse bleached, at least in part
41	Plates covered in 1 week
42	Plates covered in 2 weeks
43	Plates covered in 3 weeks
44	Plates covered in 4 weeks
45	Plates covered in 5 weeks
46	Plates covered in 6 weeks
47	Plates not covered in 6 weeks
48	Fruitbody regularly produced in 6 weeks
49	(not in use in key)
50	Odour fragrant (sweet, fruity, or wintergreen)
51	Odour musty or earthy
52	Odour suggesting an antiseptic
53	Odour noteworthy but not as described above
54	Associated with decay of angiosperms
55	Associated with decay of gymnosperms
56	Occurring in other habitats (like soil, etc.)
57	Homothallic
58	Heterothallic, but type of infertility unknown
59	Heterothallic, with bipolar interfertility
60	Heterothallic, with tetrapolar interfertility

REVISION OF CULTURAL CODE BY NAKASONE

In 1990 Nakasone published a study of cultural characteristics of wood decay fungi using Nobles code with some adjustments. Nakasone (1990) mainly expanded a few code categories to include more information. These are listed here for comparison purposes as many recent studies have based their coding on that of Nakasone. A technical difference between Nakasone (1990) and Nobles (1965) is that Nakasone used 1.5% MEA instead of Nobles 1.25% MEA for growing the cultures.

Table AIII.3 Cultural characteristics and associated codes (Nakasone 1990)

Code		Characteristic
1		Results negative in tests for extracellular oxidase
2		Results positive in tests for extracellular oxidase
	2a	Laccase present only
	2b	Tyrosinase present only
3		Thin walled hyphae clamped
	3c	Clamp connections constant or regular
	3i	Clamp connections variable
4		Advancing hyphae simple septate, older hyphae clamped
5		Thin walled hyphae simple septate, occasional clamps
6		Thin walled hyphae simple septate
7		Hyphae thin walled and undifferentiated
8		Hyphae differentiated to form fibre hyphae
	8d	Dextrinoid fibre hyphae present
	8v	Dextrinoid dichohyphidia
9		Hyphae with clamps and scattered irregular thickenings
10		Hyphae forming cuticular cells or pseudoparenchyma
11		Hyphae with numerous short branches, hooked or recurved, or thick walled nodules
12		Hyphae with contorted encrusted tips
13		Cystidia present on vegetative mycelium
14		Cystidia present on fruiting areas of mycelium only

Table AIII.3. continued...

Code		Characteristic
15		Gloeocystidia present
	15a	Positive reaction with sulfobenzaldehyde
	15b	Negative reaction with sulfobenzaldehyde
	15p	with papillae (or schizopapillae)
16		Hyphae forming strands or rhizomorphs
17		Setae on aerial mycelia or in fruiting areas
18		Setal hyphae on aerial mycelium
19		Hyphae forming distinctive moniliform terminal cells
20		Hyphae with minute projections on walls
21		Hyphae with resinous masses on walls
22		Bulbils or knots of hyphae
23		Sclerotia
24		Hyphae with walls slightly thickened and empty lumen
25		Hyphae with walls somewhat thickened and empty lumen
26		Noteworthy swellings on hyphae (ie allocysts)
27		Clamped hyphae with evenly thick walls and lumen staining
28		Capitulate or capitate spines on vegetative hyphae
29		Dextrinoid asterohyphidia present
30		Stephanocysts or echinocysts present
31		Other unusual or noteworthy hyphal swellings
	31a	Malocysts present
	31b	Drepanocysts present
	31c	Clusters of crystals in mats or agar apart from hyphae
	31d	Swollen or ampulate clamps and hyphae present
	31e	Mats turning colour in 2% KOH (pink-red-black)
	31f	Acathohyphidia or dendrohyphidia present
	31g	Capilliform hyphae present
32		Lacking conidia, chlamydospores, and oidia
33		Conidia (blastic type) present
34		Chlamydospores present
35		Arthroconidia (oidia) present
36		Hyphae hyaline, mats white or pale
37		Hyphae yellow or brown in KOH, mats yellow or brown
38		Reverse of colony unchanged in colour
39		Reverse brown, at least in part
40		Reverse bleached, at least in part
41		Plates covered in 1 week
42		Plates covered in 2 weeks
43		Plates covered in 3 weeks
44		Plates covered in 4 weeks
45		Plates covered in 5 weeks

Table AIII.3. continued...

Code	Characteristic
46	Plates covered in 6 weeks
47	Plates not covered in 6 weeks
48	Fruitbody regularly produced in 6 weeks
49	(not in use in key)
50	Odour fragrant (sweet, fruity, or wintergreen)
51	Odour musty or earthy
52	Odour suggesting an antiseptic
53	Odour noteworthy but not as described above
54	Associated with decay of angiosperms
55	Associated with decay of gymnosperms
56	Occurring in other habitats (like soil, etc.)
57	Homothallic
58	Heterothallic, but type of infertility unknown
59	Heterothallic, with bipolar interfertility
59a	Bipolar amphithallic or secondarily homothallic
60	Heterothallic, with tetrapolar interfertility
60a	Bipolar amphithallic or secondarily bipolar

APPENDIX IV

CULTURE GROWTH MEASUREMENTS

Table AIV.1 1-week and 2-week growth measurements for cultures (mm.)

Culture	Measurements (week 1)	Avg.	Measurements (week 2)	Avg.
Schizopora paradoxa				
FP-103659	11,10,12,10,12,11,11	11.0	37,38,33,33,32,34,34	34.4
HHB-6700	21,20,20,22,20,20,21	20.6	61,60,62,60,61,62,61	61.0
FP-103756	3.5, 3, 4, 3.5, 3, 2, 3	3.1	9, 7, 8, 9, 7, 9, 8	8.1
HHB-271	5, 4.5, 5.5, 6, 4, 4.5, 5	4.9	23,25,25,26,26,27,24	25.0
FP-105695	7, 8, 7, 8, 8, 8, 7	7.6	23,20,23,30,25,24,23	24.0
HHB-6507	13,14,11,12,13,11,11	12.1	35,32,33,35,32,34,36	33.9
FP-70898	11,12,11,12,10,12,11	11.3	39,42,37,42,41,41,39	40.1
L-15844	6, 8, 9, 9, 8, 8, 7	7.9	27,30,29,31,31,33,26	29.6
Schizopora apacheriensis				
HHB-4603	5.5, 6.5, 4.5, 5, 5.5, 8, 5	5.7	18,20,15,19,17,17,20	18.0
HHB-6677	9,12,12,12,13,13,12	11.9	40,45,44,44,45,40,43	43.0
FP-101821	32,33,24,36,29,27,25	29.4	75,75,75,75,75,75,75	75.0*
Schizopora flavipora				
FP-102561	14,15,17,16,15,16,16	15.6	51,52,51,49,48,49,48	49.7
PR-1257	16,19,16,17,17,17,17	17.0	58,52,51,50,56,55,42	52.0
HHB-9640	13,10,10,10,10,12,12	11.0	35,32,31,33,33,33,33	32.9
Puerto Rican cultures of *Schizopora* sp.				
ECS-1853	61,58,63,60,58,65,63	61.1	75,75,75,75,75,75,75	75.0*
ECS-2119	7, 8.5, 8, 8, 7, 8, 8	7.8	22,21,22,24,23,22,23	22.4
ECS-2129	58,60,58,59,57,58,59	58.4	75,75,75,75,75,75,75	75.0*
ECS-2218	8, 9, 9, 8.5, 8.5, 8, 8.5	8.5	24,22,22,23,23,23,22	22.7
ECS-2241	43,46,44,44,45,47,48	45.3	75,75,75,75,75,75,75	75.0*

* these cultures covered the 75mm diameter plates before the second week

APPENDIX V

GLOSSARY

GLOSSARY

This glossary is based upon definitions found in Snell and Dick (1971) and Hawksworth *et al* (1996).

Acicular – bristle-shaped, needle-shaped, very slender and sharp pointed

Aculei – prickles, spines, or teeth

Adnate – (of basidiocarps) firmly attached to the substrate

Allantoid – sausage shaped; somewhat curved, with rounded ends

Amyloid – stained blue by iodine

Apiculum – a short projection at one end of a spore; a projection by which the spore was fixed to the sterigmata

Appressed – (of hairs, scales, fibrils, etc.) closely flattened down

Arachnoid – cobweb-like; covered with, or consisting of, delicate hairs or fibrils

Arthroconidia – jointed conidia

Basionym – the name upon which a new transfer or a new combination is based

Capitate – having a minute knob at the tapering apex

Ceraceous- waxy

Chelation – to combine a metal ion with a chemical compound to form a ring

Clavate – club-like; narrowing in the direction of the base

Coriaceous – of a leathery texture

Cystidiole (s) – a sterile basidium arising from the same hymenial level as the basidia and extending slightly beyond it

Cystidium – a sterile body, frequently of distinctive shape, occurring at any surface of a basidioma, particularly the hymenium from which it frequently projects

Daedaloid – having the mouths of the tubes elongate and sinuous

Dextrinoid – stained yellowish- or reddish brown by Meltzer's iodine

Dimidiate – semicircular in outline

Dimitic - having hyphae of two kinds

Dissepiment – a partition (e.g. that between the pores of a polypore)

Drepanocysts – small clavate curling protuberances found in mycelial culture of the genera *Hyphodontia* and *Schizopora*

Effused – stretched out flat, esp. as a film-like growth

Effused-reflexed – spread out over the substrate and turned back at the margin to form a pileus

Fibrillose – having hairy filaments which are thin and thread-like, arranged more or less parallel to each other, compactly or scattered

Fimbriate – having the margin finely torn

Fusoid – somewhat spindle shaped, tapering at both ends

Gloeocystidia – a special form of cystidia of gelatinous or horny consistency and with oily, resinous, and granular contents

Guttulate – (of spores) containing one or more oily globules

Hyaline – colourless

Hydnoid – having a 'toothed' spore bearing surface

Hyphoid – resembling a hypha, hypha-like

Hymenium – the spore bearing surface of a fruitbody

Irpiciform (or irpicoid) – having flattened teeth resembling those in *Irpex*

Lacerate – as if roughly cut or torn

Lageniform – flask-shaped, gourd shaped

Lamellate – made up of thin plates

Lanceolate – lance-shaped, of much greater length than breadth, and tapering

Malocyst - small mammiform protuberances found in mycelial culture of the genera *Hyphodontia* and *Schizopora.*

Membranaceous – of or like a membrane

Monomitic – having hyphae of one kind

Mucronate – pointed; tipped with an abrupt, short point

Ochraceous – ochre-yellowish colour

Odontoid – toothed

Paraphysate (or paraphysoid) – (of hyphae) hyphal ends which appear in the hymenium which may be tramal cystidia or similar structures.

Pellicular – filmy, cuticular, skin-like

Pileate – having a pileus

Pileus – cap or the hymenium supporting part of the basidioma of non-resupinate *Basidiomycetes*

Plumose – finely feathered

Pruinose – (of a surface) as if finely powdered

Raduloid – resembling a nutmeg grater

Resupinate – flat on the substrate with the hymenium on the outer side

Reticulate – marked by lines, veins, or ridges which cross one another as in a net

Scrobiculate – roughen, furrowed; pitted

Sterigma – a tiny, spicule-like pedicel upon which a basidiospore is borne

Stipitate - stalked

Subceraceous – somewhat waxy

Subclavate – somewhat club shaped

Subicule (ar) – a net-, wool-, or crust-like growth of mycelium under the fruitbodies

Subglobose - not quite spherical

Suburniform – somewhat urn shaped

Tomentose – having a covering of soft, matted hairs

Tramal – of the layer of hyphae in the central part of a lamella of an agaric, a spine of *Hydnaceae*, or the dissepiment between pores of a polypore

Velutinous – thickly covered with delicate hairs, like velvet

Ventricose – swelling out in the middle or at one side; inflated