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Results of the research of higher fungi in Khan Khentey, Mongolia

Результаты исследований высших грибов в Хан-Хентей, Монголия

Kherlenchimeg Nyamsuren [1], Otgontsetseg Davaanyam [2], Ganbaatar Kherlenchimeg [3], Urgamal Magsar [1]

Херленчимэг Нямсурен [1], Отгонцецег Даваанам [2], Ганбатор Херленчимэг [3], Ургамал Магсар [1]

[1] Botanic Garden and Research Institute, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.
E-mails: nkherlenchimeg@gmail.com; urgaa2007@gmail.com
[1] Ботанический сад-институт, Монгольская академия наук, Улан-Батор, Монголия
[2] Institute of Geography and Geoecology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia. E-mail: otgondn@gmail.com
[2] Институт географии и геоэкологии, Монгольская академия наук, Улан-Батор, Монголия
[3] Department of Biology, School of Arts and Sciences, National University of Mongolia, Ulaanbaatar, Mongolia.
E-mail: kherlenchimegganbaatar@gmail.com
[3] Кафедра биологии, Научная школа, Монгольский государственный университет, Улан-Батор, Монголия

Summary. There were recorded currently 631 species of higher fungi belonging to 237 genera, 88 families, 31 orders of 2 phyla in Mongolia. In 2008–2021, we collected approximately 600 samples of higher fungi in Khentey region including Khuder, Eruu (Minj), Mandal (Khonin nuga) of Selenge province; Shariingol of Darkhan-Uul province; Mungunmorit of Tuv province and Batshireet, Umnudelger of Khentii province. As a result of study, there were recorded 479 species of higher fungi belonging to 201 genera, 79 families, 27 orders of 2 phyla in Khentey mountain taiga region, and it covers 75.9 percent of all higher fungi species distributed in Mongolia. In addition, we were newly added 12 species of higher fungi in species composition of Khentey mountain taiga region; moreover, it was also new to Mongolian mycoflora since 2000. Among them 4 species were referred to families Mycenaceae, Pleurotaceae and one new species belongs to each of the following families Agaricaceae, Auriscalpiaceae, Russulaceae, Suillaceae, Entolomataceae, Hygrophoraceae, Boletaceae, Tricholomataceae.

Key words. Distribution, higher fungi, Khentey mountain taiga region, rarity, species composition.

Резюме. В настоящее время в Монголии зарегистрированы 631 вид высших грибов, ринадлежащих к 237 родам, 88 семействам, 31 порядку из 2 типов высших грибов. Мы работали примерно с 600 образцами грибов, собранными в сомоне Худере, Эрее (Миндж), Мандале (Хонин нуга) из Селенгинский аймак, сомон Шарынгол из Дархан-Уула аймак, сомон Мунгунморьт из Центрального аймака и сомон Батширет и Умнуделгер Хэнтийского аймака в 2008, 2011, 2013, 2015, 2020, 2021 гг. В горно-таежном районе Хэнтей зарегистрировано 479 видов высших грибов, принадлежащих к 201 роду, 79 семействам, 27 порядка 2-х типов и охватывает 75,9 % всех видов высших грибов, распространенных в Монголии. В результате наших исследований с 2000 г. к микофлоре Хэнтейнского горно-таежного района и Монголии добавилось 12 видов грибов. Из них зарегистрировано по 2 вида из семейств Mycenaceae и Pleurotaceae и по 1 виду из семейств Agaricaceae, Auriscalpiaceae, Russulaceae, Suillaceae, Entolomataceae, Hygrophoraceae, Boletaceae и Tricholomataceae.

Ключевые слова. Видовой состав, высшие грибы, распространение, редкость, Хэнтейский горно-таежный район.

Introduction. Fungi is independent kingdom of living creatures, and they play important role to cycle of substance and energy movement in biosphere including decomposition of plant debris, organic minerals, even mountain rock as well as humus formation in soil. They have specific characteristics that cause many diseases to human, plants and animals, while they can be nutrition to human and animals. Besides, these mushroom fungi deserve a big attention because there are some edible species among them, that are produced commercially and in huge volumes.

Subkingdom of higher fungi, macromycota (Dikarya), consist of 2 phyla including Basidiomycota and Ascomycota. Nowadays, 631 species of higher fungi were registered in Mongolia, while over 10 thousand all

over the world. Total of 116 species of them are edible, 427 are inedible and 32 are poisonous (Kherlenchimeg, Burenbaatar, 2017).

Uranchimeg G. had conducted solely taxonomy research of higher fungi in Mongolia until 1998 and further she founded herbarium collection contained about 500 specimens belonging to over 250 species of higher fungi in Laboratory of the Flora and Plant Systematics, Botanic Garden and Research Institute, Mongolian Academy of Sciences (Kherlenchimeg et al., 2016). As a result of her research work, 38 species of Agaricoid, gilled mushrooms, and19 species of woody fungi were discovered from cedar-larch forest (*Pinus sylvestris–Larix sibirica*), larch forest (*Larix sibirica*) and taiga of Khentey and Khuvsgul province, Mongolia (Uranchimeg et al., 1981) as well as recorded newly 5 species belonging to Hygrophoraceae family in Khentey mountain (Uranchimeg et al., 1987). In addition, as a result of study on species composition of higher fungi in Mongol-Daguur and Khentey phyto-geographical regions of Mongolia, 264 species of higher fungi belonging to 126 genera were discovered (Uranchimeg, 1984). Therefore, 87 species belonging to 13 genera of higher fungi recorded newly in Mongolian mycoflora. Total of 68 species of edible mushroom were found at forest and steppe in Khentey mountain (Uranchimeg, 1987).

We conducted detailed study on distribution and resource of edible and medicinal fungi In Khentey region. Moreover, natural and harvesting resources of commonly distributed 7 species. Harvesting resource was determined as 1.2 t for *Clitocybe gibba*, 0.5 t for *Russula emetic*, 8 t for *Laethiporus sulphureus* and 4.5 t for *Suillus grevillei* (Kherlenchimeg et al., 2011).

Determining species composition of higher fungi in buffer zone of Khan Khentey protected area can become scientific basis to conduct further research including local fungus flora, their taxanomy, distribution and resource, and utility for food and medicine, lastly natural conservation for local mycoflora and rare species. We aimed to determine correctly nomenclature of higher taxa including phylum, class, and order in accordance with international classification system followed worldwide (Garnica et al., 2016). We aimed to following objectives:

1. To collect specimens of higher fungi distributed in buffer zone of Khan Khentey protected area as field research,
2. To integrate results of higher fungi research recorded in Khentey region based on prior research works and own work,
3. To determine taxonomical background and to analyse habitat and life form.

Materials and methods. We used 219 specimens belonging to 142 species collected before 1997 in Khentey region. These specimens are stored in the Database of the Mongolian Fungi flora and Herbarium (UBA) in Laboratory of the Flora and Plant Systematics, Botanic Garden and Research Institute, Mongolian Academy of Sciences.

In addition, researchers of Laboratory of the Flora and Plant Systematics have conducted fieldwork to detect species composition, distribution and resources of higher fungi in Khentey region since 2008. During this work, over 700 specimens of higher fungi had been collected; hence, our own investigations were also used in this paper. Fieldworks were mainly carried out as the route observation from June to September.

Study area. Research has been fulfilled in 2008–2020 in Khan Khentey protected area and its buffer zone. Protected area is situated across 9 sub-provinces of 3 provinces of Mongolia such as Batshireet, Omnodelger, Murun of Khentii province; Mungunmorit, Erdene, Batsumber of Tuv province; Mandal, Eruu, Khuder of Selenge province (Figure 1). We collected samples of higher fungi from following location:

- 35 specimens belonging to 12 species at near Khonin nuga, Zuunkharaa, Selenge province in 2008;
- 210 specimens at Shariingol, Darkhan-Uul province in 2008, 2011;
- 186 specimens (about 60 species belong to 40 genera, 6 order, 3 class) at Mungunmorit, Tuv province in 2013, 2015;
- 197 specimens (about 150 species, 16 family of higher fungi) at Batshireet, Umnudelger, Khentii province in 2014;
- 69 specimens collected from Khuder, Eruu, Selenge province in 2020;
- 32 specimens collected from gap of the Jargalant, Minj, Selenge in 2021.

We used relevant literatures, articles and methodologies to identify species of fungi specimens (Vaselieva, 1973; Vasser, 1985; Vasilkov, 1973; Kovalenko, 1989; Matheny, et al. 2006; Moncalvo, et al. 2000; Serjanina, 1984; Fedorov, 1983). Identification of some order need the following peripheral literatures. For example, **Nergui (1978)** for Botryosphaeriales, Mycosphaerellales, Pleosporales; **Puntsag (1974, 1976)** for Erysiphales, Pucciniales, Ustilaginales, Urocystidales, Microbotryales; **Dörfelt, Bumžaa (1986)** for Geastrales; **Matheny et al. (2006), Kühner (1980), Holstetter et al. (2002), Hopple, Vilgalys (1999), Moncalvo et al. (2000), Pilát**

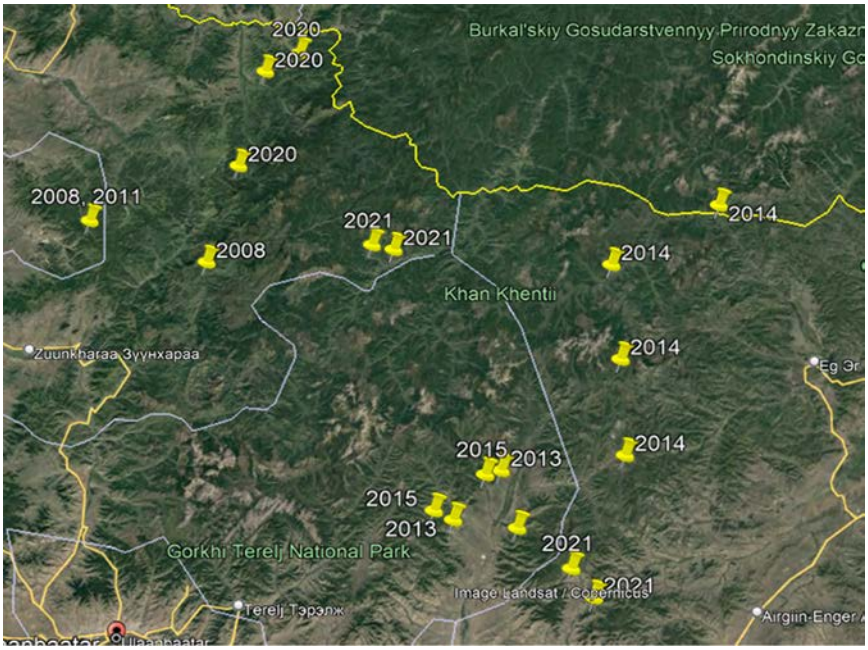

Fig. 1. The map of observations.

(1972, 1981), Petrov (1981, 1999) for Agaricales, Russulales, Boletales, separately.

We followed classification described by researchers such as **Kovalenko (1985); Malisheva (2007); Krillova (2007); Desyatova (2008); Perevedentseva (1999)** in order to separate by life form and feeding activity and determined ecological characteristic for each species based on their mostly distributed habitat.

We used MBS-10 binocular (14x) to illustrate morphology of caps, gills and stipes, and also using MBU-15 microscope (10x, 40x) to determine structure of basidium, spores and cysts.

In order to study taxanomy, species composition and diversity of Basidiomycota, we observe and record features of fungi, then collect samples. We noted definitely geographical position of collected area, forest type and species composition in forest, and vegetation cover, soil type and gravel occurence, growing characteristic or distribution type (forming fairy ring, growing in consecutive manner as a row, scattered or clustered, forming mycorrhiza, sedentary etc.) during field work.

Easily changed characteristics (mucus, surface colour and its transformation under sunshine, smell, taste, colour of hynemophores, colour alteration, change in colour after cutting off or push hyphae, whether latex secretion or not, its characteristic) of fungi after cut off were noted immediately on growing habitat or were noted when collected samples were new and wet. After drying out fungi samples, separated by species and then put in an envelope marked by etiquette. We explored microstructure of fungi using microscope and important characteristics for taxanomy including hymenophore and spores in it, basidium, number of spores on basidium, basidiol, surface of spores, spore size, number and size of oil droplet in spore, colour and shape of cystidia etc.

Research results and discussion. Nowadays, 631 species of higher fungi belong to 237 genera, 88 families, 31 orders, 2 phyla were recorded in Mongolia (Kherlenchimeg, Burenbaatar 2017).

We observed that 479 species of higher fungi belonging to 201 genera, 79 families, 27 orders, 2 phyla distributed in Khentey mountain taiga region and 217 (34 %) species of higher fungi were Agaricoid. Recorded species in Khentey region covers 79.9 % of total species of higher fungi registered in Mongolia.

Table 1

Number of species, genera, family of higher fungi distributed in Khentei region

Order name	Number of family	Number of genera	Number of species
Pezizales	3	3	5
Rhytismatales	1	1	1
Erysiphales	1	3	13
Xylariales	2	3	3
Hypocreales	1	1	1
Tremellales	1	1	1
Pucciniales	7	11	**59**
Ustilaginales.	1	1	5
Urocystidales	1	1	1

Table 1 (continuation)

Order name	Number of family	Number of genera	Number of species
Microbotryales	1	1	1
Tilletiales	1	1	2
Chantharellales	2	2	2
Phallales	1	1	1
Auriculariales	1	3	5
Gomphales	2	2	2
Geastrales	1	1	3
Hymenocheatales	4	17	29
Russulales	6	11	**52**
Amylocorticiales	1	1	1
Polyporales	6	**40**	**54**
Gloeophyllales	1	1	4
Sebacinales	1	1	1
Thelephorales	1	2	3
Trechisporales	2	2	2
Boletales	6	13	30
Agaricales	**23**	**76**	**197**
Dacrymycetales	1	1	1
27 order	**79 families**	**201 genera**	**479 species**

We registered newly 13 species of higher fungi in Khentey mountain taiga region as well as in Mongolian mycoflora. Among them 4 species were referred to families Mycenaceae, Pleurotaceae and one new species belongs to each of the following families Agaricaceae, Auriscalpiaceae, Russulaceae, Suillaceae, Entolomataceae, Hygrophoraceae, Boletaceae, Tricholomataceae (Table 2).

Table 2

New species recorded to fungus flora of Mongolia not only Khentei region since 2000

Species name	Recorded region number	Reference
1. *Auriscalpium vulgare* Gray	2	Kherlenchimeg, Burenbaatar (2016, 2017)
2. *Russula vesca* Fr.	2	Kherlenchimeg, Burenbaatar (2008, 2016)
3. *Boletus edulis* Bull.	2	Kherlenchimeg, Burenbaatar (2016); Kherlenchimeg (2017)
4. *Leccinum versipelle* (Fr. & Hők) Snell	1, 2	Petrov 1981, 1999; Kherlenchimeg, Burenbaatar (2016, 2017)
5. *Suillus granulatus* (L.) Roussel	1, 2, 4, 5	Kherlenchimeg (2009); Kherlenchimeg, Burenbaatar (2016, 2017)
6. *Coprinus comatus* (O.F. Müll.) Pers.	2, 3, 4	Kherlenchimeg (2008); Kherlenchimeg, Burenbaatar (2017)
7. *Hygrocybe coccinea* (Schaeff.) P. Kumm.	2	Kherlenchimeg, Burenbaatar (2016, 2017)
8. *Lepista panaeolus* (Fr.) P. Karst.	2	Kherlenchimeg, Burenbaatar (2008, 2017)
9. *Pleurotus cornucopiae* (Paulet) Rolland	2	Sunjidmaa (2009); Kherlenchimeg, Burenbaatar (2008, 2017)
10. *P. pulmonarius* (Fr.) Quel.	2	Sunjidmaa (2009); Kherlenchimeg, Burenbaatar (2008, 2017)
11. *Xeromphalina cauticinalis* (Fr.) Kühner & Maire	2	Kherlenchimeg, Burenbaatar (2008, 2017)
12. *X. tenuipes* (Schwein.) A.H. Sm.	2	Kherlenchimeg, Burenbaatar (2008, 2017)

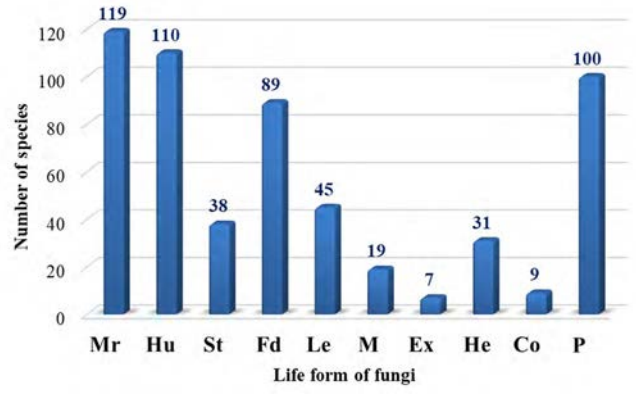

Fig. 2. Life form types of fungi: Mr – mycorrhizal, Hu – Humus saprotrophic, St – Litter saprotrophic, Fd – Grow on fallen trunk, Le – Tree saprotrophic, M – Grow on moss, Ex – Grow on dung of cattle and midden, He – Grow on plant debris, Co – Grow on cortex of living tree, P – Parasitic.

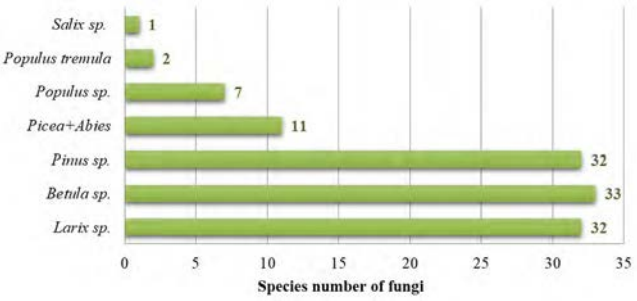

Fig. 3. Number of fungi species forming mycorrhiza with trees.

Growing substrate of fungi is very important factor on species diversity for Agaricoid. Higher fungi can have classified into two groups – biotroph and saprotroph based on growing substrate and their methods of obtaining nutrients (life form). Biotrophs depend only on living plants for their nutrition, cannot live without living hosts whereas saprotrophs depend entirely on dead or decaying organic matter for their nutrition (Lewis, 1973). Biotrophs include parasite and mycorrhizal fungi while saprotrophs include ecological groups such as xylotroph, mycotroph, coprotroph, bryotroph, herbotroph, carbotroph (Kovalenko, 1989). We clasiified all species recorded in Khentey region based on life form and growing substrate (Figure 2).

Mycorrhizal fungi (Mr) improve tree uptake of potassium, calcium, phosphorous and poorly dissolving substances while trees provide organic matters like carbon, vitamins to fungi. When trees are sorely deficient in phosphorous and nitrogen, mycorrhiza can improve uptake of some substances. Most of higher fungi species or 119 species (24.8 %) distributed in Khentey region can form symbiotic mycorrhizal association with tree (all species of order Boletales, all species of genera Russula, Lactarius, Amanita, Cortinarius, Tricholoma). Birch, larch, pine trees can form more commonly mycorrhiza with more species of fungi, for example, it was 33 fungi species for birch, 32 for larch, 32 for pine separeately. Tree species forming mycorrhiza can become key identification when determine fungi species, for instance, *Leccinum scabrum* form mycorrhiza with only birch trees, *Suillus grevillei, Hygrophorus lucorum* with only larch trees, *Gomphidius glutinosus* with spruces, *Suillus granulatus, Gomphidius maculatus* with only pine trees.

We recorded 89 species (*Crepidotus mollis, Mycena maculata, Xeromphalina campanella* etc.) or 18.5 % of saprotrophic fungi grew on fallen trunks and woody debris (**Fd**) and 31 species (*Mycena epipterygioides, Auriscalpium vulgare* etc.) or 6.4 % grew on grass debris and litter (He). In addition, 38 species (species of *Clitocybe, Gymnopus, Cystodermella* genera, *Volvopluteus gloiocephalus*) of litter saprotroph (**St**) were recorded (it is 7.9 % of total species composition). Lignin and cellulose were exposed by decomposing abilities of this type of fungus (St), consequently it become important resource of energy. Total 110 species (species of *Macrolepiota, Agaricus, Lepista, Conocybe, Melanoleuca, Agrocybe* genera) were humus saprotroph (**Hu**) and it covered 22.9 % of total species composition. They mainly distributed in the edge of the forest, forest and forest steppe zone. They enrich soil by nitrogen and so forth vegetation productivity become high and form fairy ring.

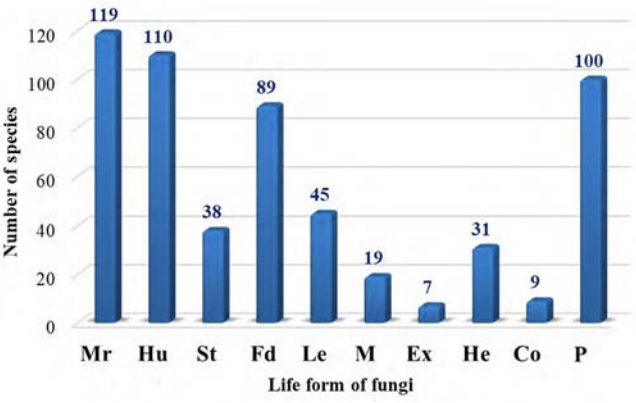

Fig. 4. Life form analysis of fungi distributed in Khentey region.

We observed 19 species (*Lichenomphalia, Pholiota, Collybia, most species of Mycena, Hygrocybe acutoconica, Tephrocybe inolens*, etc.) of bryotroph fungi (**M**) and they grow on moss and grass litter in Khentey region. Rather, 45 species (species belong to *Pleurotus, Pluteus, Gymnopilus, Hypholoma, He-*

ricium genera) of xylotroph (**Le**) were recorded and it covers 9.3 % of total species in Khentey, they grow on hardwood, branches and roots of living trees. In addition, 9 species grow on cortex of living tree (**Co**) were investigated.

Total 100 species of parasitic group including plant pathogenic fungus were recorded as well as Agaricoid named *Armillaria mellea*, which had taken organic matter from host plant or tree until dead and break down. Finally, 7 species of coprotroph (Ex) such as *Panaeolus semiglobatus, P. papilionaceus, Coprinellus micaceus* were investigated in Khentei region and they grow on cattle dung and livestock manure.

Total of 286 species were occurred in mixed forest (*Betula sp.–Pinus sibirica–Larix sibirica forest, Larix sibirica–Pinus sylvestris–Betula* sp. forest). In instance, *Leccinum versipelle, Boletinus asiaticus, Suillus sibiricus, S.tridentinus, Agaricus silvicolae-similis, Cystodermella cinnabarina, Amanita crocea, A.pantherina, A.phalloides, A.vaginata, Cortinarius torvus, Laccaria proxima, Ampulloclitocybe clavipes, Cuphophyllus virgineus, Lichenomphalia alpine, L.umbellifera, Inocybe brunnea, Gymnopus hariolorum, G.impudicus, Marasmius siccus, Megacollybia platyphylla, Mycetinis scorodonius, Rhodocollybia butyracea, Hohenbuehelia petaloides, Hypholoma fasciculare, Lactarius rufus, L.subdulcis, Russula aeruginea, R.cyanoxantha, R.claroflava, R.fragilis* were more common.

We recorded 29 species such as *Chroogomphus rutilus, Gomphidius glutinosus, Suillus bovinus, S. granulatus, Agaricus sylvaticus, Cortinarius bivelus, Hygrophorus hypothejus, Gymnopus perforans, Mycena galericulata, Xeromphalina campanella, Gymnopilus liquiritiae, G. penetrans, Auriscalpium vulgare, Lactarius deliciosus, L. resimus, Russula emetic, R. xerampelina* grow in coniferous forest.

We recorded 27 species including *Russula virescens, R. sanguinaria, Lactarius uvidus, L. torminosus, Tricholoma sulphureum, Pholiota aurivella, Psathyrella candolleana, Pleurotus ostreatus, Hygrocybe acutoconica, Laccaria amethystine, Cortinarius trivialis, Leccinum aurantiacum* grow in deciduous forest (birch–grove, willow thicket etc.).

We detected 27 species including *Agaricus arvensis, A. campestris, Macrolepiota excoriate, M. procera, Panaeolus semiglobatus, P. semiovatus, P. papilionaceus, Agrocybe pediades, A.praecox, Melanoleuca cognata* grow in the edge of forest, forest steppe and steppe.

69.9 percent, in other word 335 species of 479 species recorded in Khentey region are only distributed in this region (*Mycetinis scorodonius, Rhodocollybia butyracea, Crepidotus mollis, Inocybe asterospora, Ampulloclitocybe clavipes, Chrysomphalina chrysophylla, Cortinarius alboviolaceus, Amanita alba, Boletus edulis, Chalciporus piperatus* etc.). It can consider that species composition, distribution and resource of higher fungi in Khentei region is relatively well studied.

In recent times, Mongolians have recognized the benefit of edible mushrooms; furthermore, amount of mushrooms in main food supply has increased. Therefore, it is necessary to conduct research work to distinguish edible and inedible mushrooms and to formulate method for gathering and associated with proper processing such as safe store, cook food and prevention from poisoning.

In according to feeding importance of fungi distributed in Khentei region: 107 species (*Pleurotus ostreatus, Boletus edulis, Leccinum aurantiacum, L. scabrum, Lactarius torminosus Clitocybe gibba, Suillus grevillei, Russula cyanoxantha, R.emetic, R.exalbicans, Marasmius oreades etc.*) were edible mushrooms with good qualities and widely used to cook and store as ensiling and salting way. 19 species including *Suillus cavipes, S. viciduus, Spathularia flavida, Phyllotopsis nidulans, Cortinarius torvus, Neolentinus lepideus* were III, IV level of mushroom quality, in other words, it is available to use in little when fruitbody is young or new. In addition, 26 species were edible when spores are not produced (white coloured inside), as well as in 2 species only cap is edible because of stack is very hard to eat. In addition, we determined 7 species used in both medicine and food. All of 286 species were inedible and 6 species of inedible but not determined as poisonous were recorded.

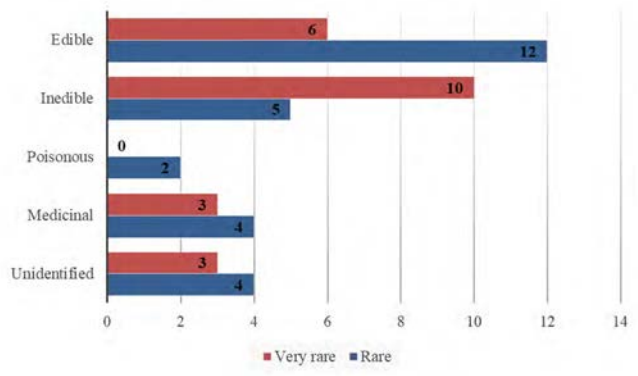

Fig. 5. Species number of edible and poisonous mushrooms.

In addition, we recorded 4 species of deadly poisonous, 23 species of poisonous, and 2 species of psychotoxic mushroom.

We recorded that 18 species of edible, 15 species of inedible, 2 species of poisonous and

7 species of medicinal and 7 species of unidentified higher fungi in Khentei region is classified into rare and very rare according to conservation status (Figure 5).

We assessed all 479 species distributed in Khentey region using international IUCN Red List assessment criteria (IUCN, 2012). According to result, 42 species were categorised in more rare categories, in other words, 5 (1 %) species were classified as Critically Endangered (CR), 10 (2 %) as Endangered (EN), 27 (5.6 %) as Vulnerable (VU), separately. Moreover, 11 species (2 %) were categorized as Near Threatened (NT), 37 (7.7 %) as Least Concern (LC), 388 (81 %) as Data Deficient and one as Not Applicable (NA).

Table 3

Threat status of higher fungi

IUCN Red List Categories		Number of species in Mongolia	Number of species in Khentey
Critically Endangered	CR	6	5
Endangered	EN	13	10
Vulnerable	VU	32	27
Near threatened	NT	11	11
Least Concern	LC	40	37
Data Deficient	DD	526	388
Not Applicable	NA	3	1
Total		631	479

Most species of higher fungi were categorized as DD in Red List. Data Deficient is therefore not a category of threat. It means there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. It indicated that more research is required on classification, diversity, distribution, resource and status of fungi in Khentey. It has possibility that future research will show that threatened classification is appropriate.

Conclusion

1. Of 479 species belonging to 201 genera, 79 families, 27 orders, 2 phyla of higher fungi were recorded in Khentey mountain taiga region during our research study, 217 (34.3 %) species were Agaricoid. We added 12 new species to Mongolian mycoflora and Khentey region.
2. We recorded that 119 species form mycorrhiza that live together with woody plants. 110 species of saprotroph grow on soil, 38 species of saprotroph grow on forest litter and 120 species grow on woody debris. This result showed that fungi can form mutualistic relationship with woody plants and saprotrophic fungi decompose lignine, cellulose, than it becomes resource of energy. Consequently, fungi play a huge role in ecosystem.
3. Of total 42 rare species according to IUCN Red list assessment, 5 species categorized as critically endangered, 10 as endangered, 27 as vulnerable in Khan Khentey protected area. There were recorded 388 species as data deficient in this area, it showed further study on diversity, taxanomy, distribution, natural resource of fungi is required inevitably in Khentey region and further, develop conservation plan is suggested.
4. We observed 107 species of edible, 7 species of medicine, 4 species of deadly poisonous, 23 species of poisonous, 286 species of inedible of higher fungi. We consider that there is need to conduct research focused on higher fungi for household use, especially in recognition and collection properly, and it has necessity to formulate handbook intended to public awareness for conservation.

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