IMI Descriptions of Fungi and Bacteria No. 2216

HEMITRICHIA SERPULA

A. Plasmodiocarp (bar = 5 mm). **B**. Plasmodiocarp (bar = 2 mm). **C**. Capillitium and spores (bar = 20 µm). [Photographs: A. Michaud]

Hemitrichia serpula (Scop.) Rostaf., *Versuch eines Systems der Mycetozoen*: 14 (1873). [*IndexFungorum* 179218; *Trichiaceae*, *Trichiida*]

Mucor serpula Scop., *Flora Carniolica* Edn 2, **2**: 493 (1772). [*IndexFungorum* 182881]

Trichia serpula (Scop.) Pers., *Tentamen Dispositionis Methodicae Fungorum*: 10 (1797). [*IndexFungorum* 180521]

Hemiarcyria serpula (Scop.) Rostaf., *Śluzowce (Mycetozoa) Monografia*: 266 (1874) [publ. 1875]. [*IndexFungorum* 182483]

Arcyria serpula (Scop.) Massee, *A Monograph of the Myxogastres*: 164 (1892). [*IndexFungorum* 249327]

Hyporhamma serpula (Scop.) Lado, *Cuadernos de Trabajo de Flora Micológica Ibérica* **16**: 48 (2001). [*IndexFungorum* 372779]

Lycoperdon lumbricale Batsch, *Elenchus Fungorum* Continuatio Prima: 259 (1786). [*IndexFungorum* 179110]

Stemonitis lumbricalis (Batsch) J.F. Gmel., *Systema Naturae* Edn 13 (Leipzig) **2**(2): 1470 (1792). [*IndexFungorum* 226206]

Trichia spongioides Vill., *Histoire des Plantes de Dauphiné* **3**(2): 1061 (1789). [*IndexFungorum* 225663]

Trichia reticulata Pers., *Neues Magazin für die Botanik* **1**: 90 (1794). [*IndexFungorum* 151258]

Hyporhamma reticulatum (Pers.) Corda, *Icones Fungorum hucusque Cognitorum* **6**: 13 (1854). [*IndexFungorum* 191954]

Trichia venosa Schumach., *Enumeratio Plantarum in Partibus Sællandiae Septentrionalis et Orientalis* **2**: 207 (1803). [*IndexFungorum* 207643]

Trichia retiformis Payer, *Botanique Cryptogamique ou Histoire des Familles Naturelles des Plantes Inférieurs* Edn 1: 122, fig. 574 (1850). [*IndexFungorum* 171453]

Hemitrichia serpula var. *tubiglabra* Y. Yamam. & Nann.-Bremek., in N.E. NANNENGA-BREMEKAMP & Y. YAMAMOTO, *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* Series C, Biological and Medical Sciences **93**(3): 283 (1990). [*IndexFungorum* 127889]

Hemitrichia serpula var. *piauiensis* L.H. Cavalc. & Mobin, in N.E. NANNENGA-BREMEKAMP & Y. YAMAMOTO, *Acta Botanica Brasilica* **15**(1): 134 (2001). [*IndexFungorum* 634758]

Vernacular names. Czech: *vlasenka plazivá*. Danish: *slange-hårbold*. Dutch: *netvormig langdraadwatje*. English: *baby jalebi*, *pretzel slime mould*. French: *hémitrichie mérule*. German: *Netzschleimpilz*.

Diagnostic features. Very conspicuous; habit usually entirely plasmodiocarpous and sessile; sporocarps unmistakable, looking like miniature versions of the Indian sweet jalebi, or pretzels; spore ornamentation a raised episporic network appearing to give the spore a border in optical section (compound microscope magnifications > ×400).

On natural substratum. *Amoebal state* no information. *Plasmodium* at first white, later yellow. *Hypothallus* red-brown. *Sporocarps* bright yellow to rusty or brownish yellow, sometimes as sessile sporangia, 0·4–0·6 mm diam. and up to 15 mm long, much more often as a sessile, elongate, worm-like branched network or ring-shaped plasmodiocarp, formed when the plasmodium concentrates protoplasm *in situ* in main veins during development, branching freely, the reticulum up to several cm in extent. *Stalks* absent. *Peridium* thin, single, membranous, shining, persistent at the base, splitting lengthwise and towards the base to expose yellow capillitial threads intermingled with yellow light-colored spores, with some large papillae and on the inner surface fine, minutely papillose, roughly fan-shaped wrinkles. *Columella* absent. *Capillitium* characteristically elastic with branched yellow threads 6–10 µm wide, decorated with 3–5 spiral bands connected by thin longitudinal ridges, and long spines up to 7 µm high and free pointed ends. *Spores en masse* and individually golden to orange yellow, 9–14 µm diam., with large and irregular, sometimes incomplete, meshes (2–4 meshes per hemisphere), 1–2 µm high; the meshes distinctive, giving the spore a border in optical section (compound microscope magnifications > ×400).

ASSOCIATED ORGANISMS & SUBSTRATA: **Animalia**. *Baeocera* sp. **Artefacts**. Balcony floor. **Fungi**. *Berkelella stilbigera* (Berk. & Broome) Sacc. [as *Byssostilbe stilbigera* (Berk. & Broome) Petch, also as *Blistum ovalisporum* (A.L. Sm.) B. Sutton]; *Biscogniauxia nummularia* (Bull.) Kuntze [as *Nummularia bulliardii* Tul. & C. Tul.]; *Nectriopsis exigua* (Pat.) W. Gams [as *Verticillium rexianum* (Sacc.) Sacc.]; *Polycephalomyces tomentosus* (Schrad.) Seifert [also as *Stilbum tomentosum* Schrad.]; *Poria* sp. **Plantae**. *Agathis australis* (D. Don) Lindl.; *Agave* sp. (leaf, wood); *Aleurites* sp.; *Areca catechu* L. (leaf); *Arecaceae* gen. indet.; *Attalea speciosa* Mart.; *Betula* sp.; *Bromeliaceae* indet.; *Calophyllum inophyllum* L.; *Camillea sinensis* (L.) Kuntze (wood); *Carya* sp.; *Cocos nucifera* L. (leaf, log, spathe); *Cyathea arborea* (L.) Sm. (trunk); *Elaeis guineensis* Jacq.; *Equisetum palustre* L.; *Gramineae* indet. (culm); *Hibiscus tiliaceus* [not traced]; *Magnoliophyta* indet. (wood); *Magnoliopsida* indet.; *Miconia* sp. (wood); *Musa paradisiaca* L. (leaf), *Musa* sp.; *Muscopsida* indet. (thallus); *Nothofagus* sp.; *Palmae* indet. (leaf, petiole, trunk); *Pandanus balfourii* Martelli; *Phoenicophorium borsigianum* (K. Koch) Stuntz; *Phytelephas* sp.; *Picea schrenkiana* Fisch. & C.A. Mey., *Picea* sp.; *Plantae* indet. (bark, branch, debris, leaf, litter, log, stump, trunk, twig, wood); *Podocarpus* sp.; *Populus tremula* L., *Populus* sp. (wood); *Pteridophyta* indet. (root); *Quercus pubescens* Willd. (branch, twig), *Quercus* sp.; *Rhopalostylis sapida* (Sol. ex G. Forst.) H. Wendl. & Drude (frond); *Roystonia regia* (Kunth) O.F. Cook (leaf, petiole);

Saccharum sp.; *Salix cinerea* L. (branch), *Salix* sp. (wood); *Theobroma cacao* L. **Protista**. *Hemitrichia clavata* (Pers.) Rostaf.; *Licea biforis* Morgan; *Perichaena* sp. **Associated organism of type specimen**. *Plantae* indet. [as '*in arborum corticibus, et truncis prope radices*']. **Comment**. This species occurs on dead fallen leaves, petioles, spathes, bark, branches, logs, stumps, trunks, twigs, and decaying wood (including artefacts) of a wide range of plants. It also occurs on the thalli of mosses.

INTERACTIONS & HABITATS: For a thorough introduction to myxomycete ecology, see MADELIN (1984). The dead plant material with which myxomycetes are very widely associated, while undoubtedly a platform for their sporocarps, is not necessarily a source of nutrition. Sporocarps are the only stage in myxomycete life cycles where species can be identified by morphology. The other states, as amoebae and plasmodia, have received little attention. SHCHEPIN *et al.* (2019) suggested that populations of myxomycete amoebae may inhabit much wider ecological niches than indicated by records of their sporocarps. There is no specific information about the ecology and nutrition of the amoebal state of *H. serpula*. In their amoebal state, myxomycetes are known to feed on small organic particles and micro-organisms (including some fungi), but the identity of those micro-organisms is rarely, if ever, recorded. This species has been observed in the following habitats: amenity & protected areas (nature reserves, parkland); woodland (natural and semi-natural broadleaf woodland, natural and semi-natural conifer woodland, natural and semi-natural mixed woodland). In one study in Thailand, collections of this species were found in equal number during the warm wet and cool dry seasons (KO KO *et al.*, 2011). TAKAHASHI (2004) suggested substratum hardness and state of decay may be significant when this species occurs on wood. Several other myxomycetes and fungi have been observed growing on the same substratum. Some fungi have been reported growing on sporocarps of this species, and may be parasitic. An association between this species and staphylinid beetles of the genus *Baeocera* has been observed in Brazil (LEMOS *et al.*, 2010).

GEOGRAPHICAL DISTRIBUTION: AFRICA: Algeria, Angola, Burundi, Cameroon, Congo, Democratic Republic of the Congo, Equatorial Guinea, Guinea, Kenya, Liberia, Madagascar, Malawi, Mayotte, Nigeria, Rwanda, Sierra Leone, South Africa, Tanzania, Uganda, Zimbabwe. NORTH AMERICA: Canada (Manitoba, Nunavut, Ontario, Quebec), Mexico, USA (Alaska, Arizona, Arkansas, California, Connecticut, Florida, Georgia, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Mexico, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Vermont, Virginia, Washington, West Virginia, Wisconsin). CENTRAL AMERICA: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama. SOUTH AMERICA: Argentina, Bolivia, Brazil (Acre, Alagoas, Amapá, Amazonas, Bahia, Ceará, Goias, Distrito Federal, Maranhao, Mato Grosso, Pará, Paraíba, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Roraima, Santa Catarina, São Paulo, Sergipe), Chile, Colombia, Ecuador (including Galapagos), French Guiana, Guyana, Uruguay, Venezuela. ASIA: China (Guangdong, Guangxi, Hainan, Hebei, Heilongjiang, Hunan, Jiangsu, Jilin, Shaanxi, Shanxi, Yunnan, Zeijiang), India (Assam, Chandigarh, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, Uttarakhand, West Bengal), Indonesia, Iran, Kazakhstan (Almaty, North Kazakhstan), Japan, Malaysia, Nepal, Pakistan, Papua-New Guinea, Philippines, Russia (Altai Krai, Chelyabinsk Oblast, Irkutsk Oblast, Khabarovsky Krai, Primorsky Krai, Sverdlovsk Oblast, Tyumen Oblast), South Korea, Sri Lanka, Taiwan, Thailand, Vietnam. ATLANTIC OCEAN: Portugal (Azores). AUSTRALASIA: Australia (New South Wales, Queensland, Victoria, Western Australia), New Zealand. CARIBBEAN: American Virgin Islands, Antigua and Barbuda, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martinique, Puerto Rico, Saint Lucia, Saint Vincent, Trinidad and Tobago. EUROPE: Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, Norway, Poland, Romania, Russia (Kirov Oblast, Krasnodar Krai, Leningrad Oblast, Moscow Oblast, Oryol Oblast, Pskov Oblast, Republic of Bashkortostan, Tver Oblast), Slovenia, Spain, Sweden, Switzerland, Ukraine, UK. INDIAN OCEAN: Mauritius, Réunion, Seychelles. PACIFIC OCEAN: French Polynesia, Marshall Islands, New Caledonia, USA (Hawaii).
Elevation (m above sea level). Records up to 3540 (Guatemala); 3000 (Kenya); 2430 (Mexico); 2000 (Colombia).

Comment. Recorded from every continent except Antarctica, and from many oceanic islands. Probably native throughout its known distribution. The geographical distribution presented here is of *H. serpula* in a broad sense (see also **Infraspecific Variation** and **Dispersal & Transmission** below).

ECONOMIC IMPACTS: There is experimental evidence that this species can accumulate heavy metals (KRYVOMAZ, 2015, 2016; KRYVOMAZ & ANDRUSISHINA, 2016; KRYVOMAZ *et al.*, 2017*c*). KRYVOMAZ (2017*a*) measured metal levels in samples of *H. serpula* on *Cocos nucifera* from the Seychelles, and in its substrata and surrounding soil. The levels of different elements were, in descending order, as follows [µg of metal per g of myxomycete tissue]: Ca (107618·61), Fe (3659·24), Mg (3596·97), Si (1169·54), Al (1133·18), Zn (191·77), Mn (122·41), Cu (12·36), Pb (9·63), Ni (3·22), As (0·48), Cr (0·2), Cd (0·15). In comparison with other myxomycetes in the study, *H. serpula* did not strongly accumulate heavy metal. An accumulation coefficient was used to calculate the concentration ratios between myxomycete and substratum, and between myxomycete and soil. The ratios revealed different accumulation patterns. These were termed by KRYVOMAZ (2017*a*) as:

- accumulation [concentration in myxomycetes higher than in substrata and soil]: in *H. serpula* this pattern was observed for Mg, Cd, Pb, Mn, Zn, Fe, Cu, Si, As;
- substratum-dependent accumulation [concentration in myxomycetes less than in substratum, but higher than in soil]: in *H. serpula* this pattern was observed for Ni;
- soil-dependent accumulation [concentration in myxomycetes less than in soil, but more than in substrata]: in *H. serpula* this pattern was observed for Cr.

Heavy metal accumulating properties are likely to have significant positive economic potential (STEPHENSON & MCQUATTIE, 2000). Although nothing has yet been developed for the present species, there is considerable interest in use of fungi with similar abilities for bioremediation and other applications (GADD, 2007). No evaluation has been made of any other possible positive economic impact of this organism (e.g. as a recycler, as a source of useful products, as a provider of checks and balances within its ecosystem, etc.). *Hemitrichia serpula* has been reported on wood from mushroom-growing farms in Taiwan as a weed and potential parasite (CHUNG *et al.*, 1998). No other reports of negative economic impacts have been found.

INFRASPECIFIC VARIATION: Three subspecific taxa have been described. *Hemitrichia serpula* var. *tubiglabra* Y. Yamam. & Nann.-Bremek. and *H. serpula* var. *piauiensis* L.H. Cavalc. & Mobin are synonyms of typical *H. serpula* and are listed above. The third is *H. serpula* var. *parviverrucospora* Lizárraga, Illana & G. Moreno. LIZÁRRAGA *et al.* (1999) provided scanning electron micrographs of this variety, which is the basionym of the now accepted species *H. parviverrucospora* (Lizárraga, G. Moreno & Illana) G. Moreno & Illana. A phylogeographic study of this species using molecular techniques and based on specimens collected in different parts of the world, found 40 different 'ribotypes' worldwide, which clearly aggregated into three clades. These showed partial correlation with the morphological variation on which these three varieties (and the fourth, typical, variety) are based. Additional study, using an independent second marker, provided clear evidence for geographical limitation of certain genotypes. Results suggested that the clades were best explained as reproductively isolated units, with the conclusion that at least some of the morphological varieties are evidence of active cryptic speciation (DAGAMAC *et al.*, 2017). For further discussion of the molecular markers used in that study, see SCHNITTLER *et al.* (2017).

DISPERSAL & TRANSMISSION: For a general discussion about myxomycete dispersal, see KRYVOMAZ & STEPHENSON (2017). Myxomycete spores are dispersed considerable distances by wind. Field experiments and mathematical modeling have shown that, with winds of 0·1 m/s, spores can travel up to *c.* 1·8 km, and when wind speed reaches 28 m/s, this rises to over 500 km (TESMER & SCHNITTLER, 2007). Spores and myxamoebae may be dispersed by rainwater and water in soil. Some local dispersal may also occur by movement of myxamoebae and plasmodia. Insects and other invertebrates feed on sporophores, as probably do terrestrial vertebrates including birds, and myxomycete spores have been found in insect faeces, suggesting that animals may play a part in their dispersal. Plant debris floating in seawater may also contribute to dispersal between land masses. The phylogeographic study by

DAGAMAC *et al.* (2017) provided evidence that, on a global scale, populations of *H. serpula* are sufficiently isolated from each other for speciation to be occurring. They suggested that, in this species at least, the traditional view of protist geographical distribution that 'everything is everywhere' may not be true.

CONSERVATION STATUS: The IUCN's Red Listing Criteria were originally designed for evaluation of vertebrate animals and flowering plants, and present challenges to those trying to apply them to organisms like myxomycetes which are unicellular for a significant part of their life cycle. A discussion of those challenges, particularly in respect of myxomycetes and climate change, is provided by KRYVOMAZ & STEPHENSON (2017). **Previous evaluations**. Exceedingly common in central Cuba (CAMINO *et al.*, 2008); abundant in northeast Brazil Atlantic forests (COSTA *et al.*, 2014); one of the most common species of southern Vietnam (NOVOZHILOV *et al.*, 2017); abundant in the Tropics especially on spathes of palm trees (KRYVOMAZ & MICHAUD, unpublished). **Information base**. Over 2800 records (specimens, databases and bibliographic sources combined, excluding duplicates) from at least 1772 to November 2018, with observations in every month of the year, peaking in the northern hemisphere from July to November. **Estimated extent of occurrence** [calculated using *http://geocat.kew.org*]. Over 141·5 million km^2 (Africa [sub-Saharan only]: 18·7 million km^2; Asia: 46·6 million km^2; Australasia: 9·2 million km^2; Europe [including north Africa]: 7·6 million km^2; North America [including the Caribbean and Central America]: 24·9 million km^2; Pacific Ocean: 16·5 million km^2; South America: 18·9 million km^2). **Estimated area of occupancy** [calculated using *http://geocat.kew.org*]. Well over 2336 km^2. The method for estimating area of occupancy has produced an artificially low figure. The species is likely to be under-recorded because of the small number of people with the skills to search for and identify it. Many of the plants with which it is associated are common and widespread species. **Threats**. Insufficient information to enable threats to be identified. In particular, possible vulnerabilities of the amoebal and plasmodial states of this species are currently completely overlooked. No reports were found of changes in geographical distribution in response to climate change. **Population trend**. In general, not known. Occasional to rare in northern Thailand (TRAN *et al.*, 2006); very rare but increasing in Saxony, Germany (HARDTKE *et al.*, 2015). Of datable records, *c.* 25% are pre-1961, 50% post-1960 but pre-2001, and 25% post-2000. **Evaluation**. Using IUCN criteria (IUCN SPECIES SURVIVAL COMMISSION. *2006 IUCN Red List of Threatened Species* [*www.iucnredlist.org*]. Downloaded on 15 May 2006), the species is assessed globally as Least Concern. ***In situ* conservation actions**. None noted. ***Ex situ* conservation actions**. 172 nucleotide sequences, 1 PopSet sequence and 37 protein sequences were found in a search of the NCBI GenBank database [*www.ncbi.nlm.nih.gov*, accessed 11 November 2019]. No living strains of this species are listed by the ATCC, CABI and Westerdijk Institute [formerly CBS] culture collections. PHATE & MISHRA (2014) reported the successful isolation and growth of this species in pure culture.

NOTES: A description of the appearance and development of *H. serpula* plasmodia was provided by MCMANUS (1962). ELLIOT (1949) provided a general account of myxomycete swarm cells, including the present species. ELLIS *et al.* (1973) provided scanning and transmission electron micrograph images of *H. serpula* capillitial threads. *Hemitrichia serpula* is an iconic species and, as such, has a presence on YouTube [e.g. *www.youtube.com/watch?v=R2RguYFuiM8*, accessed 20 November 2019].

LITERATURE & OTHER SOURCE MATERIAL: (Literature on *H. serpula* is very extensive, and the following citations should be regarded as indicative rather than exhaustive.) ADAMONYTE, G. New data on Estonian myxomycete biota. *Folia Cryptogamica Estonica* **36**: 7-9 (2000). BEZERRA, A.C.C., CAVALCANTI, L. DE HOLLANDA & DIANESE, J.C. Species of *Hemitrichia* (*Trichiaceae*, *Myxomycetes*) in Brazil. *Mycotaxon* **107**: 35-48 (2009). CAMINO, M., STEPHENSON, S.L., KRIVOMAZ, T., WRIGLEY DE BASANTA, D., LADO, C. & ESTRADA-TORRES, A. Biodiversity survey for myxomycetes in the mountains of central Cuba. *Revista Mexicana de Micología* **27**: 39-51 (2008). CAVALCANTI, L. DE H. & MOBIN, M. *Hemitrichia serpula* var. *piauiensis* (*Trichiaceae*, *Myxomycetes*) – a new variety from Brazil. *Acta Botanica Brasilica* **15**(1): 133-137 (2001). CHUNG, C.H., LIU, C.H. & TZEAN, S.S. Slime molds in edible mushroom cultivation sites. *Plant Pathology Bulletin* **7**: 141-146 (1998). COSTA, A.A.A., BEZERRA, A.C.C., LIMA, V.X. DE & CAVALCANTI, L. DE H. Diversity of myxomycetes in an environmentally protected area of Atlantic forest in northeastern Brazil. *Acta Botanica Brasilica* **28**(3): 445-455 (2014) [DOI: 10.1590/0102-33062014abb3428]. DAGAMAC, N.H.A., ROJAS, C., NOVOZHILOV, Y.K., MORENO, G.H., SCHLUETER, R. & SCHNITTLER, M. Speciation in progress? A phylogeographic study among populations of *Hemitrichia serpula* (*Myxomycetes*). *PLoS One* **12**(4): e0174825 (2017). ELLIOTT, E.W. The swarm-cells of myxomycetes. *Mycologia* **41**(2): 141-170 (1949). ELLIS, T.T., SCHEETZ, R.W. & ALEXOPOULOS, C.J. Ultrastructural observations on capillitial types in the *Trichiales* (*Myxomycetes*). *Transactions of the American Microscopical Society* **92**(1): 65-79 (1973). ERSHAD, D. *Fungi of Iran* Edn 3 (Tehran: Iranian Research Institute of Plant Protection): 558 pp. (2009). FERREIRA, I.N. & CAVALCANTI, L. DE H. Disponibilidade de microhabitats para myxomycetes em Floresta Atlântica: *Bromeliaceae*. *Biotemas* **23**(3): 1-10 (2010) [text in Portuguese]. GADD, G.M. Geomycology: biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. *Mycological Research* **111**(1): 3-49 (2007). GHOSH, G.R. & DUTTA, B.G. Myxomycetes from Orissa (India) – I. *Mycopathologia et Mycologia Applicata* **16**(2): 165-176 (1962). HARDTKE, H.J., DÄMMRICH, F. & KLENKE, F. *Rote Liste und Artenliste Sachsens-Pilze* (Dresden: Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie): 580 pp. (2015). ING, B., SPOONER, B.M. & BUTTERFILL, G.B. Myxomycetes from the Azores. *Kew Bulletin* **54**(2): 405-413 (1999). IRBE, I., KARADELEV, M., ANDERSONE, I. & ANDERSONS, B. Biodeterioration of external wooden structures of the Latvian cultural heritage. *Journal of Cultural Heritage* **13S**: S79-S84 (2012). KELLER, H.W. & EVERHART, S.E. Importance of myxomycetes in biological research and teaching. *Fungi* **3**(1): 13-27 (2010). KNIGHT, K.J. & BRIMS, M.H. Myxomycota census of Western Australia. *Nuytsia* **20**: 283-307 (2010). KO KO, T.W., STEPHENSON, S.L., HYDE, K.D. & LUMYONG, S. Influence of seasonality on the occurrence of myxomycetes. *Chiang Mai Journal of Science* **38**(1): 71-84 (2011). KRYVOMAZ, T.I. The assessment of heavy metal accumulation by myxomycetes. *Motrol* Lublin **17**(8): 157-164 (2015). KRYVOMAZ, T.I. Assessment [of] environmental safety for mangrove biome. *Підводні Технології* [*Underwater Technology*] **4**: 16-25 (2016). KRYVOMAZ, T.I. [as КРИВОМАЗ, Т.І.]. *Наукові Основи Моніторингу Забруднення Навколишнього Середовища Токсичними Елементами з Використанням Міксоміцетів* [*Scientific Basis for Monitoring Environmental Pollution by Toxic Elements using Myxomycetes*]. Дис. д-ра техн. наук [Thesis (DSc), Technical Science], 21.06.01 (Київ: Київ Національний Університет Будівництва і Архітектури [Kyiv: Kyiv National Construction and Architecture University]): 349 pp. (2017*a*) [text in Ukrainian]. KRYVOMAZ, T.I. Accumulation of toxic metals and other elements by myxomycetes. In: *Abstracts of 9th International Congress on the Systematics and Ecology of Myxomycetes* Tanabe, Japan, 18-23 August 2017: 38 (2017*b*). KRYVOMAZ, T.I. & ANDRUSISHINA, I. Assessment of mangrove environmental safety by analyses of metals transition. *Environmental Safety* **1-2**(21): 55-59 (2016). KRYVOMAZ, T., MICHAUD, A. & STEPHENSON, S.L. Patterns of myxomycetes ecology and distribution on isolated tropical islands. In: *Abstracts of 9th International Congress on the Systematics and Ecology of Myxomycetes* Tanabe, Japan, 18-23 August 2017: 31 (2017*a*). KRYVOMAZ, T.I., MICHAUD, A. & STEPHENSON, S.L. First survey of myxomycetes on Mahé Island in the Seychelles. *Nova Hedwigia* **104**(1-3): 65-84 (2017*b*). KRYVOMAZ, T.I. & STEPHENSON, S.L. Preliminary evaluation of the possible impact of climate change on myxomycetes. *Nova Hedwigia* **104**(1-3): 5-30 (2017). KRYVOMAZ, T.I., VOLOSHKINA, O., MAXIMENKO, D.V. & ZHUKOVA, O.G. [as КРИВОМАЗ, Т.І., ВОЛОШКІНА, О.С., МАКСИМЕНКО, Д.В. & ЖУКОВА, О.Г.]. Регресійні моделі переходу елементів в міксоміцетах в залежності від параметрів навколишнього середовища [Regression models for the transition of elements in myxomycetes depending on the environmental parameters]. *Екологічна Безпека та Збалансоване Ресурсокористування* [*Environmental Safety and Sustainable Resources Management*] **1**(15): 97-104 (2017*c*) [text in Ukrainian]. KYLIN, H., MITCHELL, D.W., SERAOUI, E.-H. & BUYCK, B. Myxomycetes from Papua New Guinea and New Caledonia. *Fungal Diversity* **59**: 33-44 (2013). LEMOS, D.B.N., AGRA, L. DE A.N.N., IANNUZZI, L., BEZERRA, M. DE F. DE A. & CAVALCANTI, L. DE H. Co-existence of myxomycetes and beetles in an Atlantic Rainforest remnant of Pernambuco, Brazil, with emphasis on staphylinids (*Coleoptera*: *Staphylinidae*). *Journal of Natural History* **44**(21-24): 1365-1376 (2010) [DOI: 10.1080/00222931003632724]. LIU, C.H., CHANG, J.H. & CHEN, Y.F. The genus *Hemitrichia* (myxomycetes) in Taiwan. *Collection and Research* [formerly *Bulletin of the National Museum of Natural Science*] **19**: 27-33 (2006). LIZÁRRAGA, M., ILLANA, C. & MORENO, G. SEM studies of the *Myxomycetes* from the

Peninsula of Baja California (Mexico), II. *Hemitrichia* to *Trichia*. *Annales Botanici Fennici* **36**(3): 187-210 (1999). MADELIN, M.F. Myxomycete data of ecological significance. *Transactions of the British Mycological Society* **83**(1): 1-19 (1984). MCMANUS, M.A. Some observations on plasmodia of the *Trichiales*. *Mycologia* **54**(1): 78-90 (1962). NANNENGA-BREMEKAMP, N.E. *A Guide to Temperate Myxomycetes* (Bristol, UK: Biopress Ltd): 409 pp. (1991). NDIRITU, G.G., WINSETT, K.E., SPIEGEL, F.W. & STEPHENSON, S.L. A checklist of African myxomycetes. *Mycotaxon* **107**: 353-356 (2009). NEUBERT, H., NOWOTNY, W. & BAUMANN, K. *Die Myxomyceten Deutschlands und des angrenzenden Alpenraumes unter besonderer Berücksichtigung Österreichs* **1**: *Ceratiomyxales*, *Echinosteliales*, *Liceales*, *Trichiales* (Gomaringen, Germany: Karlheinz Baumann Verlag): 344 pp. (1993). NOVOZHILOV, Y.K., ERASTOVA, D.A., SHCHEPIN, O.N., SCHNITTLER, M., ALEXANDROVA, A.V., POPOV, E.S. & KUZNETOV, A.N. Myxomycetes associated with monsoon lowland tropical forests in southern Vietnam. *Nova Hedwigia* **104**(1): 143-182 (2017). NOVOZHILOV, Y.K., ZEMLIANSKAIA, I.V., SCHNITTLER, M. & STEPHENSON, S.L. Myxomycete diversity and ecology in the arid regions of the Lower Volga River Basin (Russia). *Fungal Diversity* **23**: 193-241 (2006). PARENTE, M.P.M. & CAVALCANTI, L. DE HOLLANDA. Myxomycetes on palm trees: species on *Attalea speciosa* Mart. ex Spreng. *Advances in Microbiology* **3**: 19-23 (2013). PETCH, T. *Stilbum tomentosum* Schrad. *Transactions of the British Mycological Society* **28**(3-4): 101-109 (1945). PHATE, P. & MISHRA, R.L. Culture of *Hemitrichia serpula* on wide range of agar medium. *International Journal of Current Microbiology and Applied Sciences* **3**(2): 480-488 (2014). POULAIN, M., MEYER, M. & BOZONNET, J. *Les Myxomycètes* (Sevrier, France: Fédération Mycologique et Botanique Dauphiné-Savoie): **2** vols, 568 pp. + 544 plates (2011). ROGERSON, C.T. & STEPHENSON, S.L. Myxomyceticolous fungi. *Mycologia* **85**(3): 456-469 (1993). SCHNITTLER, M., SHCHEPIN, O.N., DAGAMAC, N.H.A., BORG DAHL, M. & NOVOZHILOV, Y.K. Barcoding myxomycetes with molecular markers: challenges and opportunities. *Nova Hedwigia* **104**(1-3): 323-341 (2017) [DOI: 10.1127/nova_hedwigia/2017/0397]. SHCHEPIN, O.N., SCHNITTLER, M., ERASTOVA, D.A., PRIKHODKO, I.S., DAHL, M.B., AZAROV, D.V., CHERNYAEVA, E.N. & NOVOZHILOV, Y.K. Community of dark-spored myxomycetes in ground litter and soil of taiga forest (Nizhne-Svirskiy Reserve, Russia) revealed by DNA metabarcoding. *Fungal Ecology* **39**(1): 80-93 (2019). STEPHENSON, S.L. Myxomycetes associated with decaying fronds of nikau palm (*Rhopalostylis sapida*) in New Zealand. *New Zealand Journal of Botany* **41**(2): 311-317 (2003). STEPHENSON, S.L. & MCQUATTIE, C.J. Assessing the potential use of myxomycetes as biomonitors of heavy metals in the environment. *Proceedings of the West Virginia Academy of Science* **72**: 32-33 (2000). TAKAHASHI, K. Distribution of myxomycetes on different decay states of deciduous broadleaf and coniferous wood in a natural temperate forest in the southwest of Japan. *Systematics and Geography of Plants* **74**: 133-142 (2004). TESMER, J. & SCHNITTLER, M. Sedimentation velocity of myxomycete spores. *Mycological Progress* **6**(4): 229-234 (2007). TRAN, H.T.M., STEPHENSON, S.L., HYDE, K.D. & MONGKOLPORN, O. Distribution and occurrence of myxomycetes in tropical forests of northern Thailand. *Fungal Diversity* **22**: 227-242 (2006). TURNER, P.D. Microorganisms Associated with Oil Palm (*Elaeis guineensis* Jacq.). *Phytopathological Papers* **14**: 58 pp. (1971). VLASENKO, A.V. & NOVOZHILOV, Y.K. [as ВЛАСЕНКО А.В. & НОВОЖИЛОВ Ю.К.] Субстратные комплексы миксомицетов сосновых лесов правобережной части верхнего приобья [Substrate assemblages of myxomycetes in the pine forests on the right-bank part of the upper Ob River]. *Микология и Фитопатология* [*Mycology & Phytopathology*] **46**(2): 122-130 (2012) [text in Russian].

Sources additional to those already cited from literature and the internet.

- *Biodiversity Heritage Library* [*www.biodiversitylibrary.org*].
- *Checklist of Fungi of the British Isles* [*https://basidiochecklist.science.kew.org/BritishFungi/FRDBI/FRDBI.asp*].
- *Cybertruffle* [*www.cybertruffle.org.uk*].
- *Discover Life (myxomycete pages)* [*www.discoverlife.org/mp/20q?guide=Myxomycetes*].
- *Fungal Records Database of Britain and Ireland* [*www.frdbi.info*]
- *Fungus Conservation Trust CATE2 Database* [*www.abfg.org*].
- *GBIF* [*www.gbif.org*].
- *Google* [*www.google.co.uk*].

- *Landcare Research New Zealand* [*http://nzfungi2.landcareresearch.co.nz*].
- *Mycoportal* [*www.mycoportal.org*].
- *Mycotaxon Regional Checklists in Downloadable Format* [*www.mycotaxon.com/mycobiota*].
- *National Center for Biotechnology Information* [*www.ncbi.nlm.nih.gov*].
- *Nomen.mycetozoa.com - an online nomenclatural information system of Eumycetozoa* [*http://eumycetozoa.com*].
- *USDA Fungal Databases* [*https://nt.ars-grin.gov/fungaldatabases*].

T.I. Kryvomaz[1], **A. Michaud**[2] & **D.W. Minter**[3]
[1]*Kyiv National University of Construction and Architecture, Kyiv, Ukraine*
[2]*93 Route de La Croizette, F-38360 Engins, France*
[3]*CABI Europe, Egham, UK*

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