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THUIDIUM THERMOPHILUM (THUIDIACEAE, BRYOPHYTA), A NEW SPECIES FROM KAMCHATKA

THUIDIUM THERMOPHILUM (THUIDIACEAE, BRYOPHYTA), НОВЫЙ ВИД С КАМЧАТКИ

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Abstract

A new species, *Thuidium thermophilum* Czernyadjeva, is described from thermal fields of the Kamchatka Peninsula (Russian Far East). Its diagnostic characters, description, illustrations, and differentiation from the other species of Thuidiaceae are provided. *Thuidium thermophilum* differs from all other *Thuidium* species in unipinnate branching, which suggests a closer relationship to *Rauiella*, but DNA analysis (nrITS and *trn*L-F) suggest closer relation to *Thuidium*.

Резюме

С полуострова Камчатка описан новый вид *Thuidium thermophilum* Czernyadjeva. Вид растет на термальных полях. Приводятся описание и рисунки вида, обсуждаются его отличия от других видов семейства. *Thuidium thermophilum,* в отличие от всех прочих видов рода *Thuidium*, имеет одиножды перистое ветвление, что ставит его ближе к роду *Rauiella*, однако анализ последовательностей ДНК (ядерной ITS и хлоропластной *trn*L-F) показывает более близкое родство непосредственно с родом *Thuidium*.

In the course of identification of specimens collected by Olga Chernyagina from central Kamchatka, Verkhnie Kireunskie thermal springs (Sredinny Range, Alnej Mountain), a species of Thuidiaceae was encountered that was impossible to identify according to both East Asian (Watanabe, 1972; Noguchi, 1991, Touw, 2001) and North American (Lawton, 1971) treatments. Plants were found in only one valley, but in six places, always near thermal springs. Later, in 2006 the same species was collected again by Chernyagina, in Rusakovskie thermal springs in northern Kamchatka, ca. 210 km from the former locality. The latter collection gave us confidence that the unusual combination of characters is not simply an environmentally induced mutation of one of a widespread *Thuidium* species. Therefore the new species is described here.

Thuidium thermophilum Czernyadjeva, species nova. Fig. 1.

Caulis prostratis, elongatis, simpliciler pinnato, 5 cm longis; paraphyllia numerosa; folia imbricata, humida erecti-patentia, valde concava, 0.6–0.8 mm longa, 0.4–0.5 mm lata, breviter acuminata, ovato-cordata, nervo ad medium evanida, cellulae medianae rotundae-rhomboideae, (6–)8–12(–17) μm, multipapillosae. A *Thuidium glaucinum* cauli unipinati differt.

Typus. Russia, Kamchatka, 56°45'N, 160°00'E, Jugum Sredinny, Montis Alnei, ripa Kirevna, Verkh-

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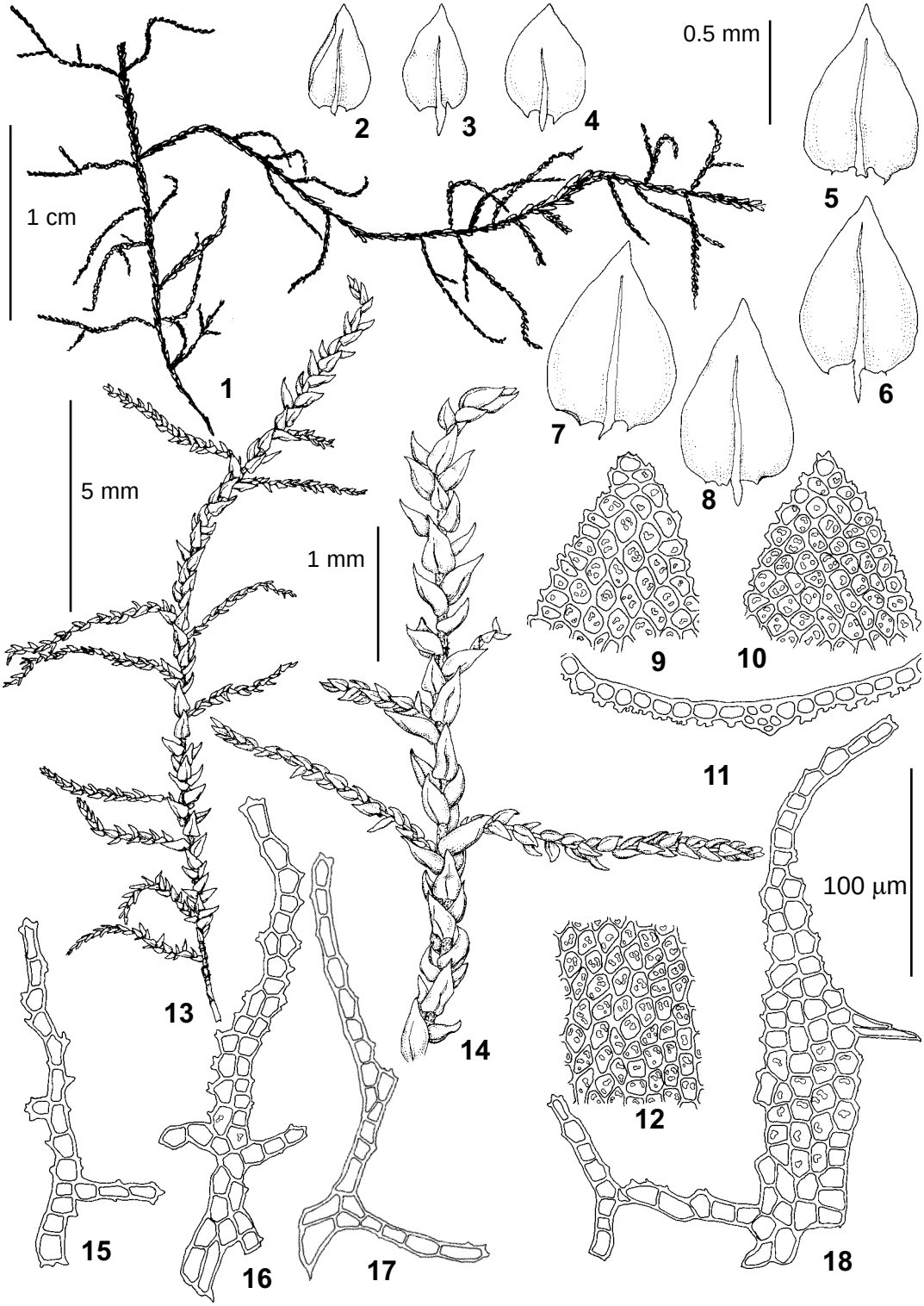

Fig. 1. *Thuidium thermophilum* Czernyadjeva (from holotype): 1 – unipinnate stem with sympodial shoot; 2-4 – branch leaves; 5-8 – stem leaves; 9-10 – upper leaf cells; 11 – leaf transverse section; 12 – mid-leaf cells; 13-14 – habit; 15-18 – paraphyllia. Scale bars: 1 cm – for 1; 5 mm – for 13; 1 mm – for 14; 0.5 mm – for 2-8; 100 μm – 9-12, 15-18.

nie Kireunskie fontes thermales, ad terra humida. Leg. 8.Aug.1991, O.A. Chernyagina (holotypus LE, isotypi MHA, VLA). Paratypus: Kamchatka, 58°30'N, 161°15'E, Jugum Sredinny, ad ripe Rusakova, Rusakovskie fontes thermales. Leg. 28.VIII.2006, O.A. Chernyagina & V. Kirichenko (VLA, MHA).

Plants yellowish to brownish green, in loose tufts. Stems to 5 cm long, unipinnate, not regularly branching, sometimes with 1–2(–3) secondary branches on a few primary branches; primary branches 2–5 mm long, more rarely to 7 mm long, secondary branches 1–2 mm long; with central strand; paraphyllia numerous on stem, not or slightly branched, mostly uniseriate, more rarely bi- to pluriseriate and rarely to ovate-lanceolate (when proximal to branch primordia), few on branches, especially near the bases of secondary branches; cells of paraphyllia papillose on both sides above the cell centre, upper cell of paraphyllia multipapillose. Stem leaves loosely arranged or at places more densely arranged, loosely appressed to erect when dry, erect-spreading when wet, slightly keeled to concave, triangular-ovate, ± shortly acuminate, 0.6–0.8 mm long, 0.4–0.5 mm broad; margins serrulate, plane; costa single, 25–30 μm wide at leaf base, 1/3–3/4 the leaf-length; median laminal cells rounded-quadrate, ovate to rectangular or rhomboidal, (6–)8–12(–17) μm, with (1–)2–3 stellate papillae at back, smooth on the upper surface, cell walls ~2 μm thick, ± uniform, rarely ± collenchymatous, practically without pores; apical cells with papillae; branch leaves crowded, imbricate, ovate to broadly ovate or triangular-ovate, 0.4–0.5 mm long, 0.25–0.35 mm broad, cells with (1–)2–3 papillae, apical cell with 2–3 papillae. Fig. 1.

Type: Russia, Far East, Kamchatka Peninsula, 56°45'N, 160°00'E, alt. 500 m. Sredinny Range, Alnej volcano, valley of Kirevna River, Verhnekireunsky hot springs, thermal field, grass-mosses association, 8.VIII.1991, *Chernyagina, #9* (holotype LE, isotype MHA). Paratype: Kamchatka Peninsula, Koryaksij Autonomous District, Karaginsky District, 58°30'N, 161°15'E, Rusakova (Sanovayam) River, Rusakovskie hot springs, 28.VIII.2006, *Chernyagina & Kirichenko s.n.* (VLA, MHA).

Other studied specimens (all collections of O.A .Chernyagina in LE): same locality as the type: (1) thermal field, *Agrostis scabra* –mosses association, 5.VIII.1991, *Chernyagina, #1*; (2) thermal field, *Agrostis scabra* –mosses association, 11.VIII.1991, *Chernyagina, #5*; (3) thermal field, *Fimbristilis ochothensis*–mosses association, 8.VIII.1991, *Chernyagina, #6*; (4) fern-dominated *Alnus* stand, 2.VIII.1991, *Chernyagina, #2, #8;* (5) bank of cold stream in thermal field, 26.VIII. 2001, *Chernyagina, #1*.

The main diagnostic character of the new species is the combination of unipinnate, moderately regularly branching of the stem, 2–3 stellate papillae over the cell lumina and ± shortly acuminate stem leaves.

This combination suggests two possible close relatives of the new species. On one hand, *Thuidium thermophilum* could be close to species of *Rauiella*: the American *Rauiella scita* (P. Beauv.) Reimers and the Japanese *R. fujisana* (Paris) Reimers are similar to *T. thermophilum* in having unipinnate branching and stellate papillae. Stem leaves of *R. fujisana* are acuminate with non-papillose uppermost cells, but the apical part of branch leaves is very similar to that found in stem (and branch) leaves of the new species. On the other hand, leaf shape and stellate papillae in our new species are very similar to the East Asian *Thuidium glaucinum* (Mitt.) Bosch & Lac. and *T. subglaucinum* Cardot, but these species are regularly bipinnate.

The latter character is an important one for generic circumscription in the family. Although some authors still keep unipinnate *Abietinella* and *Pelekium* in *Thuidium*, the most recent worldwide revision segregated *Thuidium* as a genus with bi- or tripinnate branching (Buck & Crum, 1990; Touw, 2001).

* * *

Facing the difficulty with the generic placement of the new species, we undertook a comparison of the nuclear ITS and chloroplastic *trn*L-F sequences to resolve this dilemma.

Materials and Methods

Protocols of DNA extraction and sequencing were the same as described in Budyakova & al. (2003).

Phylogenetic analysis was undertaken for ITS data only, as *trn*L-F data were available for few

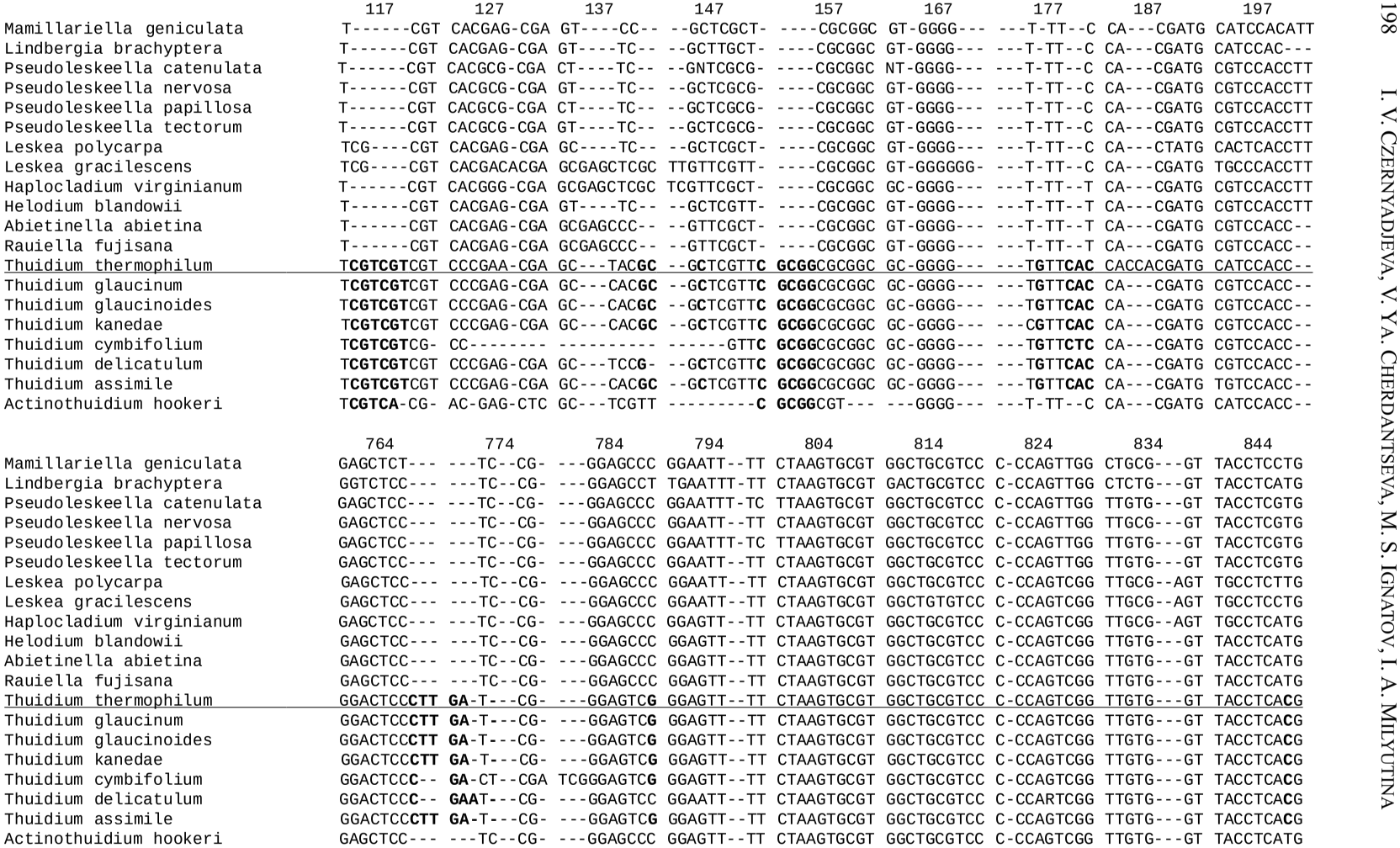

Fig. 2. Parts of alignments of ITS 1 and ITS 2. Positions are numbered according to the whole alignment of 30 species used in the phylogenetic analysis. Indels common for *Thuidium thermophilum* Czernyadjeva with the other species of *Thuidium* and thus demonstrating its closer relationship to *Thuidium* than to *Rauiella* are boldfaced.

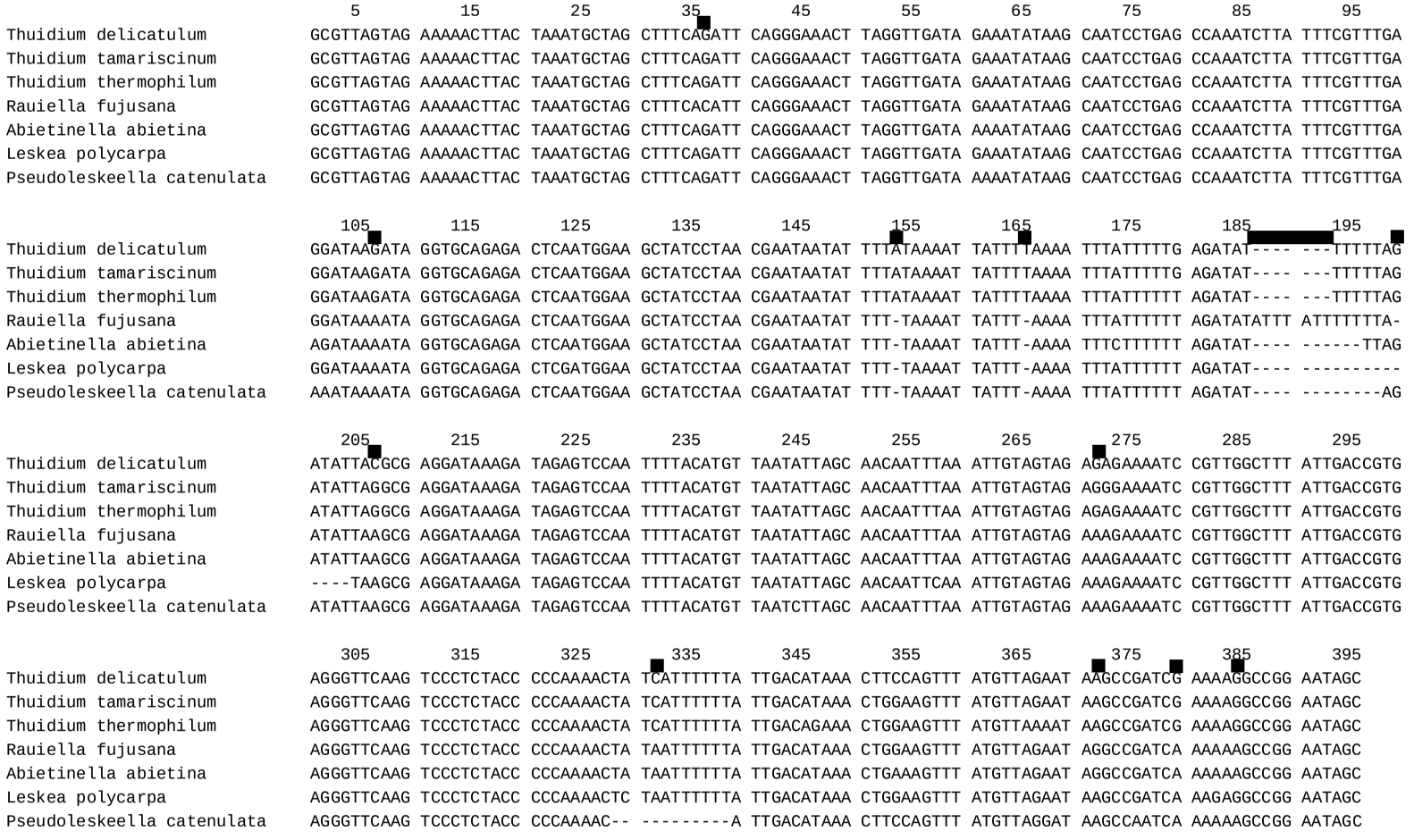

Fig. 3. Alignment of trnL-F region. Positions common for *Thuidium thermophilum* Czernyadjeva with the other species of *Thuidium* and thus demonstrating its closer relationship to *Thuidium* than to *Rauiella* are boldfaced.

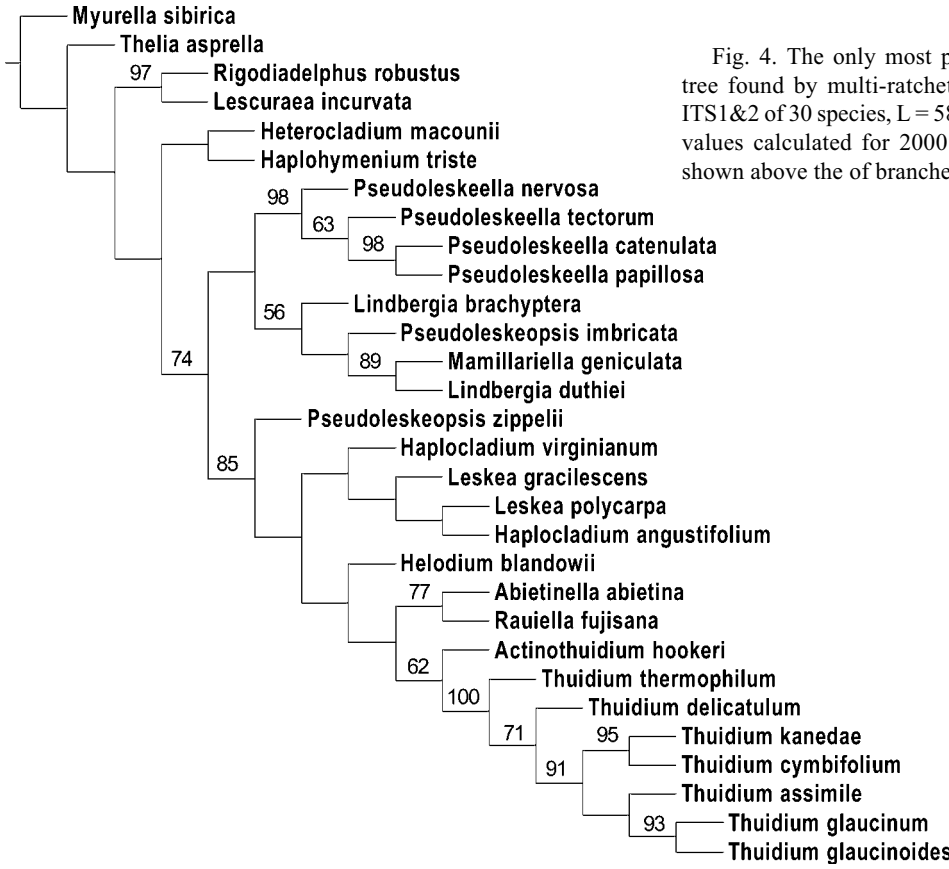

Fig. 4. The only most parsimonious tree found by multi-ratchet analysis of ITS1&2 of 30 species, L = 584. Jackknife values calculated for 2000 replications shown above the of branches.

Thuidium species. However *trn*L-F data are shown in the alignment of a small set of seven species (*Thuidium thermophilum* plus two *Thuidium*, *Rauiella fujisana*, and two species of the Leskeaceae and Pseudoleskeellaceae).

For ITS, the set was built for 30 taxa of Thuidiaceae and Lesceaceae in traditional circumscription. Voucher information is in Table 1. Part of this alignment showing characteristic indels (Fig. 2) comprise a somewhat reduced set of the whole alignment of 30 species used for the Nona analysis.

Parsimony analysis was done with Nona (Goloboff, 1994) within the Winclada (Nixon, 1999a) shell. A multi-ratchet option with five sequential parsimony ratchet runs was used (Nixon, 1999b). Each replicate included 200 iterations and 10 trees were held in memory during the iterations. During ratcheting 25% of the characters were resampled. Jackknifing with 2000 replications including 10 searches and 20 starting trees in each replication was performed with Nona within the Winclada shell.

RESULTS

Results of the simple comparison of substitutions of nuclear loci (Fig. 2) and chloroplastic ones (Fig. 3), as well as parsimony analysis (Fig. 4) obviously support a much closer relationship of the new species to *Thuidium*, than to *Rauiella*, although within *Thuidium* its position was found the most basal in the *Thuidium*-clade (Fig. 4). At the same time the position within *Thuidium*-clade received 100% jackknife support.

DISCUSSION

The present analysis was not specifically focused on which group of *Thuidium* the new species belongs. We mostly took the data available from GenBank and from our previous analysis of Leskeaceae in its traditional circumscription (Gardiner & al., 2005). However the fact that *T. thermophilum* is a member of *Thuidium* is quite obvious from the simple comparison of substitutions of nuclear (Fig. 2) and chloroplastic (Fig. 3) loci, as well as from the parsimony analysis (Fig. 4).

Table 1. Genbank accessions numbers

Species	ITS1	ITS2	trnL-F
Abietinella abietina (Hedw.) M. Fleisch.	AY009802	AY009802	AY009850
Actinothuidium hookeri (Mitt.) Broth.	AY568547	AY568547	
Haplocladium angustifolium (Hampe & Muell. Hal.) Broth.	AY528884	AY528885	
Haplocladium virginianum (Brid.) Broth.	AF168160	AF168160	
Haplohymenium triste (Cesati) Kindb.	AY568551	AY568551	
Helodium blandowii (F. Weber & D. Mohr) Warnst.	AY009803	AY009803	
Heterocladium macounii Best	AY528894	AY528895	
Lescuraea incurvata (Hedw) Lawt.	AY693661	AY693661	
Leskea gracilescens Hedw.	AF176277	AF176277	
Leskea polyacrpa Hedw.	AY528889	AF516151	AY527134
Lindbergia brachyptera (Mitt.) Kindb.	AY695760	AY695763	
Lindbergia duthie Broth.	AF516170	AF516153	
Mamillariella geniculata Laz.	AY693652	AY693652	
Myurella sibirica (Muell. Hal.) Reim.	AJ288415	AJ277227	
Pseudoleskeella catenulata (Brid. ex Schrad.) Kindb.	AY695747	AF516154	AY683578
Pseudoleskeella nervosa (Brid.) Loeske	AF516167	AF516152	
Pseudoleskeella papillosa (Lindb.) Kindb.	AY695753	AY695784	
Pseudoleskeella tectorum (Funck ex Brid.) Kindb. ex Broth.	AF516168	AY695776	
Pseudoleskeopsis imbricata (Hook. & Wilson) Ther.	AY693653	AY693653	
Pseudoleskeopsis zippelii (Dozy & Molk.) Broth.	AY695749	AY695777	
Rauiella fujisana (Paris) Reimers	AY568546	AY568546	AY683600
Rigodiadelphus robustus (Lindb.) Nog.	AF516166	AF516156	
Thelia asprella (Schimp.) Sull. & Lesq.	AJ288413	AJ277225	
Thuidium assimile (Mitt.) A.Jaeger	AJ416442	AJ416442	
Thuidium cymbifolium (Dozy & Molk.) Dozy & Molk.	AY568542	AY568542	
Thuidium delicatulum (Hedw.) Bruch et al.	AF176278	AF176278	AF161132
Thuidium glaucinoides Broth.	AY568544	AY568544	
Thuidium glaucinum (Mitt.) Bosch & Sande Lac.	AY568540	AY568540	
Thuidium kanedae Sakurai	AY568541	AY568541	
Thuidium tamariscinum (Hedw.) Bruch et al.			AF023770
Thuidium thermophilum Czernyadjeva	EF368013	EF368013	EF368012

This fact is important in terms of circumscription of the genus: unipinnate branching may occur in this genus, although indeed it is rare. Two hypotheses for further studies can be tested: either *T. thermophilum* is really basal to all bipinnate species, being an ancient relic surviving in "greenhouse conditions" near one of few natural heating systems. Otherwise the loss of ability to produce bipinnate branching would be a secondary reduction, being a result of "relaxation" due to growth in a "resort" habitat. The additional molecular studies may be able to choose among these two (plus others?) possibilities.

In the type locality, *Thuidium thermophilum* grows in the Kirevna River valley (flowing from the slopes of Alnei Volcano in the Sredinny Range). This valley forms a deep canyon across the plateau; its cliffy banks are formed by acidic andezite, basaltic lava rocks and volcanic tuffs. Thermal springs occur along several km in the valley; its water has a basic reaction and a low H_2S content (see details in e. g., Lyubimova, 1961; Pijp, 1937). The immediate surroundings of the springs lack any vegetation, but more distantly wet meadows and swamps develop. *Thuidium thermophilum* was found three (of five) times on warm (or hot) and wet soil, where the vegetation is primarily composed of mosses: *Aulacomnium palustre* (Hedw.) Schwägr., *Climacium dendroides* (Hedw.) F. Weber & D. Mohr, *Entodon rubicundus* (Mitt.) A. Jaeger, *Pleurozium schreberi* (Brid.) Mitt., and *Dicranum leioneuron* Kindb. Among the frequent vascular plants are *Agrostis scabra* Willd., *Artemisia opulenta* Pamp. and *Fimbristylis ochotensis* (Meinsh.) Kom. Once *Thuidium thermophilum* was

collected on soil in a fern-dominated *Alnus* forest, once on rocks along a cold stream, but in both cases these localities were quite close to hot springs. Interestingly, *Entodon rubicundus*, more southern in distribution, grows in Kamchatka only near thermal springs, as well as the Kamchatkan endemic, *Fimbristylis ochothensis*.

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