Nova Hedwigia **89** 3—4 437—450 Stuttgart, November 2009

Fungal diversity in brackish and saline lakes in Egypt

by

Hassan M. El-Sharouny[1], Youssuf A.M.H. Gherbawy[2] and Faten A. Abdel-Aziz[1,*]

[1]Department of Botany, Faculty of Science, Sohag University, Sohag 82524, Egypt

[2]Department of Botany, Faculty of Science, South Valley University, Qena, Egypt

With 3 tables

El-Sharouny, H.M., Y.A.M.H. Gherbawy & F.A. Abdel-Aziz (2009): Fungal diversity in brackish and saline lakes in Egypt. - Nova Hedwigia 89: 437–450.

Abstract: Aquatic filamentous fungi were surveyed from two brackish and two saline lakes in Egypt. Ninety-seven fungi (40 ascomycetes, 55 anamorphic fungi and 2 basidiomycetes) were identified from 764 fungal collections recorded from 545 samples collected from Lakes Edku, Marriott, Burullus and Quaron. Of these, 70 are new records for Egypt. This study represents the first report of aquatic fungi from the four lakes. Fungal communities in the four lakes were markedly different. Common fungi recorded at the four lakes were: *Periconia prolifica* (21.7%), *Clavatospora bulbosa* (12.8%), *Cirrenalia basiminuta* (12.7%), *Panorbis viscosus* (6%) and *Ceriosporopsis halima* (6%). Specious genera were: *Cirrenalia* (8 species), *Phoma* (8 species), *Aniptodera* (8 species), *Achaetomium* (6 species), *Pleospora* (4 species) and *Zalerion* (3 species). Higher fungal diversity was recorded from the two brackish lakes than those recorded from the saline lakes. In general, there was a decrease in fungal diversity with increasing salinity. Anamorphic fungi dominated the mycobiota at the four lakes and this is in harmony with the published data.

Key words: ascomycetes, brackish fungi, ecology, marine fungi, subtropical fungi.

Introduction

Marine fungi comprise a well defined ecological group that is different from its terrestrial and freshwater counterparts both in morphology and in its physiological requirements (Barghoorn & Linder 1944, Johnson & Sparrow 1961, Jones 1976, 2000, Kohlmeyer & Kohlmeyer 1979, Meyers 1996). Some of these fungi, however, may occur in both seawater and freshwater or terrestrial habitats (Jones 2000). Jones & Oliver (1964) found that the assemblages of fungi in seawater were very different to those found in brackish or freshwater. However, some species were common in both fresh and brackish water. There have been fewer studies on fungi of brackish water and the gradual

*Corresponding author; E mail: bhfaten@yahoo.com

DOI: 10.1127/0029-5035/2009/0089-0437 0029-5035/09/0089-0437 $ 3.50

change of fungal communities along salinity ranging from freshwater to seawater (e.g., Shearer 1972, Fryar et al. 2004, Van Ryckegem et al. 2007).

Fungi utilize many different substrates within the aquatic environment including wood (Shearer & Bodman 1983, Abdel-Raheem & Shearer 2002, Bucher et al. 2004), leaves (Premdas 1991), algae (Haythorn et al. 1980), coral (Morrison-Gardiner 2002), soil (Mer et al. 1980), insects (Williams & Lichtwardt 1990, Cafaro 2002), and various other substrates (Czeczuga 1996, Czeczuga & Muszyńska 2004). Their spores even occur in tree holes and gutters (Gönczöl & Révay 2003, 2004). There is often a different assemblage of fungi on each substrate, although some generalists utilize more than one substrate.

Some 520 species of filamentous marine fungi have been described (Jones et al. 2007). A few studies have examined marine fungi in Africa (Kohlmeyer 1968, Kohlmeyer & Kohlmeyer 1971, Jones et al. 1972, Schaumann 1975, Aleem 1980, Steinke & Jones 1993), while the greatest diversity for aquatic fungi was recorded from temperate regions followed by Asian tropical areas. These two regions are the most intensively researched areas for fungi (Shearer et al. 2007).

Weston (1929) described the first freshwater fungi from lentic habitats, and he described *Loramyces juncicola* Weston from fallen culms of *Juncus militaris* Bigelow from a small pond in America. A hundred freshwater ascomycetes and their anamorphs are known from lakes and ponds (Shearer 1993). Lakes and ponds provide calm environments in which fungi can grow. However, the mild wave action may result in oxygen deficiency and reduce fungal diversity (Bärlocher 1992). Hyde & Goh (1998) surveyed the fungal community on submerged wood from lake Barrine, Australia. That was the first study to record aquatic fungi from a tropical lake. In the following years more lakes and salt marshes were explored from tropical and subtropical habitats (e.g., Poon & Hyde 1998, Wong & Hyde 2001, 2002, Cai et al. 2002, Luo et al. 2004).

In Egypt, a few studies have been carried out on higher aquatic marine fungi from the Red Sea (El-Sharouny et al. 1998, Abdel-Wahab et al. 2001a, b, Pang et al. 2002, Abdel-Wahab 2005) and one study from a brackish lake (Abdel-Aziz 2008). This study has been carried out to document the diversity of aquatic fungi in the four lakes: Edku, Marriott, Burullus and Quaron.

Materials and methods

Study sites

LAKE EDKU is a shallow coastal lagoon of the Nile Delta. It lies to the west of the Rosetta branch of the Nile, at 30°15'N and 31°15'E. It has an area of 126 km^2 and water depth ranging from 50 to 150 cm. The lake connects with the Mediterranean Sea (Abu-Qir Bay) through a short deep channel (Bougaz El-Maadya). Its salinity has been reduced by freshwater overload from the Nile drains. Salinity during sample collection was 1.6 g/L, pH was 6.55 and water temperature 24°C.

LAKE MARRIOTT, located south west of Alexandria, is a heavily polluted lake (Saad 2003) and its water is pumped to the sea. It is divided artificially into four basins and the area of the lake reaches 27.3 km^2 and its depth ranges from 90 to 150 cm. Salinity during sample collection was 2.9 g/L, pH was 6.7 and water temperature 24°C.

LAKE BURULLUS is situated between the two River Nile branches, it has an oblong shape extending for a distance of 47 km. Lake depth varies between 70 cm near the shores and 240 cm near the sea outlet (Bughaz El-Burullus) (El Bayomi 1999). Salinity during sample collection was 16 g/L, pH was 7.4 and water temperature 26°C.

LAKE QUARON located at the Fayoum province 80 km south west of Cairo, 320 km south of the Mediterranean coast of Egypt. It is the third largest lake in Egypt, it is 40 km in length, 5.7 km in width and at 34 m below sea level with depth ranges from 5 m in the east to 12 m in the west. Lake Quaron is the only completely closed lake in Egypt, the drainage water enters the lake through two main drains (El-Wadi and El-Batts drains) holding the Fayoum agricultural and domestic pollution. The lake has no outlet and loses water only by evaporation. The lake was historically a fresh water lake, by time its regime was changed to a drainage reservoir and become a salty lake with high salinity of 35 g/L. The pH during sample collection was 7.5. Surface water temperature was 25°C.

Collection of material

Five hundred and forty-five samples of submerged wood (including twigs and branches at various stages of decay, decayed stems of herbaceous plants and driftwood), were collected randomly from the four lakes. On 24 July 2002, 210 samples were collected from Lake Quaron. One hundred and twenty, 90 and 125 samples were collected from lakes Edku, Marriott, and Burullus, respectively, between 24 and 26 June 2003. Samples were placed in clean plastic bags and returned to the laboratory. Samples were rinsed with sterile tap water to remove attached mud and sand grains attached to the surfaces of substrata. Samples were examined for filamentous fungi under a stereomicroscope and incubated in sterile plastic boxes containing moistened sterile paper toweling. Samples were examined periodically for 3–4 months (Jones & Hyde 1988, Shearer et al. 2004). Fungi were recorded, isolated whenever possible, and voucher slides were deposited at the third author's herbarium. Identification of the fungi was done using the original descriptions of the species known from aquatic habitats and other relevant literatures. The fungi found in this study were presented in terms of percentage frequency of occurrence, number of fungi per sample and species richness (S'), Shannon index (H') (Shannon & Weaver 1949).

The equations are as follows:

$$\text{Percentage frequency of occurrence of a species} = \frac{\text{Number of collections of the fungus}}{\text{Number of samples collected}} \times 100$$

$$\text{Number of fungi per sample} = \frac{\text{Total number of fungal collections}}{\text{Number of samples collected}}$$

Shannon index (H') = $-\Sigma\, Pi \log2\, Pi$

where Pi is the probability of finding each taxon in a collection.

Results

A total of 97 (41 ascomycetes, 54 anamorphic fungi and 2 basidiomycetes) species were identified from 764 fungal collections recorded from 545 samples collected from lakes Edku, Marriott, Burullus and Quaron. Fungi recorded are classified as very frequent (above 20%), frequent (10–20%), common (5–10%) and infrequent (below 5%). The most common species was *Periconia prolifica* with 21.7% overall frequency of occurrence and recorded consistently from the four lakes. Two other fungi were recorded consistently from the four lakes, these species are: *Cirrenalia basiminuta* (12.7%) and *Cirrenalia fusca* (2.9%). Sixty-two, 44, 30 and 21 fungi were recorded from lakes Edku, Marriott, Burullus and Quaron, respectively. Fungal communities in the four lakes were markedly different from one to another with 27, 7, 10 and 9 were unique to Edku, Marriott, Burullus and Quaron, respectively. Eighteen fungi were recorded consistently from lakes Edku and Marriott only. Three fungi were recorded consistently from Edku and Burullus, while *Cirrenalia macrocephala* was recorded consistently from Edku and Quaron only (Table 1).

Specious genera recorded from the four lakes were: *Aniptodera* (8 species), *Cirrenalia* (8 species), *Phoma* (8 species), *Achaetomium* (6 species), *Pleospora* (4 species), *Zalerion* (3 species) and two species belong to each of the following genera; *Chaetomium*, *Goleosporidina*, *Leptosphaeria*, *Microthelia*, *Podospora*, *Trichocladium* and *Zopfiella* (Table 1).

Lake Edku

The diversity of fungi found on samples collected from Lake Edku was the highest among the four collections sites, with a shannon index of 6 and 62 taxa were recorded (26 ascomycetes and 36 anamorphic fungi). The ratio of anamorphic taxa/ ascomycetous taxa was 1.4. The total number of fungal collections was 177 recorded from 120 samples, with an average of 1.5 species identified on each sample. Frequency of occurrence of all taxa ranged from 0.8 to 20.8%.

Panorbis viscosus (20.8%) was the most frequent species. *Halosarpheia phragmiticola* (13.3%) was frequent species. *Cirrenalia adarca* (7.4%), *Cirrenalia fusca* (6.7%), *Hapalosphaeria deformans* (6.7%), *Leptosphaeria agnita* (5.8%), *Periconia prolifica* (5%), and *Phoma betae* (5%) were occasional species. Fifty-four fungi were recorded as rare species and listed in Table 1.

Lake Marriott

Forty-four fungi (14 ascomycetes and 30 anamorphic fungi) were identified from 152 fungal collection from 90 samples with an average of 1.7 species identified on each sample and a shannon index of 5.5 .The ratio of anamorphic taxa/ ascomycetous taxa was 2.1. Frequency of occurrence of all taxa ranged from 1.1 to 20%. *Zopfiella leucotricha* (20%) was the most common species, *Panorbis viscosus* (14.4%), *Phoma betae* (12.2%) and *Periconia prolifica* (10%) were frequent species. *Phoma medicaginis* (7.8%), *Catenophora pruni* (6.7%), *Hapalosphaeria deformans* (6.7%), *Microthelia heterospora* (5.6%) and *Podospora carpinicola* (5.6%) were occasional species. Thirty-five fungi were recorded as rare species and listed in Table 1.

Lake Burullus

Thirty taxa (10 ascomycetes and 20 anamorphic fungi) were identified from 172 fungal collections from 125 samples with a shannon index of 4.9 and an average of 1.4 species identified on each sample. Frequency of occurrence of all taxa ranged from 0.8 to 45.6%. *Cirrenalia basiminuta* (45.6%) and *Chaetomium* sp. 1 (20%) were very frequent species. *Periconia prolifica* (9.6%), *Pleospora* sp.1 (6.4%), *Microthelia triseptata* (5.6%) and *Cirrenalia* sp. 1 (5.6%) were occasional species. Twenty-four species were recorded as rare fungi and listed in Table 1.

Lake Quaron

The diversity of fungi found in samples collected from Lake Quaron was the lowest among the four collection sites, with a shannon index of 4.4 and 21 taxa were recorded, including 6 ascomycetes, 13 anamorphic fungi and 2 basidiomycetes. The ratio of anamorphic taxa/ascomycetous taxa was 2.2. The total number of fungal collections was 263 recorded from 210 samples, with an average of 1.3 species identified on each sample. Frequency of occurrence of all taxa ranged from 0.5 to 43.3%.

Periconia prolifica (43.3%) and *Clavatospora bulbosa* (33.3%) were very frequent species. *Ceriosporopsis halima* (15.7%) was a frequent species. *Halocyphina villosa* (5.2%) was an occasional species. Seventeen species were recorded as rare fungi and listed in Table 1. Most of the recorded fungi (18 taxa) in this lake were reported previously from marine habitats. Three fungi were recorded from the lake namely, *Microthelia triseptata*, *Hypocline penniseti* and *Westerdykella dispersa* which were not previously recorded from marine habitats. However, the last three fungi were among the rare species.

Discussion

This study extends our knowledge on the higher aquatic fungi in Egypt. A few studies have been carried out on higher aquatic marine fungi in Egypt from the Red Sea. El-Sharouny et al. (1998) recorded 50 fungi from three mangrove sites at the Red Sea shores. Thirty nine species were recorded from six mangroves stands at the Red Sea coast bringing the total number of marine fungi in Egypt to 84 (Abdel-Wahab 2005). Three new species and one new genus were described from aquatic habitats in Egypt (Abdel-Wahab et al. 2001 a, b, Pang et al. 2002). Fungi recorded in this study from the four lakes and from mangrove sites in the previous studies are almost different with only ten taxa which were common to both habitats (Abdel-Wahab 2005).

In estuarine sites (Lakes Edku and Marriott) where salinity range between 1.6–2.9 g/L great changes in the fungal community has been recorded with 26 fungi were common to both habitats.

In saline lakes (Burullus and Quaron) where salinity range is 16–35 g/L, only forty-three (14 ascomycetes, 27 anamorphic fungi and 2 basidiomycetes) fungi were recorded. Eight fungi were common to both lakes. Twenty-one and thirteen fungi were unique to Burullus and Quaron lakes, respectively.

Of the five most common fungi recorded from the four lakes only two species, namely *Periconia prolifica* and *Cirrenalia basiminuta*, were recorded consistently from the four sites (Table 2). Frequency of occurrence of *P. prolifica* increased from brackish water to saline, where it was highest at Lake Quaron (43.3%) followed by 9.6% at Burullus and 10% at Marriott, while its frequency of occurrence dropped to 5% at Lake Edku. *P. prolifica* is frequent fungus in marine habitats [e.g., Kuwait (Zainal & Jones 1984); Seychelles (Hyde 1986) and Hong Kong (Vrijmoed et al.

Table 1. Fungi recorded from samples collected from Lakes Edku, Marriott, Burullus and Quaron

Fungi	Edku		Marriot		Burullus		Quaron		Total	
	N	%	N	%	N	%	N	%	N	%
Ascomycetes:										
Achaetomium indicum J.N.Rai & H.J.Chowdhery	2	1.7	-	-	-	-	-	-	2	0.4
Achaetomium macrosporum J.N.Rai, Wadhwani& J.P.Tewari	1	0.8	-	-	-	-	-	-	1	0.2
Achaetomium variosporum Sultana, Malik& L.R.Batra	1	0.8	-	-	-	-	-	-	1	0.2
Achaetomium sp. 1	1	0.8	-	-	-	-	-	-	1	0.2
Achaetomium sp. 2	3	2.5	-	-	-	-	-	-	3	0.6
Achaetomium sp. 3	1	0.8	-	-	-	-	-	-	1	0.2
Aniptodera aquadulcis (S.Y.Hsieh, H.S.Chang & E.B.G.Jones) J.Campb., J.L.Anderson & Shearer	3	2.5	-	-	-	-	-	-	3	0.6
Aniptodera chesapeakensis Shearer & M.A.Mill.	1	0.8	1	1.1	-	-	-	-	2	0.4
Aniptodera fusiformis Shearer	2	1.7	-	-	-	-	-	-	2	0.4
Aniptodera limnetica Shearer	-	-	1	1.1	-	-	-	-	1	0.2
Aniptodera lignicola K.D.Hyde, W.H.Ho & K.M.Tsui	1	0.8	1	1.1	-	-	-	-	2	0.4
Aniptodera margarition Shearer	1	0.8	-	-	-	-	-	-	1	0.2
Aniptodera sp. 1	1	0.8	-	-	-	-	-	-	1	0.2
Aniptodera sp. 2	1	0.8	-	-	-	-	-	-	1	0.2
Bathyascus sp.	-	-	-	-	-	-	1	0.5	1	0.2
Ceriosporopsis halima Linder	-	-	-	-	-	-	33	15.7	33	6
Chaetomium sp. 1	-	-	1	1.1	25	20	-	-	26	4.8
Chaetomium sp 2.	-	-	1	1.1	-	-	-	-	1	0.2
Halosarpheia phragmiticola Poon & K.D.Hyde	16	13.3	1	1.1	-	-	-	-	17	3.1
Leptosphaeria agnita (Desm.) De Not. & Ces	7	5.8	-	-	1	0.8	-	-	8	1.5
Leptosphaeria sp.	5	4.2	-	-	-	-	-	-	5	0.9
Lignnincola sp.	1	0.8	1	1.1	-	-	-	-	2	0.4
Lophiostoma arundinis (Pers.) Ces. & De Not.	4	3.3	2	2.2	-	-	-	-	6	1.1
Lulworthia grandispora Meyers	-	-	3	3.3	-	-	9	4.3	12	2.2
Microthelia heterospora Eitner	1	0.8	5	5.6	4	3.2	-	-	10	1.8
Microthelia triseptata Räsänen	-	-	-	-	7	5.6	2	1	9	1.7
Nais aquatica K.D.Hyde	1	0.8	-	-	-	-	-	-	1	0.2
Natantispora lotica (Shearer) J.Campb., J.L.Anderson & Shearer	1	0.8	-	-	-	-	-	-	1	0.2
Panorbis viscosus (I.Schmidt) J.Campb., J.L.Anderson & Shearer	25	20.8	13	14.4	-	-	-	-	38	7
Pleospora gaudefroyi Patouillard	-	-	-	-	2	1.6	-	-	2	0.4
Pleospora vagans Niessl	-	-	-	-	1	0.8	-	-	1	0.2
Pleospora sp. 1	-	-	-	-	8	6.4	-	-	8	1.5

Pleospora sp. 2	-	-	-	-	5	4	-	-	5	0.9
Podospora carpinicola Mouch.	3	2.5	5	5.6	-	-	-	-	8	1.5
Podospora minicauda Faurel & Locquin-Linard	-	-	-	-	-	-	2	1	2	0.4
Swampomyces sp.	-	-	-	-	1	0.8	-	-	1	0.2
Tirispora unicaudata E.B.G.Jones & Virjmoed	3	2.5	-	-	-	-	-	-	3	0.6
Torpedospora radiata Meyers	-	-	-	-	5	4	-	-	5	0.9
Westerdykella dispersa (Clum) Cejp & Milko	-	-	4	4.4	-	-	2	1	6	1.1
Zopfiella leucotricha (Speg.) Malloch & Cain	3	2.5	18	20	-	-	-	-	21	3.9
Zopfiella sp.	2	1.7	-	-	-	-	-	-	2	0.4
Mitosporic fungi										
Ahmadia pentatropidis Syd.	3	2.5	1	1.1	-	-	-	-	4	0.7
Alveophoma caballeroi Bausà Alcalde	2	1.7	2	2.2	3	2.4	-	-	7	1.3
Aristastoma oeconomicum (Ellis & Tracy)Tehon apud Lefebvre & Stevenson	1	0.8	-	-	-	-	-	-	1	0.2
Catenophora pruni Luttr.	2	1.7	6	6.7	3	2.4	-	-	11	2
Chaetophoma quercifolia Cooke	2	1.7	2	2.2	-	-	-	-	4	0.7
Ciferriella domingensis Petrak & Ciferri	1	0.8	2	2.2	-	-	-	-	3	0.6
Cirrenalia adarca Kohlm., Volkm.-Kohlm. & O.E.Erikss	9	7.4	-	-	-	-	-	-	9	1.7
Cirrenalia fusca Schmidt	8	6.7	1	1.1	1	0.8	6	2.9	16	2.9
Cirrenalia macrocephalia (Kohlm.) Meyers & Moore	2	1.7	-	-	-		2	1	4	0.7
Cirrenalia pseudomacrocephala Kohlm.	1	0.8	-	-	-		-	-	1	0.2
Cirrenalia basiminuta Raghuk. & Zainal	1	0.8	3	3.3	57	45.6	8	3.8	69	12.7
Cirrenalia sp. 1	2	1.7	-	-	7	5.6	5	2.4	14	2.6
Cirrenalia sp. 2	-	-	-	-	-	-	1	0.5	1	0.2
Cirrenalia sp. 3	-	-	-	-	-	-	2	1	2	0.4
Clavatospora bulbosa (Anastasiou) Nakagiri & Tubaki	-	-	-	-	-	-	70	33.3	70	12.8
Colletogloeum obtusum B.Sutton	-	-	-	-	3	2.4	-	-	3	0.6
Crandallia juncicola Ellis & Sacc.	1	0.8	1	1.1	-	-	-	-	2	0.4
Cumulospora marina I.Schmidt	-	-	4	4.4	-	-	2	1	6	1.1
Cylindroglocum trillii Petrak	-	-	-	-	2	1.6	-	-	2	0.4
Cystotichia striola Erikss.	3	2.5	4	4.4	1	0.8	-	-	8	1.5
Dasysticha sapindophila Speg.	1	0.8	1	1.1	-	-	-	-	2	0.4
Didymostilbe sp.	1	0.8	2	2.2	-	-	-	-	3	0.6
Discosporium populeum (Sacc.) B.Sutton	-	-	2	2.2	1	0.8	-	-	3	0.6
Epithyrium resinae (Sacc. & Berl.) Trotter	1	0.8	-	-	1	0.8	-	-	2	0.4
Gloeosporidina canthiicola B.Sutton	2	1.7	1	1.1	1	0.8	-	-	4	0.7
Gloeosporidina moravica Petrak	2	1.7	4	4.4	-	-	-	-	6	1.1
Graphium sp.	-	-	3	3.3	-	-	-	-	3	0.6
Hapalosphaeria deformans Syd.	8	6.7	6	6.7	1	0.8	-	-	15	2.8

Table1 continued.

Fungi	Edku		Marriot		Burullus		Quaron		Total	
	N	%	N	%	N	%	N	%	N	%
Harknessia globosa B.Sutton	-	-	-	-	1	0.8	-	-	1	0.2
Humicola alopallonella Meyers & R.T.Moore	1	0.8	-	-	-	-	-	-	1	0.2
Hypocline penniseti Syd.	-	-	-	-	-	-	6	2.9	6	1.1
Neozythia handelii (Bubák) Petr.	-	-	-	-	5	4	-	-	5	0.9
Nigrospora sp.	1	0.8	-	-	-	-	-	-	1	0.2
Periconia prolifica Anastasiou	6	5	9	10	12	9.6	91	43.3	118	21.7
Phacidiella asperulina (Bubák) B.Sutton	-	-	2	2.2	-	-	-	-	2	0.4
Phaeoisaria sp.	2	1.7	2	2.2	-	-	-	-	4	0.7
Phoma betae Frank	6	5	11	12.2	4	3.2	-	-	21	3.9
Phoma complanata Desm.	1	0.8	-	-	-	-	-	-	1	0.2
Phoma destructiva Plowr.	1	0.8	-	-	-	-	-	-	1	0.2
Phoma exigua Desm.	1	0.8	4	4.4	-	-	-	-	5	0.9
Phoma fimeti Brunaud	1	0.8	1	1.1	-	-	-	-	2	0.4
Phoma laminariae Cooke & Massee	1	0.8	-	-	-	-	-	-	1	0.2
Phoma medicaginis Malbr. & Roum.	1	0.8	7	7.8	-	-	-	-	8	1.5
Phoma suaedae Jaap	1	0.8	-	-	-	-	-	-	1	0.2
Septocyta ruborum Petrak	1	0.8	-	-	-	-	-	-	1	0.2
Stachybotrys sp.	-	-	1	1.1	-	-	-	-	1	0.2
Stagonospora macropycnidia Cunnell	1	0.8	-	-	-	-	-	-	1	0.2
Trichocladium achrasporum Meyers & Moore	-	-	2	2.2	1	0.8	2	1	5	0.9
Trichocladium constrictum Schmidt	-	-	1	1.1	-	-	-	-	1	0.2
Zalerion maritima (Linder) Anastasiou	-	-	2	2.2	1	0.8	2	1	5	0.9
Zalerion varium Anastasiou	-	-	-	-	2	1.6	1	0.5	3	0.6
Zalerion sp. 1	2	1.7	-	-	1	0.8	-	-	3	0.6
Unidentified fungus sp. 1	1	0.8	2	2.2	-	-	-	-	3	0.6
Unidentified fungus sp. 2	-	-	2	2.2	-	-	-	-	2	0.4
Basidiomycetes:										
Halocyphina villosa Kohlm. & E.Kohlm.	-	-	-	-	-	-	11	5.2	11	2
Nia globispora Barata & Basilio	-	-	-	-	-	-	5	2.4	5	0.9
Number of samples examined		120		90		125		210		545
Number of fungal collections		177		152		172		263		764
Number of species per sample		1.5		1.7		1.4		1.3		1.4
Total number of species		62		44		30		21		97

Table 2: Five most common fungi recorded from the studied sites.

Lake Edku	Lake Marriott	Lake Brullus	Lake Quaron	Total
Panorbis viscosus	*Zopfiella leucotricha*	*Cirrenalia basiminuta*	*Periconia prolifica*	*Periconia prolifica*
Halosarpheia phragmiticola	*Panorbis viscosus*	*Chaetomium* sp. 1	*Clavatospora bulbosa*	*Cirrenalia basiminuta*
Cirrenalia adarca	*Phoma betae*	*Periconia prolifica*	*Ceriosporopsis halima*	*Clavatospora bulbosa*
Cirrenalia fusca	*Periconia prolifica*	*Pleospora* sp. 1	*Halocyphina villosa*	*Panorbis viscosus*
Hapalosphaeria deformans	*Phoma medicaginis*	*Cirrenalia* sp. 1	*Lulworthia grandispora*	*Ceriosporopsis halima*

1986 a, b)]. The other taxon, *Cirrenalia basiminuta* was the most common fungus at Lake Burullus, however its frequency was lower at the other three lakes. This fungus might prefer the salinity level of Lake Burullus (16 g/L) or prefer the host *Arthrocnemon glaucum*, where most of the samples collected from Lake Burullus (95 out of 125 samples) were decayed stems of *A. glaucum*.

Ceriosporopsis halima, *Halocyphina villosa* and *Clavatospora bulbosa* were common fungi and confined to Lake Quaron. These fungi are typically marine species (Kohlmeyer & Volkman-Kohlmeyer 1991). This is the first record for the three fungi in Egypt. *C. halima* is a very common cosmopolitan fungus on driftwood in the intertidal zone (e.g., Tubaki 1969, Koch 1982, Zainal & Jones 1984, Vrijmoed et al. 1986 a, b, Tan & Leong 1992). *H. villosa* is a very common mangrove fungus (e.g., Hyde 1986, Chinnaraj 1993, Alias & Jones 2000). *C. bulbosa* is the anamorphic stage of *Corollospora pulchella* (Nakagiri & Tubaki 1985). *C. pulchella* was not recorded previously from the marine habitats in the earlier studies. Anamorphic stages are more common during the hot season and in the tropical habitats while teleomorphic stages are more common in temperate regions (Kohlmeyer & Charles 1981, Nakagiri & Tubaki 1985) and it might explain why higher numbers of the anamorphic stages were recorded from Lake Quaron in the current study.

Panorbis viscosus was confined to lakes Edku and Marriott. This species was first described by Shearer & Crane (1980) from brackish water (salinity 2–11.6 g/L) at Patuxent River, USA. The fungus was recorded later from similar salinity levels in other studies, e.g. Mai Po mangroves in Hong Kong (Jones & Vrijmoed 1997, Abdel-Wahab 2000), on *Spartina maritima* at salt marshes in Portugal (Barata 2002).

Fungi recorded from the saline lakes in this study were almost different from fungi recorded from mangroves in the Red Sea (El-Sharouny et al. 1998, Abdel-Wahab 2000, Abdel-Wahab et al. 2001a, b, Abdel-Wahab 2005). The different hosts (mangrove vs. weeds), habitat types (lentic vs. open sea) and salinity level (16–35 g/L in the current study vs. 44–46 g/L in Red Sea mangroves) may account for the difference in fungal communities.

Table 3. Summary of fungi collected from Lakes Edku, Marriott, Brullus and Quaron

	Edku	Marriot	Brullus	Quaron	Total
Ascomycetes	26	14	10	6	41
Bitunicate ascomycetes	4	3	7	2	10
Unitunicate ascomycetes	22	11	3	4	30
Ratio of bitunicate to unitunicate	0.2	0.3	2.3	0.5	0.3
Mitosporic fungi	36	30	20	13	54
Coelomycetes	25	21	11	1	33
Hyphomycetes	11	9	9	12	23
Ratio of coelomycetes to hyphomycetes	2.3	2.3	1.2	0.1	1.4
Basidiomycetes	-	-	-	2	2
Species richness (S')	62	44	30	21	98
Shannon index (H')	6	5.5	4.9	4.4	-
Total number of collection	177	152	172	263	764
Number of species per sample	1.5	1.7	1.4	1.3	1.4
Ratio of mitosporic to ascomycetes	1.4	2.1	2.0	2.3	1.3
Total number of samples	120	90	125	210	545

Several foliicolous coelomycetous genera (e.g. *Aristastoma*, *Colletogloeum* and *Gloeosporidina*) were recorded during this study. Their presence on decayed submerged plant materials might be explained by having different teleomorphic stages that live in aquatic habitats, but this need to be confirmed by molecular studies.

Some species recorded for Lake Manzala (Abdel-Aziz 2008) are identical with those found in brackish and saline lakes in this study; 18 fungi were common to Lakes Manzala and Edku, 17 species with Lake Marriott, 9 species with Lake Burullus and 5 species with Lake Quaron. Lake Manzala shares more fungal species with Lakes Edku and Marriot (brackish lakes) than with Lakes Burullus and Quaron (saline lakes)

Low fungal diversity in saline lakes (Burullus and Quaron) might go for the fact that few freshwater fungi could tolerate that level of salinity, high pollution levels especially in Lake Quaron (Abdel-Moniem 1991), host type and availability of fungal inocula. Most of the samples collected from Lake Burullus were decayed stems of small herbaceous plants with small diameter (0.2–1.1 cm) that dry out easily and hence support fungi that tolerate desiccation only.

Quaron is a closed lake that is a remnant of a much bigger one. It was originally a freshwater lake; the only water that enters the lake is drainage water, which might contain freshwater fungi inocula that cannot tolerate high salinity. The low fungal diversity in this lake might be attributed for low availability of fungal inocula and high pollution level (Abdel-Moniem 1991, Mansour et al. 2000).

Higher numbers of anamorphic fungi recorded from the four lakes (54 anamorphic vs. 41 ascomycetes). There was an increase in the number of anamorphic and decrease in the number of ascomycetes by increasing salinity. The ratios of anamorphic to teleomorphic taxa were 1.4, 2.4, 2.1 and 2.0 at lakes Edku, Marriott, Burullus and Quaron, respectively (Table 3). These results agree with those of Abdel-Aziz (2008) who recorded 26 ascomycetes and 34 anamorphic fungi from Lake Manzala (brackish) in Egypt and with results of Fryar et al. (2004) who recorded 23 ascomycetes and 27 anamorphic fungi from a brackish site in Brunei, and with the culture observations of Byrne & Jones (1975) who stated that asexual reproduction was less severely affected by high salinities compared to sexual reproduction. Hyde & Goh (1998) concluded that teleomorphic ascomycetes play a larger role in the decay of wood in streams, while anamorphic fungi are more important in lakes. A higher numbers of pyrenomycetes was recorded from the four lakes (30 pyrenomycetes vs. 10 loculoascomycetes). Coelomycetous anamorphs were predominating in Lakes Edku, Marriott and Burullus, while hyphomycetous anamorphs were predominant at Lake Quaron (Table 3).

Conclusion

Biogeography of aquatic fungi in the African continent and Middle East are scarcely known. Of 97 fungi recorded in this study, 70 taxa are newly recorded for Egypt. Similar studies are needed in order to know the distribution of this group of fungi and the role they play in their habitats. Higher fungal diversity was recorded from the two brackish lakes, while low fungal diversity was recorded from saline lakes, in general there was a decrease in fungal diversity with increasing salinity. High numbers of anamorphic fungi were recorded from the four lakes and this might reflect that they play more active roles than teleomorphic stages in lakes and salt marshes habitats.

Acknowledgement

Sohag University is acknowledged for providing financial support.

References

ABDEL-AZIZ, F.A. (2008): Diversity of aquatic fungi on *Phragmites australis* at Lake Manzala, Egypt. - Sydowia **60**: 1–14.

ABDEL-MONIEM, A.M. (1991): Changes in phytoplankton composition of Lake Quaron in relation to variation in salinity. - M. Sc. Thesis, Ain Shams University.

ABDEL-RAHEEM, A. & C.A. SHEARER (2002): Extracellular enzyme production by freshwater ascomycetes. - Fungal Diversity **11**: 1–19.

ABDEL-WAHAB, M.A. (2000): Biodiversity of fungi in subtropical mangroves. Ph. D. thesis, Faculty of Science at Sohag, South Valley University.

ABDEL-WAHAB, M.A. (2005): Diversity of marine fungi from Egyptian Red Sea mangroves. - Bot. Mar. **48**: 348–355.

ABDEL-WAHAB, M.A., H.M. EL-SHAROUNY & E.B.G. JONES (2001a): Two new intertidal lignicolous *Swampomyces* species from Red Sea mangroves in Egypt. -Fungal Diversity **8**: 35–40.

ABDEL-WAHAB, M.A., K.L. PANG, H.M. EL-SHAROUNY & E.B.G. JONES (2001b): *Halosarpheia unicellularis* sp. nov. (Halosphaeriales, Ascomycota) based on morphological and molecular evidence. - Mycoscience **42**: 255–260.

ALEEM, A.A. (1980): Distribution and ecology of marine fungi in Sierra Leone (tropical West Africa). - Bot. Mar. **23**: 679–688.

ALIAS, S.A. & E.B.G. JONES (2000): Colonization of mangrove wood by marine fungi at Kuala Selangor mangrove stand, Malaysia. - Fungal Diversity **5**: 9–12.

BARATA, M. (2002): Fungi on the halophyte *Spartina maritima* in salt marshes. - In HYDE, K.D. (Ed.): Fungi in Marine Environments: 179–193. Fungal Diversity Research Series, Hong Kong University Press, Hong Kong.

BARGHOORN, E.S. & D.H. LINDER (1944): Marine fungi: their taxonomy and biology. - Farlowia **1**: 395–467.

BÄRLOCHER, F. (1992): Stream Ecology and its relevance to aquatic mycology. - In BÄRLOCHER, F. (Ed): The Ecology of Aquatic Hyphomycetes: 16–37. Springer-Verlag, Berlin, Germany.

BUCHER, V.V.C., K.D. HYDE, S.B. POINTING & C.A. REDDY (2004): Production of wood decay enzymes, mass loss and lignin solubilization in wood by marine ascomycetes and their anamorphs. - Fungal Diversity **15**: 1–14.

BYRNE, P.J. & E.B.G. JONES (1975): Effect of salinity on the reproduction of terrestrial and marine fungi. - Trans. Brit. Mycol. Soc. **65**: 185–200.

CAFARO, M.J. (2002): Species richness patterns in symbiotic gut fungi (Trichomycetes). - Fungal Diversity **9**: 47–56.

CAI, L., C.K.M. TSUI, K.Q. ZHANG & K.D. HYDE (2002): Aquatic fungi from lake Fuxian, Yunnan, China. - Fungal Diversity **9**: 57–70.

CHINNARAJ, S. (1993): Higher marine fungi from mangroves of Andaman and Nicobar islands. - Sydowia **45**: 109–115.

CZECZUGA, B. (1996): Mycoflora of the Suprasl River and its tributaries. - Acta Mycologia **31**: 13–32.

CZECZUGA, B. & E. MUSZYŃSKA (2004): Aquatic zoosporic fungi from baited spores of cryptogams. - Fungal Diversity **16**: 11–22.

EL-BAYOMI, G.M. (1999): Lake Burullus*:* a geomorphological study. - Ph.D. thesis, Helwan University.

EL-SHAROUNY, H.M., A.M. ABDEL-RAHEEM & M.A. ABDEL-WAHAB (1998): Manglicolous fungi of the Red Sea in Upper Egypt. - Microbiol. Res. **153**: 81–96.

FRYAR, S.C., J. DAVIES, I.J. HODGKISS & K.D. HYDE (2004): Succession of fungi on dead and live wood in brackish water in Brunei. - Mycologia **96**: 219–225.

GÖNCZÖL, J. & Á. RÉVAY (2003): Tree hole fungal communities: aquatic, aero-aquatic and dematiaceous hyphomycetes. - Fungal Diversity **12**: 19–34.

GÖNCZÖL, J. & Á. RÉVAY (2004): Fungal spores in rainwater: stemflow, throughfall and gutter conidial assemblages. - Fungal Diversity **16**: 67–86.

HAYTHORN, J.M., E.B.G. JONES & J.L. HARRISON (1980): Observations on marine algicolous fungi, including the hyphomycete *Sigmoidea marina* sp. nov. - Trans. Brit. Mycol. Soc. **74**: 615–623.

HYDE, K.D. (1986): Frequency of occurrence of lignicolous marine fungi in the tropics. - In MOSS, S.T. (Ed.): The Biology of Marine Fungi: 311–322. Cambridge University Press, Cambridge.

HYDE, K.D. & T.K. GOH (1998): Fungi on submerged wood in Lake Barrine, north Queensland, Australia. - Mycol. Res. **102**: 739–749.

JOHNSON, T.W. & F.K. SPARROW (1961): Fungi in Oceans and Estuaries. - Cramer, Weinhem.

JONES, E.B.G. (1976): Lignicolous and algicolous fungi. - In JONES, E.B.G. (Ed.): Recent Advances in Aquatic Mycology: 135–175. Elek Science, London.

JONES, E.B.G. (2000): Marine fungi: some factors influencing biodiversity. - Fungal Diversity **4**: 53–73.

JONES, E.B.G. & K.D. HYDE (1988): Methods for the study of mangrove marine fungi. - In AGATE, A.D., SUBRAMANIAN C.V. & M. VANNUCCI, M. (Eds.): Mangrove microbiology. Role of microorganisms in nutrient cycling of mangrove soils and waters: 9–27. UNDP/UNESCO, New Delhi.

JONES E.B.G. & A.C. OLIVER (1964): Occurrence of aquatic hyphomycetes on wood submerged in fresh and brackish water. - Trans. Brit. Mycol. Soc. **47**: 45–48.

JONES, E.B.G. & L.L.P. VRIJMOED (1997): Observations on subtropical fungi on driftwood from mangroves and sandy beaches in the Pearl River Estuary. In JANARDHANAN, K.K., RAJENDRAN, C., NATARAJAN, K. & HAWKSWORTH, D.L. (Eds.): Tropical Mycology: 51–59. Science Publishers, Inc.

JONES, E.B.G., H. KÛHNE, P.C. TRUSSELL & R.D. TUMER (1972): Results of an international co-operative research programme on the biodeterioration of timber submerged in the sea. - Mat. Org. **7**: 93–118.

JONES, E.B.G., J. SAKAYAROJ, S. SOMRITHIPOL & K.L. PANG (2007): Classification of marine basidiomycota and ascomycota. - In SIJAM, K., Z.A.M. AHMED, V. SABARATNAM, S.A. ALIAS & T.J. YEN (Eds.): Changing scenarios in fungal research and innovation: 113. Asian Mycology Congress (AMC, 2007) and 10th International Marine and Freshwater Mycology Symposium (IMFMS). Penang, Malaysia 2–6 December. Book of abstract.

KOCH, J. (1982): Some lignicolous marine fungi from Sri Lanka. - Nord. J. Bot. **2**: 163–169.

KOHLMEYER, J. (1968): Marine fungi from the tropics. - Mycologia **60**: 252–270.

KOHLMEYER, J. & T.M. CHARLES (1981): Sclerocarps: undescribed propagules in a sand-inhabiting marine fungus. - Can. J. Bot. **59**: 1787–1791.

KOHLMEYER, J. & E. KOHLMEYER (1971): Marine fungi from tropical America and Africa. - Mycologia **3**: 831–861.

KOHLMEYER, J. & E. KOHLMEYER (1979): Marine Mycology, the Higher Fungi. - Academic Press, New York.

KOHLMEYER, J. & B. VOLKMANN-KOHLMEYER (1991): Illustrated Key to the filamentous higher marine fungi. - Bot. Mar. **34**: 1–61.

LUO, J., J.F. YIN, L. CAI, K. ZHANG & K.D. HYDE (2004): Freshwater fungi in Lake Dianchi, a heavily polluted lake in Yunnan, China. - Fungal Diversity **16**: 93–112.

MANSOUR, S.A., S.S. MESSEHA & M.M. SIDKY (2000): Ecotoxicological Studies. 1. Qualitative and quantitative determination of salt composition in Lake Quaron water and its sources. Egypt. - J. Aquat. Biol. Fisher. **4**: 271–303.

MER, G.S., S.C. SATI & R.D. KHULBE (1980): Occurrence, distribution and seasonal periodicity of some aquatic fungi of Sat-Tal (Nainital), India. - Hydrobiologia **76**: 201–205.

MEYERS, S.P. (1996): Fifty years of marine mycology: Highlights of the past, projections for the coming century. - SIMS News **46**: 119–127.

MORRISON-GARDINER, S. (2002): Dominant fungi from Australian coral reefs. - Fungal Diversity **9**: 105–121.

NAKAGIRI, A. & K. TUBAKI (1985): Teleomorph and anamorph relationships in marine ascomycetes (Halosphaeriaceae). - Bot. Mar. **28**: 485–500.

PANG, K.L., M.A. ABDEL-WAHAB, S. SIVICHAI, H.M. EL-SHAROUNY & E.B.G. JONES (2002): Jahnulales (Dothideomycetes, Ascomycota): a new order of lignicolous freshwater ascomycetes. - Mycol. Res. **106**: 1031–1042.

POON, M.O.K. & K.D. HYDE (1998): Biodiversity of intertidal estuarine fungi on *Phragmites* at Mai Po Marshes, Hong Kong. - Bot. Mar. **41**: 141–155.

PREMDAS, P.D. (1991): Seasonal sporulation of some aero-aquatic fungi. - Archiv für Hydrobiologie **122**: 479–482.

SAAD, M.A.H. (2003): Impact of diffuse pollution on the socio-economic development opportunities in the coastal Nile delta lakes. - In BRUEN, M. (Ed.): Proceedings of the 7th International Conference on Diffuse Pollution and Basin Management: 81–85. Dublin, 17–22 August 2003. University College Dublin Press, Ireland.

SCHAUMANN, K. (1975): Marine Pilzfunde von der Norwegischen Rinne, der Barents-See und von den Kûsten Westafrikas und der kanarischen Inseln. - Veröff. Inst. Meeresforsch. Bremerh. **15**: 183–194

SHANNON, C.E. & W. WEAVER (1949): The mathematical theory of communication. - University Illinois Press, Urbana, IL.

SHEARER, C.A. (1972): Fungi of the Chesapeake Bay and its tributaries. III. The distribution of wood-inhabiting Ascomycetes and fungi imperfecti in the Patuxent River. - Amer. J. Bot. **59**: 961–969.

SHEARER, C.A. (1993): The freshwater ascomycetes. - Nova Hedwigia **56**: 1–33.

SHEARER, C.A. & S.B.V. BODMAN (1983): Patterns of occurrence of ascomycetes associated with decomposing twigs in a Midwestern stream. - Mycologia **75**: 518–530.

SHEARER, C.A. & J.L. CRANE (1980): Fungi of the Chesapeake Bay and its tributaries VIII. Ascomycetes with unfurling appendages. - Bot. Mar. **23**: 607–615.

SHEARER, C.A., D.M. LANSAM, J.E. LONGCORE (2004): Fungi in freshwater habitats. - In: MUELLER, G.M., G.F. BILLS, M.S. FOSTER (Eds.): Biodiversity of fungi: inventory and monitoring methods: 513–531. Elsevier, Amsterdam.

SHEARER, C.A., E. DESCALS, B. VOLKMANN-KOHLMEYER, J. KOHLMEYER, L. MARVANOVÁ, D. PADGETT, D. PORTER, H.A. RAJA, J.P. SCHMIT, H. THORTON & H. VOGLMAYR (2007): Fungal biodiversity in aquatic habitats. - Biodiv. Conserv. **16**: 49–67.

STEINKE, T.D. & E.B.G. JONES (1993): Marine mangrove fungi from the Indian Ocean coast of South Africa. - S. Afr. J. Bot. **59**: 385–390.

TAN, T.K. & W.F. LEONG (1992): Lignicolous fungi of tropical mangrove wood. - Mycol. Res. **96**: 413–414.

TUBAKI, K. (1969): Studies on the Japanese marine fungi lignicolous group (III), algicolous group and a general consideration. - IFO Research Communication **4**: 12–41.

VAN RYCKEGEM G., M.O. GESSNER & A. VERBEKEN (2007): Fungi on leaf blades of *Phragmites australis* in a brackish tidal marsh: Diversity, succession, and leaf decomposition. - Microbial Ecology **53**: 600–611.

VRIJMOED, L.L.P., I.J. HODGKISS & L.B. THROWER (1986a): Effects of surface fouling organisms on the occurrence of fungi on submerged pine blocks in Hong Kong coastal waters. - Hydrobiologia **135**: 123–130.

VRIJMOED, L.L.P., I.J. HODGKISS & L.B. THROWER (1986b): Occurrence of fungi on submerged pine and teak blocks in Hong Kong coastal waters. - Hydrobiologia **135**: 109–122.

WESTON, W.H. (1929): Observations on *Loramyces*, an undescribed aquatic ascomycete. - Mycologia **21**: 55–76.

WILLIAMS, M.C. & R.W. LICHTWARDT (1990): Trichomycete gut fungi in New Zealand aquatic insects larvae. - Can. J. Bot. **68**: 1045–1056.

WONG, M.K.M. & K.D. HYDE (2001): Diversity of fungi on six species of Gramineae and one species of Cyperaceae in Hong Kong. - Mycol. Res. **105**: 1485–1491.

WONG, M.K.M & K.D. HYDE (2002): Fungal saprobes on standing grasses and sedges in a subtropical aquatic habitat. - In Hyde, K.D. (Ed.): Fungi in Marine Environments: 195–212. Fungal Diversity Research Series, Hong Kong University Press, Hong Kong.

ZAINAL, A. & E.B.G. JONES (1984): Observation on some lignicolous marine fungi from Kuwait. - Nova Hedwigia **39**: 569–583.

Received 7 September 2008, accepted in revised form 12 March 2009.