Macedonian Journal of Ecology and Environment
Vol. 22, Issue 1
pp. 5 - 16
Skopje (2020)
ISSN 1857 - 8330 (on-line)
Original scientific paper
Available online at www.mjee.org.mk

Diversity of wood-inhabiting fungi (Basidiomycota) in Macedonian cultural heritage

Рановидност на габи кои живеат во дрво (Basidiomycota) во македонското културно наследство

Liljana Kovachovska[1*], Katerina Rusevska[2] and Mitko Karadelev[2]

[1]*National Institution Museum of Macedonia, Central Conservation Laboratory, Josif Mihajlovik str.7, Skopje, 1000, The Republic of North Macedonia*

[2]*Institute of Biology, Faculty of Natural Science, St. Ciril and Methodius University, Arhimedova str. 5, Skopje, 1000, The Republic of North Macedonia*

Abstract

The study of biological damage of cultural monuments in the Republic of North Macedonia was conducted between 2012 and 2016. The research was focused on the biodeterioration caused by wood-inhabiting fungi and slime moulds. Eighty-four cultural monuments in total, including monasteries, churches, and many old houses were inspected in different parts of the country. A total number of 109 wood-inhabiting fungi were observed both on the indoor wood construction (ceiling, stairs, inner portions of the roof, etc.) and external woodwork (gateway, bridge, outer door, roof, stairs, etc.). In this paper are presented the fungi from the phylum Basidiomycota. The majority of the identified species belong mainly to the genera: *Antrodia, Athelia, Botryobasidium, Ceriporiopsis, Coniophora, Dacrymyces, Gloeophyllum, Hyphoderma, Hyphodontia, Phanerochaete, Peniophora, Phlebia, Postia, Stereum, Tapinella, Tomentellina* etc. Decay fungi prevailed on the roof constructions of the inspected buildings. Fresh fungal damage found in monasteries and churches is detrimental to wood constructions and frescoes, and it must be eliminated in order to preserve important cultural heritage.

Key words: Biodeterioration, wood-decay fungi, cultural monuments, North Macedonia

Апстракт

Истражувањата за биолошките оштетувања на културно-историските споменици во Република Северна Македонија, прикажани во овој труд, се вршени во периодот 2012-2016. Главен акцент беше ставен на биразградувањето предизвикано од лигниколни габи. За таа цел беа посетени вкупно 84 културно-историските споменици, како што се манастири, цркви и повеќе стари куќи од различни делови на земјата. Видовите се собрани од внатрешни (тавани, скали,

Submitted: 26.02.2020
Accepted: 26.06.2020

* Author for correspondence: *lkovachovska@yahoo.com*

куполи, прозорски рамки, внатрешен дел од кровови) и од надворешни конструкции (кровови, тремови, балкони, чардаци, камбанарии, кули, дрвени порти, мостови, огради). При тоа беа регистрирани 109 вида лигниколни габи, кои припаѓаат на типот Basidiomycota и тоа главно на родовите: *Antrodia, Athelia, Botryobasidium, Ceriporiopsis, Coniophora, Dacrymyces, Gloeophyllum, Hyphoderma, Hyphodontia, Phanerochaete, Peniophora, Phlebia, Postia, Stereum, Tapinella* и *Tomentellina*. Најмногу видови се регистрирани на кровни конструкции. Габите кои се развиваат на културно-историските споменици предизвикуваат оштетувања на дрвните констукции и фреските и истите треба да се отстранат со цел заштита на значајното културно богатство.

Клучни зборови: биодетериорација, габи на дрвни конструкции, културно-историски споменици, Северна Македонија

Introduction

The Republic of North Macedonia is a country centrally positioned in the Balkan Peninsula, a corridor through which many civilizations have passed throughout history, thereby contributing to the diversity of its cultural heritage. The nation possesses in excess of 10,000 valuable cultural and historic monuments and artefacts, as follows: 5,160 archaeological sites, 4,681 monuments and landmarks, 29 urban and rural compounds or segments, 1,156 churches and monasteries, 112 mosques, 51 fortresses, bridges, towers, 71 other objects dating between 15th and 19th century and 22,800 icons, some of them registered in the world anthology (Kjornakov et al. 1971, Pavlovska et al. 2011).

It was the cultural and historic monuments distributed all over the territory of the RM that were our subject of research: monastery compounds, churches, old houses with traditional folk architecture in rural and urban environment, archaeological sites, historical memorial houses and museums, mosques, dervish lodges (tekkes), Turkish baths, inns, the old bazaar in Skopje, and a plethora of artworks and artefacts, deposited in the museums (Trichkova et al. 2008). Their protection and conservation is in direct correlation to the public and national interest of R. North Macedonia but it is also of international interest.

The largest portion of the fungi were spotted on the external wooden structures (wooden structures of inns, roof constructions, wooden awnings, gateways, balconies, canopies, ceilings, doors and windows) whereas an inconsiderable number of species were found in the interior of the buildings. Several groups of fungi were recorded on the outer joinery (bridges, chairs, benches, gates, staircases, bell towers and auxiliary facilities that are an integral part of monastery compounds).

The most significant wood-decay fungi within buildings in Europe and North America are the fungi that cause brown-rot in conifers. White-rot fungi, which preferentially attack hardwoods, are less common in buildings (Singh 1994). Often, only three fungal genera are mentioned as the most common house-rot fungi in Europe, as follows: *Serpula* (*S. lacrymans*), *Coniophora* spp. and *Antrodia* spp. (Schmidt 2006).

Our prior research focusing on biodeterioration caused by wood-decaying fungi in Macedonian cultural heritage had been conducted in June 2004 and June 2005. Twenty-eight monasteries and churches and one fortress in total had been inspected in various parts of the country. A third of them had fungal damage while twenty-six fungal species had been identified on the construction and decorative materials of the monuments. The most frequently encountered wood-decay fungus was *Xylodon crustosus,* collected on five occasions (Irbe et al. 2008).

Research aims

Cultural and historic monuments distributed throughout the territory of the RM were subject of our research, as follows: monastery compounds, churches, along with old houses with traditional folk architecture in rural and urban environment. The aim was to inspect biodeterioration triggered by wood-decay fungi (Basidiomycota) of the Macedonian cultural heritage. Research consisted of damage diagnosis *in situ*, identification of fungi, and examination of the attacked materials.

Materials and methods

The inspection encompassed approximately a hundred objects located in different regions all over R. North Macedonia, as follows: Skopje, Skopska Crna Gora Mt, Kumanovo, Kratovo, Kriva Palanka, Probistip, Stip, Berovo, Delcevo, Strumica, Katlanovo, Veles, Negotino, Kavadarci, Bitola, Prilep, Krusevo, Resen, Prespa, Struga, Ohrid, Debar, Mavrovo and so forth. With 84 studied objects, biodeterioration of wood constructions revealed presence of fungal infections and insects. In this papaer are presented the results of fungi belonging to basidiomecetes.

The inception phase comprised field research and inspection of the objects themselves (*in situ*), wherefrom more than 350 fungal specimens were collected. The specimens were subsequently brought to the Mycological Laboratory within the Institute of Biology at the Faculty of Natural Science and Mathematics in Skopje, R. North Macedonia, where they were analysed in detail.

Field research was concentrated on collection of material from wooden constructions from the exterior and interior in equal measure. The analysis entailed wooden elements and constructions built in the objects such as beams inside the building, barrel vaults, staircases, doors and window frames. Pertaining to the objects' exterior, the following were inspected: roof structures, wooden awnings, ceilings, gateways, balconies, porches, bell towers, towers. As for the exterior joinery, the following were examined: wooden gates, bridges, benches, fences and stone fences with wooden awnings, which define the quarter of the monastery compounds (Trichkova et al. 2008, Pavlovska et al. 2011).

The collected field material, most commonly the fungal fruiting bodies, were photographed, labelled and packaged into paper or plastic bags, and prepared for transportation to the laboratory. The specimens were dried at room temperature or in a dryer at a temperature of around 40°C. Specimens were studied macroscopically and microscopically by applying specific reagents (5% KOH, Melzer's reagent, Congo Red, Cotton Blue, sulphovanillin). Voucher specimens of fungi were deposited in the Macedonian Mycological Collection (MCF) at the Institute of Biology, Faculty of Natural Science and Mathematics.

Identification of basidiomycete fungi was conducted on the basis of their macro- and micro-morphological characters exclusively. Literature used for identification is: Eriksson 1958; Eriksson & Ryvarden 1973, 1975, 1976; Eriksson et al. 1978, 1981, 1984; Hjortstam et al. 1987, 1988; Breitenbach & Kränzlin 1984, 1986, 1991, 1994, 2000, 2005; Bech-Andersen 1995; Julich 1984; Ryvarden 1991; Bernicchia & Gorjón 2010. Slime moulds were identified according to Neubert et al. 1993, 2000. The identification of the ascomycete fungi was according to: Breitenbach & Kränzlin 1984, Hansen & Knudsen 2000, and anamorphic fungi according to Samson et al. 2004. Fungal names have been provided in compliance with the fungal databases Index Fungorum (Kirk 2011, accessed 26.02.2020) and Mycobank (Stalpers & Cock 2013, accessed 26.02.2020).

Results

The analysis of the results demonstrated that changes in wooden structures were caused by biodegraders' activity, connected to their physical, chemical and mechanical activity. The scope of damage was strictly related to the species of pest, its dimensions, type of material, its condition, environment conditions, microclimate exposure and the level and type of air pollutants. Biodegradation of wood constructions on the territory of R. North Macedonia is the most dominant on the external wood constructions exposed to open areas – with 70% while damage incurred in the interior area amounts to only 30%.

The greatest fungal diversity was established in the Skopje region, where only from Skopska Crna Gora Mt (northern Skopje bishopric) with 7 monastery compounds scrutinized, 79 specimens and 55 different fungi species from the phylum Basidiomycota were identified. In the vicinity of Skopje (southern Skopje bishopric), 11 objects (monasteries and churches) were examined, and 22 fungal species were recorded. The southwestern part of R. North Macedonia was the second region by species occurrence and diversity. Specifically, in Ohrid-Struga region, 20 objects were inspected, 27 fungi species recorded while in Resen-Bitola region, 15 objects were inspected, and 24 fungi species registered. Then follows the region of eastern R. North Macedonia – Strumica, Stip, Berovo and Delcevo: 10 objects were inspected, and 25 different species of fungi ascertained. Afterward, the northeastern part of R. North Macedonia – Kumanovo area, Kratovo-Zletovo: 11 objects examined, and 17 different fungal species found; in the region of Povardarie bishopric, 5

Figure 1 Map of the studied areas in R. North Macedonia.

objects reviewed, 17 fungal species identified. In Debar-Kicevo bishopric, 5 objects were inspected, and 12 species recorded, and, finally, in Tetovo region, 3 objects were inspected and 9 fungal species recorded (Fig. 1, Tab. 1).

The greater part of fungi i.e. 30 species were collected from the old guest-house in the monastery with the church of the Holy Archangels Michael and Gabriel (14th century) in Kucheviste village, in Skopska Crna Gora Mt in Skopje region (Fig 2a). The following genera occurred in the foregoing object: *Antrodia*, *Athelia* (Fig 2b), *Botryobasidium*, *Ceriporiopsis*, *Coprinus*, *Dacryomyces*, *Galerina*, *Hyphoderma*, *Hyphodontia*, *Lopharia*, *Marasmius*, *Mycena*, *Phanerochaete*, *Phlebia*, *Pluteus*, *Postia*, *Radulomyces*, *Resupinatus*, *Sistotrema* and *Schizopora*. They were predominantly recorded on deciduous and rarely on coniferous tree species from the roof construction. Representatives of *Myxomycota* were also found, such as *Badhamia utricularis*, *Comatricha nigra*, *Physarum globuliferum* and *Physarum* sp., on the roof wooden structures. The genus *Hyphodontia* (10 species) is the most common one: *H. crustosa* recorded in seven, *H. aspera* in one and *H. pallidula* in two cases of the specimens collected. Three of the established species – *Dacryomyces stillatus*, *Galerina* sp. and *Antrodia* sp. caused a brown rot while the remaining 32 caused a white rot. The specimens were collected from an old monastery inn during its restoration period when the entire roof structure had been dismantled and laid down in the yard.

St. Nicholas Monastery (14th century) is situated in close proximity to Ljubanci village in Skopje region. During reconstruction of one of the wings of the dismantled inn wooden structures (Fig 3a), 17 fungal species were identified, as follows: *Coniophora olivacea, Exidia glandulosa, Gloeocystidiellum luridum, Gloeophyllum abietinum, Hyphoderma puberum, H. setigerum* (Fig 3b), *Hyphodontia microspora, Irpex lacteus, Phanerochaete sordida, Ph. velutina, Schizopora paradoxa, Skeletocutis percandida, Tapinella panuoides, Tomentella* sp., *T. ferruginella, Trechispora*

Table 1. Taxonomy, occurrence and decay type of fungi (Basidiomycota) collected on wooden construction in cultural heritage objects in R. North Macedonia.

Fungal species Basidiomycota	Taxonomy Order/Family	Occurrence exterior & interior	Rot B/W
Agrocybe cylindracea (DC.) Maire	*Agaricomycetes*, *Agaricales*	stump	W
Antrodia sinuosa (Fr.) P. Karst.	*Polyporales*, *Fomitopsidaceae*	ceiling beams	B
Antrodia sp. (sterile)	*Polyporales*, *Fomitopsidaceae*	roof construction, ceiling beams	B
Athelia decipiens (Höhn. & Litsch.) J. Erikss.	*Atheliales*, *Atheliaceae*	porch, old guest house	W
Athelia epiphylla (Höhn & Litsch.) J. Erikss. Pers.	*Atheliales*, *Atheliaceae*	roof construction	W
Athelia sp. (sterile)	*Atheliales*, *Atheliaceae*	roof construction	W
Athelia neuhoffii (Bres.) Donk	*Atheliales*, *Atheliaceae*	roof construction	W
Athelia pyriformis (M. P. Christ) Jülich	*Atheliales*, *Atheliaceae*	roof construction	W
Auricularia auricula-judae (Bull.) J. Schröt.	*Agaricomycetes*, *Auriculariaceae*	fence, bench	W
Auricularia mesenterica (Dicks.) Pers.	*Agaricomycetes*, *Auriculariaceae*	beams of porch, chairs, fence	W
Bjerkandera adusta (Willd.) P. Karst.	*Polyporales*, *Meruliaceae*	roof of porch, wooden stairs	W
Botryobasidium obtusisporum Johan Erikson	*Agaricomycetes*, *Botryobasidiaceae*	roof construction, stairs	W
Ceriporiopsis aneirina (Sommerf. Ff.) Dom	*Polyporales*, *Meruliaceae*	roof construction	W
Ceriporiopsis excelsa (S. Lundell) Parmasto	*Polyporales*, *Meruliaceae*	beams of the bell tower	W
Ceriporiopsis resinascens (Romell) Domanski	*Polyporales*, *Meruliaceae*	old guest house	W
Ceriporiopsis sp.	*Polyporales*, *Meruliaceae*	old guest house	W
Chondrostereum purpureum (Pers.) Pouzar	*Agaricales, Cyphellaceae*	roof construction	W
Cylindrobasidium evolvens S. (Fr.) Fr.	*Agaricomycetes*, *Physalacriaceae*	beams of the bell tower	W
Coniophora arida (Fr.) Karst	*Boletales*, *Coniophoracea*	beams in basement	W
Coniophora olivacea (Fr.) Karst	*Boletales*, *Coniophoracea*	roof construction	B
Coniophora puteana (Schumach.) P. Karst.	*Boletales*, *Coniophoracea*	old guest house	B
Coprinellus micaceus (Bull.) Vilgalys, Hopple & Jacq. Johnson	*Polyporales*, *Polyporaceae*	old beams	W
Coriolopsis galica (Fr.) Ryvarden	*Polyporales*, *Polyporaceae*	wooden doors	W
Coriolopsis trogii (Berk.) Domanski	*Polyporales*, *Polyporaceae*	old timber, wooden bench	W
Corticium evolvens (Fr.) Frjűl - (Fr.) Fr.	*Agaricomycetes*, *Corticiaceae*	roof construction	W
Crepidotus cesatii (Rabenh.) Sacc.	*Agaricales*, *Inocybaceae*	wooden beams	W
Dacryomyces stillatus Nees: Fr.	*Dacrymycetales*, *Dacrymycetaceae*	wood used in construction, old guest house	B
Daedalea quercina (L.) Pers.	*Polyporales*, *Fomitopsidaceae*	DW, wooden beams in the yard	W
Exidiopsis sp.	*Auriculariales*, *Auriculariaceae*	wooden gateway, boards, poles	W
Exidia glandulosa (Bull.) Fr.	*Auriculariales*, *Auriculariaceae*	indoor staircase, roof, beams	W
Funalia gallica Fr. Bondartsev & Singer	*Polyporales*, *Polyporaceae*	DW, old timber	W
Funalia trogii (Berk.) Bondarsev & Singer	*Polyporales*, *Polyporaceae*	DW, stairs of bell tower	W

Fungal species Basidiomycota	Taxonomy Order/Family	Occurrence exterior & interior	Rot B/W
Galerina sp.	*Hymenogastraceae*, *Cortinariaceae*	CW, (*Abies*) boards, poles	W
Ganoderma adspersum (Schulzer) Donk	*Polyporales*, *Ganodermataceae*	DW, watch tower	W
Gloeocystidiellum convolvens P. Karst. Donk	*Russulales*, *Gloeocystidiellaceae*	CW, wood used in construction	W
Gloeocystidiellum luridum (Bres.) Boidin	*Russulales*, *Stereaceae*	DW, wooden gate, wooden planks	W
Gloeocystidiellum porosum (Berk. & M. A. Curtis) Donk.	*Russulales*, *Gloeocystidiellaceae*	side beams, poles, interior stairs	B
Gloeophyllum abietinum (Bull.) P. Karst.	*Agaricomycetes*, *Gloeophyllaceae*	ceiling, roof construction tower beams	B
Gloeophyllum sepiarium (Wulfen) P. Karst.	*Agaricomycetes*, *Gloeophyllaceae*	CW, wood used in construction	B
Gloeophyllum trabeum (Pers.: Fr.) Murrill	*Agaricomycetes*, *Gloeophyllaceae*	CW, outside the stairs - bell tower	B
Hapalopilus nidulans (Fr.) P.Karst.	*Polyporales*, *Phanerochaetaceae*	roof construction	W
Hymenochaete cinnamomea Pers. (Quèl.)	*Agaricomycetes*, *Hymenochaetaceae*	CW, tree near old guest house	W
Hymenochaete fuliginosa (Pers.) Lév.	*Agaricomycetes*, *Hymenochaetaceae*	beams of roof construction	W
Hyphoderma obtusiforme J. Erikss & Å.Strid	*Polyporales*, *Meruliaceae*	roof construction, old guest house	W
Hyphoderma praetermissum (P. Karst.) J. Erikss.& Å. Strid	*Polyporales*, *Meruliaceae*	wood awning on stone fence	W
Hyphoderma puberum (Fr.) Wallr.	*Polyporales*, *Meruliaceae*	wooden staircase, old beams bell tower	W
Hyphoderma setigerum (Fr.) Donk	*Polyporales*, *Meruliaceae*	wooden platform, roof construction	W
Hyphodontia arguta (Fr.) J. Erikss.	*Hymenochaetales*, *Schizoporaceae*	wood used in construction, old guest house	W
Hyphodontia aspera (Fr.) J. Erikss.	*Hymenochaetales*, *Schizoporaceae*	DW, inner door	W
Hyphodontia crustose (Pers.) J. Erikss	*Hymenochaetales*, *Schizoporaceae*	roof construction, porch, old guest house	W
Hyphodontia microspora J. Erikss. & Hyortst	*Hymenochaetales*, *Schizoporaceae*	wooden beams, stairs, chairs	W
Hyphodontia pallidula (Bres.) J. Erikss.	*Hymenochaetales*, *Schizoporaceae*	wood on construction porch, fence	W
Hyphodontia sambuci (Pers. Erikss.)	*Hymenochaetales*, *Schizoporaceae*	wooden beams, stairs, chairs	W
Hyphodontia subalutacea P. Karst J. Erikss	*Hymenochaetales*, *Schizoporaceae*	wood on construction porch, fence	W
Hyphodontia sp. (sterile)	*Hymenochaetales*, *Schizoporaceae*	roof construction	W
Hypholoma fasciculare (Huds.: Fr.) P. Kumm.	*Agaricales*, *Strophariaceae*	DW, bench	W
Junghuhnia nitida (Pers.) Ryvarden	*Polyporales*, *Phanerochaetaceae*	wooden gate	W
Inonotus hispidus (Fr.) Karst	*Hymenochaetales*, *Hymenochaetaceae*	tree and fallen branches	W
Irpex lacteus (Fr.) Fr.	*Polyporales*, *Steccherinaceae*	wooden chairs and benches, barrel vaults	W
Laetiporus sulphureus (Bull.) Murrill	*Polyporales*, *Polyporaceae*	cut wood in the yard	B
Lenzites betulina (L.) Fr.	*Polyporales*, *Polyporaceae*	cut wood in the yard	W
Lenzites reichardtii Schulzer	*Polyporales*, *Polyporaceae*	cut wood in the yard	W
Lenzites warnieri Durieu & Mont.	*Polyporales*, *Polyporaceae*	cut wood in the yard	W
Leucogyrophana pseudomollusca (Parmasto) Parm.	*Boletales*, *Hygrophoropsidaceae*	(*Pinus*), wood beams from quarters	B
Lopharia spedicea (Pers.) Boidin	*Polyporales*, *Polyporaceae*	roof construction	W
Funalia gallica (Fr.) Bondartsev & Singer	*Polyporales*, *Polyporaceae*	roof construction	W

Fungal species Basidiomycota	Taxonomy Order/Family	Occurrence exterior & interior	Rot B/W
Marasmius torquescens Quél.	*Agaricales*, *Marasmiaceae*	wooden support of bell tower	W
Mycena sp. (Pers.) Roussel	*Agaricales*, *Marasmiaceae*	roof porch	W
Oxyporus corticola (Fr.) Ryvarden	*Hymenochaetales*, *Schizoporaceae*	cut wood in the yard	W
Oxyporus obducens Donk (Pers.)	*Hymenochaetales*, *Schizoporaceae*	cut wood in the yard	W
Peniophora cinerea (Pers.) Cooke	*Russulales*, *Peniophoraceae*	wood used in construction, old guest house	W
Peniophora incarnate (Pers.) P. Karst.	*Russulales*, *Peniophoraceae*	wood used in construction, old guest house	W
Peniophora pithya (Pers.) J. Erikss.	*Russulales*, *Peniophoraceae*	roof porch	W
Phanerochaete calotricha (P. Karst.) J. Erikss. & Ryvarden	*Russulales*, *Peniophoraceae*	roof from the north, the canopy of wood	W
Phanerochaete filamentosa (Berk & M.A. Curtis) Burds.	*Russulales*, *Peniophoraceae*	wood used in construction, old guest house	W
Phanerochaete laevis (Fr.) J. Erikss. & Ryvarden	*Russulales*, *Peniophoraceae*	wooden beams and boards	W
Phanerochaete sordida (Karst.) Erikss. & Ryvarden	*Russulales*, *Peniophoraceae*	roof of lodge, old guest house	W
Phanerochaete tuberculate (Karst.) Parm.	*Russulales*, *Peniophoraceae*	roof construction church in open dome	W
Phanerochaete radicata (Henn.) Nakasone	*Russulales*, *Peniophoraceae*	wooden beams and boards	W
Phanerochaete velutina (DC.) P. Karst.	*Russulales*, *Peniophoraceae*	roof construction, wine barrels, benches	W
Phellinus punctatus (P. Kurst) Pilát	*Hymenochaetales*, *Hymenochaetaceae*	roof construction, wood fence	W
Phlebia livida (Pers.) Bres.	*Polyporales*, *Meruliaceae*	wood used in construction, old guest house	W
Phlebia segregata (Bourdot & Galzin) Parmasto	*Polyporales*, *Meruliaceae*	wood used in construction, old guest house	W
Phlebiopsis roumegueri (Bresad.) Jülich & Stalp	*Polyporales*, *Phanerochaetaceae*	wood used in construction, old guest house	W
Pleurotus dryinus (Pers.) P. Kumm.	*Agaricales*, *Pleurotaceae*	wooden support of bell tower	W
Pleurotus ostreatus (Jacq.) Quélet	*Agaricales*, *Pleurotaceae*	cut wood in the yard	W
Pluteus phlebophorus (Dimar: Fr.) P.Kumm	*Agaricales*, *Pleurotaceae*	roof construction	W
Postia subcaesia (David) Jül.	*Polyporales*, *Fomitopsidaceae*	roof construction, old guest house	B
Radulomyces confluens (Fr.) M.P.Christ.	*Agaricales*, *Pterulaceae*	roof construction, old guest house	W
Resupinatus applicatus (Batsch: Fr.) Gray	*Agaricales*, *Tricholomataceae*	roof construction, old guest house	W
Serpula lacrimans (Wulfen) P. Karst.	*Boletales*, *Serpulaceae*	construction in basement, floor boards	B
Sistotrema efibulatum J. Erikss.	*Cantharellales*, *Hydnaceae*	roof construction, old guest house	W
Schizophyllum commune Fr.	*Agaricales*, *Schizophyllaceae*	cut wood in the yard	W
Schizopora paradoxa (Schrad.) Donk	*Hymenochaetales*, *Schizoporaceae*	roof construction, old guest house	W
Skeletocutis percandida (Malencon & Bertault) J. Keller	*Polyporales*, *Polyporaceae*	roof construction, old guest house	W
Steccherinum ochraceum (Pers.) Gray	*Polyporales*, *Phanerochaetaceae*	cut wood in the yard	W
Steccherinum bourdotti Saliba & A. David	*Polyporales*, *Phanerochaetaceae*	wooden beams and boards	W
Stereum hirsutum (Willd.) Pers.	*Russulales*, *Stereaceae*	wooden chairs and benches, barrel vaults	W
Tapinella panuoides (Batsch) E.-J. Gilbert	*Boletales*, *Tapinellaceae*	roof construction, old guest house	B
Tomentellina fibrosa (Berk.&Curtis) Larsen.	*Thelephorales*, *Thelephoraceae*	wood used in construction	B

Fungal species Basidiomycota	Taxonomy Order/Family	Occurrence exterior & interior	Rot B/W
Tomentella ferruginella Pers. Ex Pat.	*Thelephorales*, *Thelephoraceae*	wood used in construction	B
Trametes hirsuta (Wulfen) Pilát	*Polyporales*, *Polyporaceae*	old tree, branches, beams near building	W
Trametes versicolor (L.) Lloyd	*Polyporales*, *Polyporaceae*	chairs, benches, cut tree, fallen branch	W
Trechispora farinacea (Pers.: Fr.) Liberta	*Hydnodontaceae*, *Corticiaceae*	wood used in construction, old guest house	W
Trechispora sp.	*Hydnodontaceae*, *Corticiaceae*	wood used in construction, old guest house	W
Tremella mesenterica (Schaeff.) Retz.	*Tremellales*, *Tremellaceae*	wood used in construction, old guest house	W
Tubulicrinis glebulosum (Fr.) Donk	*Hymenochaetales*, *Tubulicrinaceae*	roof structure of church, inner dome	W
Tubulicrinis medius (Bourdot & Galzin) Oberw.	*Hymenochaetales*, *Tubulicrinaceae*	roof construction, beams of barrel vaults	W
Tyromyces cf. *tephroleucus* (Fr.) Donk	*Polyporales*, *Polyporaceae*	roof construction, old guest house	B

B – brown rot; W – white rot; CW – coniferous wood; DW - deciduous wood

farinacea, Tremella mesenterica; *Ascomycetes* representatives: *Tapesia* sp. and several pyrenomycete species. Four species caused a brown rot whereas the remaining 13 caused a white rot.

Eleven fungal species were found in the old inn of monastery compound St. Nicetas in Banjani village (14th century) in Skopje region (Fig 4a). Twenty-three specimens were collected, whereof the following taxa were determined: *Athelia* sp., *Auricularia mesenterica*, *Cylindrobasidium evolvens*, *Coniophora olivacea*, *Gloeophyllum sepiarium*, *Hyphodontia crustosa* (Fig 4b), *Irpex lacteus*, *Phanerochaete velutina*, *Schizopora paradoxa*, *Stereum hirsutum* and *Trechispora farinacea*.

Of the 319 collected specimens, 109 different fungal taxa belonging to the phylum *Basidiomycota* were identified, affiliated with 62 different genera.

The most prevalent were the species from the phylum *Basidiomycota*, with 110 species from 64 genera, whereat the following genera occur with the largest number of species: *Hyphodontia* (48), *Phanerochaete* (19), *Athelia* (18), *Coniophora* (16), *Gloeocystidiellum* (15), *Hyphoderma*, *Auricularia*, *Irpex* and *Trametes* (9), while *Ceriporiopsis* and *Stereum* (8). Other genera are represented by a small number of species. *Hyphodontia crustosa* was the most widespread species from this genus and it was ascertained in 27 cases whereas *H. sambuci* was recorded in 8 cases. The most widespread species from the genus *Phanerochaete* is *Ph. velutina*, found in 9 cases while the species *Ph. tuberculata* and *Ph*. *sordida* were found only in three objects. *A. neuhoffii* was the most widespread species from the genus *Athelia*, recorded in 5 cases, while the species *Coniophora puteana* (Fig 5), recorded in 10 cases, and *C*. *olivacea,* found in 5 cases, were the most common ones from the genus *Coniophora.* As for the other representatives, the following species were the most common: *Schizophyllum commune* (11), *Irpex lacteus* (9) - Fig 6, *Stereum hirsutum* (8), *Trametes versicolor* (8), *Gloeophyllum abietinum* (6), *Auricularia mesenterica* (6) etc.

It was the wooden structures exposed to the outdoor environment that were attacked most frequently by fungi, and such were wooden doors, staircases, roof constructions, ceilings, gateways, porches and so forth. The main part of the registered fungi was corticioid species, as follows: *Gloeocystidiellum porosum*, *Hyphoderma praetermissum*, *Hyphodontia aspera*, *H. crustosa* and *Athelia decipiens.* Regarding poroid species, the most widespread ones were the representatives of the genera *Antrodia*, *Coriolopsis* and *Trametes* while *Antrodia sinuosa* was the most common species. Corticioid species normally cause a white rot, while poroid species cause a brown rot.

Discussion and conclusion

In comparison with research from other European countries, there are a range of differences in species occurrence. Thus, in Latvia (Irbe and Andersons, 2010), fungi causing a brown rot occur with 78.2% compared to fungi causing a white rot, which constitute 21.8% of

Figure 2a Church of the Holy Archangels Michael and Gabriel (14th century) in Kucheviste village in Skopje region.

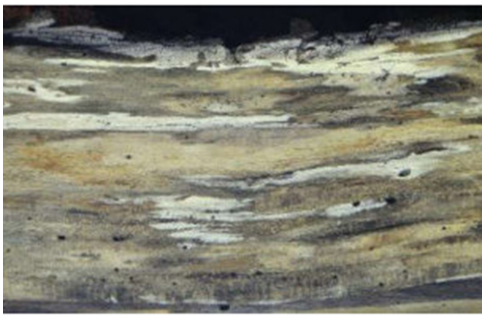

Figure 2b Corticioid fungal species *Athelia decipiens* developed on wooden beams of the church.

Figure 3a Guest house of St. Nicholas Monastery in Ljubanci village in Skopje region.

Figure 3b Roof construction of guest house with developed fruitbody of *Hyphoderma setigerum*

Figure 4a St. Nicetas in Banjani village (14th century) in Skopje region

Figure 4b *Hyphodontia crustosa* on roof construction of Monastery guest house.

Figure 5 *Coniophora puteana* on roof construction.

Figure 6 *Irpex lacteus* on old beams.

the analysed cases. The assumptions are that the predominance of brown-rot fungi species is related to the widespread usage of coniferous tree species for the wood constructions in the studied objects. The most common species causing a brown rot have been the following: *Serpula lacrymans*, *Coniophora puteana*, different species from the genera *Poria* and *Gloeophyllum*, then *Paxillus panuoides* and *Lentinus lepideus* according to Irbe et al. (2010). In Denmark, *Coniophora puteana* has been the most widespread species on wooden structures, and it comprises 50% of the entire wood damage in the country Viitanen (2001), Pilt et al. (2009). Other authors Singh (1994), Bech-Andersen (1995) and Pilt et al. (2009) have also verified the dominant occurrence of *Serpula lacrymans* and *Coniophora puteana* in northern Europe while in Norway, species from the genus *Antrodia* prevail, represented by 18.4% of the cases studied during the research of Alfredsen et al. (2005). In Estonia, *S. lacrymans* (79%), *C. puteana* (7.0%) and species from the genus *Antrodia* with 5.3%, are the most common, according to Pilt et al. (2009). In contrast to the occurrence of *S. lacrymans* in northern European countries – in Estonia with 79% and in Latvia with 47% – the state of affairs in R. North Macedonia is very different. *S. lacrymans* was established only on two occasions, which substantiated its very rare incidence on the territory of R. North Macedonia.

During the extensive research carried out by Irbe et al. (2008) regarding degrader-fungi of cultural and historic monuments in R. North Macedonia in 2008, it was concluded that there was greater occurrence of white-rot fungi (81%), whereof *Hyphodontia* species were the most common ones, whereas brown rot was observed in 19% of the cases, primarily caused by species from the genera *Coniophora*, *Antrodia* and *Gloeophyllum*. According to Irbe et al. (2008) R. North Macedonia is subtropical country and probably it is the reason why the dry-rot was not found during the inspection. To their knowledge, the fungus *S. lacrymans* has never been found in R. North Macedonia.

In the course of our research two cases of *Serpula lacrymans* were discovered. One was in Kavadarci in the old industrial object – the Tikvesh Winery as protected architectural heritage. The species was detected on the support-beams of wooden barrels in the basement. The other case was discovered in the basement structure of old house in the Berovo region. On the territory of Republic of R. North Macedonia, three different climatic zones are found: sub-Mediterranean, continental and mountain.

The species *Serpula lacrymans* was for the first time mentioned by Papazov (1989), identified in the roof construction of the Church of St. John in Krushevo. Papazov presented it in a short report "Registration of wood-decay fungi of churches and monasteries in the Republic of Macedonia". Another case was also found by Papazov (1988) in Drachevo – Skopje, in wooden houses, built of mounting structural material donation from Finland and Sweden after the Skopje earthquake in 1963. The report noted that the species is often present in the countries of central and northern Europe, causing serious damage. He concluded that R. North Macedonia is perhaps the southernmost border where the species can stretch and it was compared with data obtained from Portugal.

References

Alfredsen G., Solheim H., Jenssen K. M. (2005). Evaluation of decay fungi in Norwegian buildings. Document IRG/WP 05-10562. International Research Group on Wood Protection, Stockholm.

Bech-Andersen J. (1995). The dry rot fungus and other fungi in houses. Holte, Denmark: Hussvamp Laboratoriet ApS, 139 pp.

Bech-Andersen J. (2004) – Indoor Climate and Moulds. Holte, Denmark: Hussvamp Laboratoriet ApS, 89 pp.

Berniccchia A. & Gorjón S. P. (2010) – Corticiceae s.l. Fungi Europaei no 12, Italia: Edizioni Candusso.

Breitenbach J. & Kränzlin F. (1984) – Fungi of Switzerland, Vol. 1. 1st ed. Slough, UK: Richmond Publishing.

Breitenbach J. & Kränzlin F. (1986). – Fungi of Switzerland. Vol. 2: Non Gilled Fungi: Heterobasidiomycetes, Aphyllophorales, Gastromycetes, pp. 412. Lucerne, Switzerland: Verlag Mykologia.

Breitenbach J. & Kränzlin F. (1991). Fungi of Switzerland. Vol. 3: Boletes and Agarics (Part 1), pp. 360. Lucerne, Switzerland: Verlag Mykologia.

Breitenbach J. & Kränzlin F. (1994). Fungi of Switzerland. Vol. 4: Agarics, (Part 2), pp 368. Lucerne, Switzerland: Verlag Mykologia.

Breitenbach J. & Kränzlin F. (2000). Fungi of Switzerland. Vol. 5: Agarics, (Part 3), pp 338. Lucerne, Switzerland: Verlag Mykologia.

Breitenbach, J. & Kränzlin F. (2005). – Fungi of

Switzerland. Vol. 6: Russulaceae, pp. 319. Lucerne, Switzerland: Verlag Mykologia.

Eriksson J. (1958). Studies in the Heterobasidiomycetes and Homobasidiomycetes - Aphyllophorales of Muddus National Park in North Sweden. Vol. 16:1-172. Oslo, Norway: Fungiflora.

Eriksson J. & Ryvarden L. (1973). The Corticiaceae of North Europe. Vol. 2 (Aleurodiscus – Confertobasidium). Oslo, Norway: Fungiflora.

Eriksson J. & Ryvarden L. (1975). The Corticiaceae of North Europe. Vol. 3 (Coronicium – Hyphoderma). Oslo, Norway: Fungiflora.

Eriksson J. & Ryvarden L. (1976). The Corticiaceae of North Europe. Vol. 4 (Hyphodermella – Mycoacia). Oslo, Norway: Fungiflora.

Eriksson J., Hjortstam K. & Ryvarden L. (1978). The Corticiaceae of North Europe. Vol. 5 (Mycoaciella – Phanerochaete). Oslo, Norway: Fungiflora.

Eriksson J., Hjortstam K. & Ryvarden L. (1981). The Corticiaceae of North Europe. Vol. 6 (Phlebia – Sarcodontia). Oslo, Norway: Fungiflora.

Eriksson J., Hjortstam K. & Ryvarden L. (1984). The Corticiaceae of North Europe. Vol. 7 (Schizopora – Suillosporum). Oslo Norway: Fungiflora.

European Standard EN 113. (2000). Wood preservatives. Method of test for determining the protective effectiveness against wood destroying Basidiomycetes. Brussels, Belgium: European Committee for Standardization, CEN.

Hansen, L. & Knudsen, H. (2000). Nordic Macromycetes. 1. Ascomycetes. Copenhagen, Sweden: Nordswamp.

Hjortstam K. & Larsson K.-H., Ryvarden, L. (1987). The Corticiaceae of North Europe, Vol 1. Oslo, Norway: Fungiflora.

Hjortstam K., Larsson, K.-H., Ryvarden, L. (1988). The Corticiaceae of North Europe, Vol. 8. Oslo, Norway: Fungiflora.

Irbe, I. & Andersons I. (2010). Wood decay fungi in Latvian buildings including cultural monuments. Braga, Portugal: Firenze University Press, Firenze. Proceedings of the International Conference held by COST Action IE0601. pp. 94–100. Gril J, (Ed.).

Irbe, I., Karadelev, M., Andersons, I., Andersons, B. (2008). Biodeterioration of cultural monuments in the Republic of Macedonia. The International Research Group on Wood Protection, Section 1, Biology, 39th Annual Meeting Istanbul, Turkey: 1-9.

Julich W. (1984) – Die Nichtblatterpilze Gallertpilze und Bauchpilze. Stuttgart, Germany: Gustav Fischer Verlag.

Kirk. P. (2011). Index fungorum. Website: http://www.indexfungorum.org (accessed 01.11.2018)

Kjornakov, D., Nikolovski, A., Balabanov, K. (1971). Cultural monuments in SR Macedonia. Skopje, Misla. (in Macedonian)

Neubert. H., Nowotny, W. & Baumann. K. (1993, 1995, 2000). Die Myxomyceten. Band 1-3. Gomaringen, Germany: Karlheinz Baumann Verlag.

Papazov, V. (1988). Považni razložuvači na drvoto na nekoi kulturnoistoriski crkvi i manastiri. Godišnik na Šum. inst. Skopje, 24: 384-394.

Papazov, V. (1989). Pojava na Merulius lacrymans (Wulf) Fr. vo vgradeno drvo vo Makedonija. Godišnik na Šum. inst. Skopje, 25:71-80.

Pavlovska, J., Nikjiforovikj, N., Kocevski, O. (2011). Map of sacral objects in Macedonia. Skopje, Menora.

Pilt, K., Oja, J., Pau, K. (2009). The wood-destroying fungi in buildings in Estonia. Tallinn, Estonia: Structural Studies, Repairs and Maintenance of Heritage Architecture XI, ISSN 1743-3509.

Ryvarden, L. (1991). Genera of polypores, nomenclature and taxonomy. Synopsis Fungorum. 5:1-373. Oslo, Norway: Fungiflora.

Ryvarden, L., Gilbertson, R. L. (1993). European Polypores. Part.1. Synopsisfungorum 6: 1–387. Oslo, Norway: Fungiflora.

Samson, R. A., Hoekstra, E. S & Frisvad J. C. (2004). Introduction to food and airborne fungi. Utrecht, Netherlands: Centraalbureau Voor Schimmelcultures.

Schmidt, O. (2006). Wood and tree fungi. Berlin, Heidelberg, Germany: Springer – Verlag.

Singh, J. (1994). Building mycology Management of decay and health in buildings. London, UK: E & FN Spon.

Stalpers, J. & Cock A. (2013). Onward (Continuously updated). MycoBank. Website: http://www.mycobank.org (accessed 01.11.2018)

Trichkova, J., Serafimova, A., Popovska-Korobar, V. (2008). Christian monuments. Skopje, Matica.

Viitanen, H. (2001). Biodegradation of cultural heritage state of the art, Finland. VTT Building and Transport, PB 1806, 02044 VTT, Finland.