Macrofungi of the Bieszczady Mountains

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Abstract

The Bieszczady Mts, a mountain range in SE Poland, is a hot spot of fungal richness and diversity in Poland. This paper summarizes 5 years of studies in the Bieszczady Mts, as well as previously published research. A total of 1,377 macromycetes taxa were found, including many (464) which were protected, red-listed, or very rare in Poland. Thirty-eight taxa (nine Ascomycota and 29 Basidiomycota) have been reported in Poland for the first time: Agrocybe gibberosa, Auriporia aurulenta, Bolbitius variicolor, Bulgarilla pulla, Chaetosphaerella phaeostroma, Clitocybe subspadacea, Clitopilus passeckerianus, Cortinarius anomalus var. subcaligatus, C. fervidus, C. flexipes var. inolens, C. syvae-norvegicae, Cudoniella tenuispora, Entoloma bisporigerum, E. oliforniae, E. poliopus var. parvisporigerum, E. sericeoides, Galerina caule cystidiata, Gymnopilus joserandii, Hymenoscyphus subferrugineus, Hypholoma alveocinctum, Inocybe queletii, Laccaria altaica, Lactarius romagnesi, L. rostratus, Mycena epityperrygia var. atroviscosa, M. epityperrygia var. candida, M. polygramma f. candida, Octavia bullet, O. mutabilis, Pachyella violaceonigra, Paneaulus mossiaceus var. capitatacystis, Phaeocollybia jennyae, Psathyrella almerensis, Pyrenopeziza inornata, Scutellinia torrentis, Tricholoma basirubens, Tricholomopsis flammula, and Vibrissea decolorans. For all new taxa, short descriptions based on the collected material have been provided.

Keywords
Bieszczady National Park; Ascomycota; Basidiomycota; diversity

Introduction

Study area

The Bieszczady Mts are a mountain range located in Poland, Slovakia, and Ukraine making up the western part of the Outer Eastern Carpathians. They are part of the Beskidy Mts, a series of the mountain ranges lying between the Czech Republic and Ukraine. The Polish Bieszczady Mts are classified as the Western Bieszczady Mts and are part of the mesoregion of the Beskidy Lesiste located in the eastern part of Podkarpackie Province [1,2]. The Polish part of this range occupies an area of ca. 1,450 km² and is bounded by Polish-Ukrainian and Polish-Slovakian borders in the south and east, respectively; the Łupkowska Pass, Oława valley, and the road between Szczawne and Czaszyn in the
west; and by the Leskie Foothills, the San River valley, and the line connecting N shore of the Victorini bay and the borderland village Michniowiec in the north (Fig. 1). This definition of the Bieszczady Mts also includes the Otryt and Ostre ranges. It is worth noting that the legend of “the wild Bieszczady” is still alive in Poland; therefore, many adjacent regions are often called “the Bieszczady Mts” (e.g., the Sanocko-Turczańskie Mts, Słonne Mts, or Przemyskie Foothills) for mainly commercial reasons. This misconception is reproduced in many books, scientific papers, websites, touristic folders, or popular tourist guides; however, these areas are not part of the Bieszczady Mts in terms of geology and physio-geography. The topography of the Bieszczady Mts has a characteristic system of straight ridges arranged from NW to SE, separated by deep valleys. The highest peak is Tarnica Mt (1,346 m a.s.l.), while the maximal denivelation is 700 m. The hydrological network is dense with numerous springs. Unlike the other parts of the Polish Carpathians, the Bieszczady Mts contain a high concentration of raised bogs, located mainly in the San and Wołosate valleys [1,3,4].

Fig. 1 Location of the area studied. Red dotted lines – borders of mesoregions (BZM – Bieszczady Zachodnie Mts; STM – Sanocko-Turczańskie Mts; BNM – Beskid Niski Mts; BF – Bukowskie Foothills). Green dotted lines – borders of the Bieszczady National Park. Black dots – selected villages (Ba – Baligród; Be – Bereżki; BG – Brzegi Górne; Bu – Bukowiec; C – Cisna; K – Komańcza; L – Lutowiska; Mo – Moczarne; Mu – Muczne; NŁ – Nowy Łupków; Po – Polańczyk; Ps – Pszczeliny; S – Smerek; TN – Tarnawa Niżna; UG – Ustrzyki Górne; We – Wetlina; Wo – Wołosate; Z – Zatwarnica). Blue lines – major rivers and streams (B – Beskidnik; GS – Górna Solinka).

Approximately 80% of the Bieszczady Mts are covered by forests. The most widespread are beech forests (Dentario glandulosae-Fagetum, Luzulo nemorosae-Fagetum), growing between the foothill and lower montane zones (Fig. 2). The stream valleys and seeps are covered by alder forests (Caltho-Alnetum, Alnetum incanae; Fig. 3). Communities with sycamore dominate (Sorbo-Aceretum carpaticum, Lunario-Aceretum, Phyllitido-Aceretum, Aceri-Fagetum) the upper montane zone, boulders, and rock outcroppings often at the upper forest margins, northern shady slopes, and deep valleys. In bogs and wet meadows, miscellaneous damp shrubs and forests occur, e.g., Salicetum pentandro-cinereae, Vaccinio uliginosi-Pinetum, Vaccinio uliginosi-Betuletum pubescentis, or Sphagno-Piceetum. Natural coniferous mountain forests (Abieti-Piceetum montanum) are rare; however, artificial spruce and fir forests are quite common, e.g., in the upper San valley. A unique
Fig. 2  Carpathian beech forest (*Dentario glandulosae-Fagetum*) on the slopes of the Otryt mountain range, Bieszczady Mts (Aug 16, 2009). Photography by G. Domian.

Fig. 3  Grey alder community (*Alnetum incanae*) in Wołosatka valley, Bieszczady Mts (Sep 2, 2011). Photography by K. Kujawa.
feature for the Bieszczady Mts are the shrub communities with green alder (Fig. 4), *Athyrio distentifoliae-Sorbetum alnetosum viridae*, *Pubnonario filarskyanae-Alnetum viridis*, *Calamagrostis-Alnus viridis*, or *Salix silesiaca-Alnus viridis* in subalpine areas. Hornbeam forests are rare and represented only by *Tilio-Carpinetum*; additionally, common alder communities are extremely rare. The nonforest plant communities in the Bieszczady Mts were strongly influenced by the pasturage of sheep, goats, and horses in the past. Shepherding has resulted in the formation of unique landforms in the subalpine zone (above 1,200 m a.s.l.), called polonynas (Polish: *poloniny*, Fig. 5), which are characteristic of the Eastern Beskidy Mts. Over 40 plant communities have been described in the subalpine zone of the Polish Bieszczady Mts. In the lower montane zone, over 50 types of nonforest plant communities are present. Of these, raised bogs (*Oxycocco-Sphagnetea*; Fig. 6), poor fens (*Scheuchzerio-Caricetea*), and poor meadows with *Nardus stricta* are the most valuable [3,5].

The soils of the Bieszczady Mts are derived from the Carpatian Flysch Belt rocks. The most common soils are eutrophic and dystrophic loamy brown earths (cambisols), shallow initial soils (leptospos, regospos), and soils characteristic of moist habitats, such as river banks (fluvisols), bogs (histosols), or meadows (gleysols) [3]. From a mycological point of view, the major soil characteristic influencing the fungal diversity is their pH. The soils of Bieszczady Mts are, in general, acidic or neutral (pH = 5.5–7.0 in water) with low concentrations of carbonates [Ca(Mg)CO₃]. This limits the number of fungal taxa, e.g., the calciphilous species of hypogeous or boletoid fungi do not occur in Bieszczady Mts.

Due to their unique character, and natural and cultural value, the Bieszczady Mts are protected. Over 290 km² are protected as the Bieszczady National Park (BdPN). Established in 1973, it has since been expanded a few times and is the third largest national park in Poland. The BdPN buffer zone is over 520 km². BdPN covers the most valuable parts of the Polish Bieszczady Mts. In 1992, the East Carpathian Biosphere Reserve was...
Fig. 5 Subalpine zone (poloninas) on Kopa Bukowa Mt, Bieszczady Mts (Sep 10, 2011). Photography by K. Kujawa.

Fig. 6 Raised bog “Dźwiniacz” in the upper San valley, Bieszczady Mts (Aug 18, 2009). Photography by G. Domian.
established by the UNESCO. It is a transboundary protection project that includes parts of Poland, Ukraine, and Slovakia. The entire Polish section is located in the Bieszczady Mts and is almost 1,090 km² large. It includes the BdPN and two landscape parks: Ciśniański-Wetliński Landscape Park and San Valley Landscape Park. The Bieszczady Mts are also protected as two Natura 2000 areas: Special Protection Area (Bieszczady SPA, PLC1800001) and part of the Basin of the Upper San Special Area of Conservation (PLH180021) [6,7]. Fourteen natural reserves have been established in the Bieszczady Mts: Cisy na Górze Jawor, Gołoborze, Hulskie im. prof. Stefana Myczkowskiego, Krywe, Nad Jeziorem Myczkowieckim, Olsza kosa w Stężnicy, Olszyna Łęgowa w Kalnicy, Przełom Olsawy pod Dusztynem, Przełom Sanu pod Grodziskiem, Sine Wiry, Śnieżycia wiosenna w Dwerniczku, Zakole, and Zwiezione [6,8]. Moreover, seven landscape-nature complexes (Wieś Krywe, Młyn w Hulskim, Cerkiew w Hulskim, Cmentarz w Ruskiem, Młyn w Dwerniku, Wieś Smolnik, Cmentarz w Stuposianach) and 44 ecological sites have been established in the Bieszczady Mts [7].

Current state of mycological studies in the Bieszczady Mts

Highly diverse habitats and their largely natural character results in an above average macromycete richness. The first mycological data from the Bieszczady Mts were published by Gumińska as a result of an 11-day trip of Polish mycologists (S. Czyżewska, S. Domański, B. Gumińska, A. Nespiak, A. Skirgielło, and W. Truszkowska) to the mountain range, in the vicinity of the village Wetlina [9]. The interesting results obtained from this trip inspired further studies by a group of scientists from various academic centers and specializing in different systematic groups. T. Majewski and W. Wojewoda joined the previous participants. Three excursions were made between 1960 and 1970, and their findings were published in four papers [10–13]. A preliminary red list of macromycetes of the Polish Carpathians was published in 1991, while a checklist of the corticioid fungi of this region was published in 1999 [14,15]. Both were based on earlier published data including those from the Bieszczady Mts. No further systematic mycological studies were conducted in the area of the Bieszczady Mts until 2008; however, some data have been published in many chorological or taxonomic papers and monographs (see references list). In 2008, Gierczyk and coworkers started a 5-year study of the mycobiota of the Bieszczady Mts. The first results (together with all available literature data) were published in 2009 [16]. In 2011, a protection plan for the BdPN was prepared by Kujawa et al.; however, it was not published. A short description of the characteristics of the mycobiota of the BdPN was prepared and published in the monograph on fortieth anniversary of the Park [17]. Selected results from this study have also been published by the participants of this project in papers on particular species or systematic groups [18–27]. Some species from the Bieszczady Mts have also been reported in the internet Database of Protected and Endangered Fungi (GREJ) (e.g., [28–34]). The diversity of lichenized or lichenicolous macromycetous fungal species (Lichenomphalia, Multiclavula, Tremella) have also been published in papers and monographs on the Bieszczady Mts lichen biota [35–42]. In last few years, two forestry science reports were published, containing lists of the observed fungi [43,44].

In the current paper, all available data on the Bieszczady Mts mycobiota have been reviewed and published, including the published reports and the authors’ unpublished data.

Material and methods

Route studies were performed from 2008 to 2013. Every year, 3–5 weeks were devoted to exploration. Almost all types of habitats characteristic of the Bieszczady Mts were checked each season. The specimens collected were identified by standard methods used in fungal taxonomy, i.e., determination of micro- and macrocharacters using a binocular or optical microscopy. Standard staining techniques, including an aqueous ammonia solution, 10% KOH in water, Congo red in ammonia, Melzer reagent, sulfovanilin, aniline (cotton) blue in lactophenol or lactic acid, brilliant cresyl blue
in water, acetocarmine, or carbol fuchsine, were used. Macrochemical reaction tests included aqueous ammonia solution, 10% KOH in water, and guaiac resin in ethanol. Specimens were identified using the following general keys and atlases: *Funga Nordica* [45,46], *Nordic Macromycetes* [47–49], *Flora Agaricina Neerlandica* [50–55], *Röhrlinge und Blätterpilze in Europa* [56], *Die Nichtblätterpilze, Gallertpilze und Bauchpilze* [57], *Fungi of Switzerland* [58–63], *Pilzkompendium* [64–71], and *Microfungi on land plants* [72]. The following monographs and taxonomic papers were also used: *Agaricus* [73–75], *Amanita* [76,77], *Conocybe* and *Pholiota* [78], *Crepidotus* [79], *Entoloma* [80,81], *Galerina* [82–85], *Gymnopilus* [86], *Helvella* [87], *Hemimycena* and *Xeromphalina* [88], *Hygrophorus* and *Hygrocybe* [89–91], *Inocybe* [92,93], *Lactarius* [94,95], *Peziza* [96], *Ramaria* [97], *Russula* [98,99], *Scutellinia* [100], *Tricholoma* [101,102], *Boletales* [103,104], *Geoglossaceae* [105–107], *Strophariaceae* [108,109], clavarioid fungi [110,111], jelly fungi [112,113], marasmioid fungi [114], hypogeous fungi [115], and gastromycetes [116]. Ascomycota were also determined based on the keys, iconography, and descriptions provided in a DVD edition by Baral [117]. Taxa names follow *Funga Nordica 2* [46] (except for a few taxa, as indicated in the species list) when available; otherwise names from the MycoBank Database [118] are used. The macrofungi group has been arbitrarily delimited as species forming sporocarps (basidiomata, ascomata) and stromata visible to the naked eye. In general, this overlaps with the concept accepted by the authors of *Nordic Macromycetes* [47–49], *Funga Nordica* [46], and *Fungi of Switzerland* [58–63], i.e., representatives of Boliniales, Chaetosphaeriales, Diaporthales, Hypocreales, Pleosporales, Rhytismatales, Sordariales, Taphrinales, Trichosphaeriales, and Xylariales have been included on the list. The checklist by Mirek et al. [119] has been used for the names of flowering plants and pteridophytes, while the checklist by Ochyra et al. [120] was used for the names of mosses. The distribution of species in Poland have been compiled based on checklists of Polish micro- and macromycetes [121–123], lichens and lichenicolous fungi [124,125], and the database of Polish mycological literature [126]. The threat categories were assigned according to “Red list of macrofungi in Poland” [127], and the protected species were indicated according to the Ministry of the Environment regulation from 2014 [128].

Dry specimens have been deposited in the Błażej Gierczyk private fungarium and the Fungarium of the Division of Mycology and Forest Phytopathology, Warsaw University of Life Sciences – SGGW (W AML). Geographic names from the touristic-toponimic map by Krukar [129] have been used.

**Results**

The complete list of macrofungi species found by the authors in the Bieszczady Mts together with the associated literature data has been supplied as supportive material (Appendix S1). Data is presented according to the following scheme: species name; threat category, species protection; LR: literature data (with synonymous names used by cited authors); PP: data included in the Bieszczady National Park Protection Plan (2011; unpublished); UP: unpublished data from the years 2008–2013. Notes: additional information and comments (doubts, misconceptions, errors, etc.); description of the taxa new to Poland.

For PP and UP records, localities, phenological information, habitats, and substrata have been reported. In the LR section, the paper by Gierczyk et al. [16] has been cited only if this paper provided original data.

**Discussion**

The available literature on the fungal diversity in the Polish Bieszczady Mts has been reviewed and the new data collected by the authors in the years 2008–2015 is presented. The current list of macrofungi species identified in the Bieszczady Mts includes 1,377 species, subspecies, varieties, and forms: 235 taxa of Ascomycota and 1,142 taxa of Basidiomycota (in the Bieszczady National Park 1,206 species: 196 of Ascomycota and
1,010 of Basidiomycota) comprising 30% of the total number of macrofungi known in Poland. A further 71 taxa are supported by dubious data (16 Ascomycota and 55 Basidiomycota). The number of taxa from the Bieszczady NP listed by Kujawa [130] is higher (1,304), because it includes some unpublished data on corticioid fungi collected by Dariusz Karasiński and some dubious data. This mycobiota richness makes the Bieszczady Mts the third richest region in macrofungi in Poland, after Białowieża Primeval Forest (ca. 2,000 known taxa) [131] and Kampinos NP (ca. 1,600 taxa) [132]. In comparison, 1,233 taxa of macrofungi have been reported from the Slovakian Poloniny National Park [133–135]. Unfortunately, the mycological data for Uzhanian National Park (Ukraine) are not available. The official website of the Nature Reserve Fund of Ukraine mentions a total of 66 fungal species from Uzhanian National Park [136]. Many taxa recorded in the Bieszczady Mts are very valuable (Tab. 1). Four species (Hericium erinaceum, Hydnellum concrescens, Corticium polygonioide, and Skeletocutis odora) are strictly protected and another 14 (Bondarzewia mesenterica, Clavariadelphus pistillaris, Gomphus clavatus, Hericium alpestre, H. coralloides, Inonotus obliquus, Morchella conica, M. esculenta, Pychoverpa bohemia, Sparassis brevipes, Strobilomyces strobilaceus, Tremiscus helvelloides, Verpa conica, and Xerocomus pelletieri) are partially protected in Poland. Two hundred and ninety taxa recorded in the Bieszczady Mts are red-listed comprising 30% of all species in the Polish red list. In the current paper, 219 taxa not previously known to be present in the Bieszczady Mts are reported. They include 38 taxa (nine Ascomycota and 29 Basidiomycota) hitherto not known in Poland: Agrocybe gibberosa, Auriporia aurulenta (Fig. 7), Bolbitius varicolor, Bulgariella pulla (Fig. 8), Chaetosphaerella phaeostroma, Clitocybe subspadicea, Clitopilus passeckerianus (Fig. 9), Cortinarius anomalus var. subcaligatus, C. fervidus, C. flexipes var. inolens, C. sylvae-norvegicae, Cudoniella temuviisora (Fig. 10), Entoloma bisporigerum, E. olorinum, E. polius var. parvisporigerum, E. sericeoides, Galerina caulocystidiata, Gymnopilus josserandii, Hymenoscyphus subferrugineus, Hypholoma olivaceotinctum, Inocybe

| Tab. 1 | Rare, protected, and red-listed macrofungi in the Bieszczady Mts. |
|-------|-------------------------------------------------------------|
| Strictly protected species | Ascomycota | Basidiomycota | Total |
| Partially protected species | 0 | 4 | 4 |
| Red-listed species | 15 | 275 | 290 |
| Category Ex | 0 | 4 | 4 |
| Category E | 1 | 82 | 83 |
| Category V | 4 | 63 | 67 |
| Category R | 10 | 115 | 125 |
| Category I | 0 | 11 | 11 |
| Taxa rare in Poland (known from up to three contemporary localities) | 44 | 147 | 191 |
| Taxa known in Poland only from the Bieszczady Mts | 20 | 57 | 77 |
| Taxa with locus classicus in the Bieszczady Mts | 0 | 2 | 2 |
| Taxa not mentioned Polish on checklists of fungi | 18 | 139 | 157 |
| Indicator species of nature value of beech forests follow on European scale [137] | 0 | 16 | 16 |
| Species of special interest [139] | 3 | 59 | 62 |
| Class A | 1 | 4 | 5 |
| Class B | 0 | 29 | 29 |
| Class C | 2 | 26 | 28 |
Fig. 7 Basidiomata of *Auriporia aurulenta* A. David, Tortić & Jelić from the Bieszczady Mts (Sep 5, 2011). Photography by K. Kujawa.

Fig. 8 Ascomata of *Bulgariella pulla* (Fr.) P. Karst. from the Bieszczady Mts (Aug 8, 2009). Photography by G. Domian.
Fig. 9  Basidiomata of *Clitopilus passeckerianus* (Pilát) Singer from the Bieszczady Mts (Aug 1, 2011). Photography by K. Kujawa.

Fig. 10  Ascomata of *Cudoniella tenuispora* (Cooke & Massee) Dennis from the Bieszczady Mts (Jun 2, 2015). Photography by T. Pachlewski.
queletii, Laccaria altaica, Lactarius romagnesii, L. rostratus, Mycena epipterygia var. atriviscosa, M. epipterygia var. candida, M. polygramma f. candida, Octavianina lutea, O. mutabilis (Fig. 11), Pachyella violaceaconigr, Panaeolus papilionaceus var. capitato-cystis, Phaeocollybia jennyae (Fig. 12), Psathyrella almerensis, Pyrenopeziza inornata, Scutellinia torrentis (Fig. 13), Tricholoma basirubens, Tricholomopsis flammula, Vibrissea decolorans (Fig. 14). This makes Polish Bieszczady Mts a hot spot of fungal diversity, in both Poland and Europe. Sixteen taxa listed on the list of indicators of the nature value of beech forests in Europe [137] have been found in the Bieszczady Mts. This is higher than that reported for other beech forests of European importance including Poloniny National Park (Slovakia) [134,138], the forest with the hitherto highest value published (15). The number of the taxa designated as species of special interest (SSI), which are selected from wood-inhabiting fungi in European beech forests [139], is also high (62). Reported values of this parameter for other beech forests in Europe are lower varying from 23 (Poloniny National Park, Slovakia) to 51 (UNESCO World Natural Heritage Kellerwald-Edersee National Park, Germany) [134]. Many SSI species observed in the Bieszczady Mts are common within this area, e.g., Hericium coralloides or Dentipellis fragilis. Many other taxa selected by Slovakian mycologists as species of special interest during the study of beech forests in that country (e.g., Antrodiella pallescens or Perenniporia narymica) [140] have also been found in the Polish Bieszczady Mts. One should note that the evaluation systems proposed by Christensen et al. [137] and Ódor et al. [139] were based on Western and Southern European data, therefore need to be tested and adjusted for Central European forest conditions. The Bieszczady Mts are the only place where 77 taxa are found in Poland making it an important refuge of macrofungi. Another 114 taxa reported in the Bieszczady Mts are extremely rare in Poland and have only been found in three or fewer localities in this country. Its unique ecosystems (e.g., Alnus viridis communities or postpasture habitats) must be protected to preserve the macrofungi richness of this mountain range. The unusually high availability of forest biomass in the Bieszczady Mts region [141], the most important parameter determining the presence of many rare, wood-inhabiting fungi, should be especially emphasized. It is difficult to indicate the regions in the Bieszczady Mts with the highest mycological value. The most interesting findings have been made on the northern slopes, in humid stream valleys, e.g., Hylaty Valley or Górna Solinka Valley, and in places with high concentrations of large, dead tree trunks on the forest floor. One could expect further

Fig. 11 Basidiomata of Octavianina mutabilis E. Bommer & M. Rousseau from the Bieszczady Mts (Nov 29, 2011). Photography by P. Chachuła.
valuable findings, as many fungal groups (genera *Russula* and *Cortinarius*, corticioid and hypogeous fungi, small Ascomycota) are still undercollected and underrepresented on the current species lists. Moreover, although field work has been conducted throughout the Bieszczady Mts, the greatest emphasis has been placed on the study of the Bieszczady National Park mycobiota. In consequence, the northern and western parts of the Bieszczady Mts have only been cursorily studied. Analysis of data on the Poloniny NP has showed that 462 species of macrofungi known from the Slovakian part of the Eastern Carpathians have not been observed yet in the Bieszczady Mts. Some of these, for example fungi inhabiting old oak trees and logs (e.g., *Buglossoporus quercinus*), are unlikely to be collected in the Bieszczady Mts due to the absence of suitable habitats and substratum; however, most of these 462 taxa probably also grow on the Polish side of the border. Almost 1,840 macrofungi taxa are known from the Polish and Slovakian parts of the East Carpathian Biosphere Reserve.

Fig. 12  Basidioma of *Phaeocollybia jennyae* (P. Karst.) Romagn. from the Bieszczady Mts (Aug 2, 2011). Photography by K. Kujawa.
Fig. 13  Ascoma of *Scutellinia torrentis* (Rehm) T. Schumach. from the Bieszczady Mts (Aug 2, 2011). Photography by K. Kujawa.

Fig. 14  Ascomata of *Vibrissea decolorans* (Saut.) A. Sánchez & Korf (Jun 3, 2010). Photography by T. Pachlewski.
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Supplementary material

The following supplementary material for this article is available at http://pbsociety.org.pl/journals/index.php/am/rt/suppFiles/am.1124/0:

Appendix S1 Macrofungi of the Bieszczady Mountains – list of species.

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