Bull. Natl. Mus. Nat. Sci., Ser. B, 42(1), pp. 1–18, February 22, 2016

Lichens of Mikura-jima Island, Izu Islands, Central Japan

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(Received 15 November 2015; accepted 22 December 2015)

Abstract Lichens of Mikura-jima Island, Izu Islands, central Japan, were investigated. As the results of taxonomic study, 78 taxa (77 species and 1 variety) were recognized from the island. Among them, *Graphis mikuraensis* Y. Ohmura & M. Nakan. is described as a new species. *Lepraria finkii* and *L. lobificans*, based on the emended species concept, were confirmed to occur in Japan. A new combination, *Rhabdodiscus inalbescens* (Nyl.) Frisch is proposed. Phytogeographic discussion is made for the listed species. The lichen flora of Mikura-jima Island is characterized by the high percentage of pantemperate element species together with tropical and subtropical species. A remarkable range extension is noted for *Physma radians*, and the find represents the northernmost locality for this pacific element species. *Nipponoparmelia laevior*, which was common before 1981, may have become extinct or drastically reduced in this island during the past 30 years.

Key words: inventory, lichenized fungi, new record, new species, phytogeography, taxonomy.

Mikura-jima Island, one of the Izu Seven Islands, is located ca. 200 km south of central Tokyo in the Pacific Ocean (N33°52′, E139°36′); its shape is roughly circular (ca. 5 km in diameter), and the highest peak, Mt. Oyama, reaches 851 m elev. (Fig. 1). This island is a stratovolcano but the last volcanic activity occurred around 6,000 years ago.

The annual precipitation is more than 5,000 mm (Hamada, 2001). Monthly average temperatures range from 5.4℃ to 24.1℃ at 300 m elev., 3.8℃ to 23.0℃ at 500 m elev., and 2.1℃ to 21.7℃ at 720 m elev. (Hoshino *et al.*, 1995).

The natural vegetation is dominated by *Castanopsis sieboldii* (Makino) T.Yamaz. & Mashiba and *Machilus thunbergii* Sieb. & Zucc. at lower elevations, *Castanopsis sieboldii* at higher elevations, and a mixed forest with *Trochodendron aralioides* Sieb. & Zucc., *Daphniphyllum macropodum* Miq., *Cerasus speciosa* (Koidz.) H. Ohba, *Dendropanax trifidus* (Thunb.) Makino, etc. in the plateau at the top of the island (Ohba, 1971).

From a phytogeographic point of view, it should be noted that subalpine species of vascular plants [e.g. *Maianthemum dilatatum* (A.W. Wood) A.Nelson & J.F.Macbr., *Viburnum furcatum* Blume ex Maxim., and *Rhus ambigua* Lavall. ex Dipp. (Ohba, 1971)] and bryophytes [e.g. *Pleurozium schreberi* (Brid.) Mitt., *Campylopus fragilis* (Bridel) Bruch & Schimper, *Dicranum viride* var. *hakkodense* (Cardot) Takaki, and *Gollania varians* (Mitt.) Broth. (Higuchi and Nishimura, 2001)] have been reported from this island, although they are usually found at elevations higher than 1,000 m in central Honshu and/

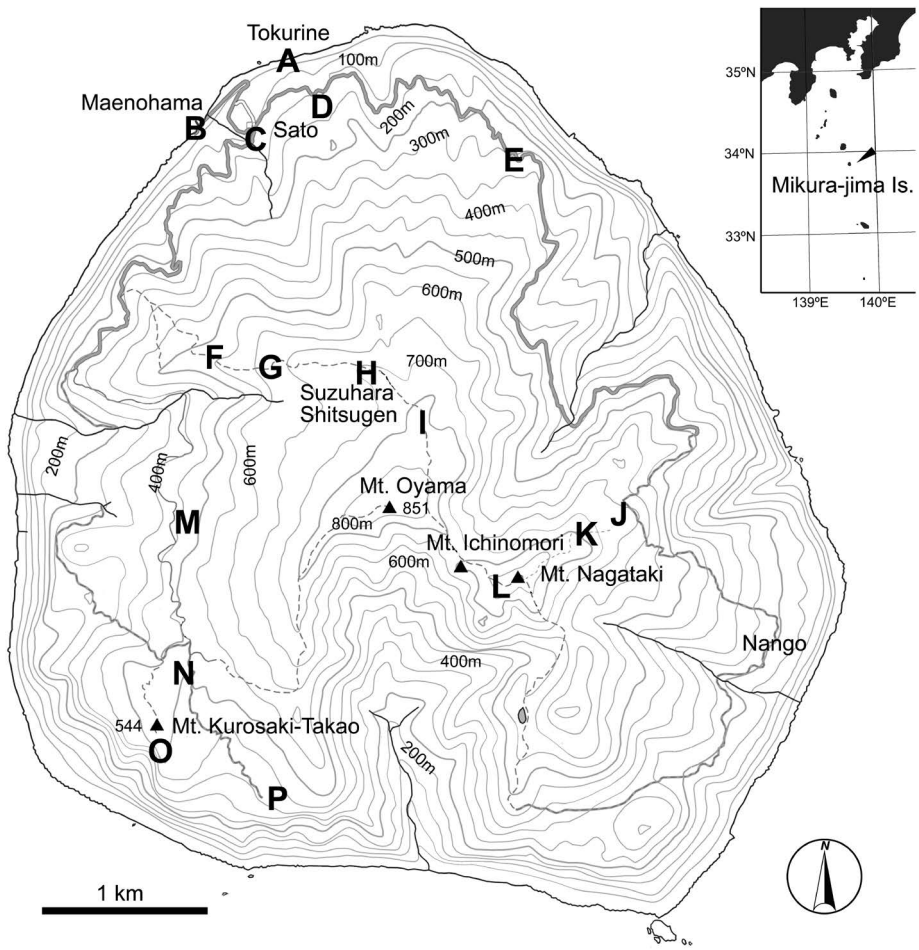

Fig. 1. Map showing investigated sites in Mikura-jima Island.

or on Hokkaido, northern Japan.

The lichen flora of Mikura-jima Island has been poorly known and the first report of 11 species was made by Asahina (1955) based on the specimens collected by Dr. Hisashi Tsuyama in August 1952. Subsequently two additional species and one variety were reported in the area (Asahina, 1969; Kashiwadani and Kurokawa, 1981; Miyawaki, 1988). As part of an environmental educational project organized by the Mikurajima-mura Administration and the Nonprofit Organization Nature center risen (Mikura Museum, 2012), the first author had opportunities to collect lichens in 2010 and 2011. The purpose of this study was to inventory the lichens of Mikura-jima Island and discuss the species from the phytogeographic point of view.

Materials and Methods

Field surveys were carried out by the first author on 20–22 December 2010 and 10–13 November 2011. The locality data of the collection sites are shown in Fig. 1. In addition to the first author's collections, herbarium specimens from Mikura-jima Island housed in the National Museum of Nature and Science (TNS) were also used for the present study. A total of 154 specimens were examined. All collections examined are housed in TNS unless otherwise indicated.

Morphological observations were made using Olympus SZ61 and BX51 microscopes on hand

cuttings mounted in GAW solution (glycerin : ethanol : water = 1 : 1 : 1). Chemical substances were detected by means of thin layer chromatography (TLC) with solvents A, B′ and/or C (Orange *et al.*, 2010).

Collection sites

The data for collection sites (A–P) investigated by the first author and the collection dates (d/m/y) are provided as below. The symbols (A–P) correspond to those in Fig. 1. For the specimens of other collectors, the locality information on the specimen labels is shown in the list of species.

A: Tokurine, Mikura-jima Island, 20 m elev. 10/11/2011
B: Maenohama, Mikura-jima Island, 10 m elev. 21/12/2010
C: Inane Shrine, Sato, Mikura-jima Island, 100–120 m elev. 22/12/2010 or 12, 13/11/2011
D: Sato, Mikura-jima Island, 165 m elev. 13/11/2011
E: ca. 1.5 km E of Sato, Mikura-jima Island, 300 m elev. 13/11/2011
F: along the trail, NW slope of Mt. Oyama, Mikura-jima Island, 550 m elev. 21/12/2010 or 10/11/2011
G: along the trail, NW slope of Mt. Oyama, Mikura-jima Island, ca. 600 m elev. 21/12/2010
H: Suzuhara Shitsugen, N slope of Mt. Oyama, Mikura-jima Island, ca. 700 m elev. 21/12/2010
I: N slope of Mt. Oyama, Mikura-jima Island, ca. 750 m elev. 21/12/2010
J: along the Prefectural Road 223, NE slope of Mt. Nagataki, Mikura-jima Island, 680 m elev. 21/12/2010
K: NE slope of Mt. Nagataki, Mikura-jima Island, ca. 700 m elev. 21/12/2010 and 10/11/2011
L: around the top of Mt. Nagataki, Mikura-jima Island, ca. 800 m elev. 21/12/2010
M: along the Prefectural Road 223, W slope of Mt. Oyama, Mikura-jima Island, 510 m elev. 20/12/2010
N: along the trail of Mt. Kurosaki-Takao, Mikura-jima Island, ca. 500 m elev. 20/12/2010
O: Mt. Kurosaki-Takao, Mikura-jima Island, 530 m elev. 20/12/2010
P: Inane Shrine, Mt. Kurosaki-Takao, Mikura-jima Island, 370 m elev. 20/12/2010

Results and Discussion

Based on the results of taxonomic study and the reference information, 78 taxa (77 species and 1 variety) are reported from the present area. They are arranged alphabetically in the list below. Some specimens related to *Adelolecia*, *Enterographa*, *Lecanora*, *Lecidella*, *Ocellularia*, *Parmentaria*, *Porina*, *Strigula*, and unidentified specimens even at the genus level are not included in the list as further taxonomic revisions are required for their complete species-level identification.

Abbreviations for collectors are as follows. HM: H. Miyakawa, JH: J. Hasegawa, MH: M. Higuchi, NN: N. Nishimura, NS: N. Satomi, YD: Y. Doi, and YO: Y. Ohmura. Numeral following collector abbreviation indicates the collection number of MH, NN or YO.

List of species

1). **Agonimia pacifica** (H.Harada) Diedrich
Specimen examined. K: YO&HM-7815 (on bark of *Buxus microphylla* var. *japonica*).

2). **Caloplaca spodoplaca** (Nyl.) Zahlbr.
Specimen examined. B: YO&HM-7844 (on rock).

3). **Cladonia coniocraea** (Flörke) Spreng.
This species was already reported from the present area by Asahina (1955), and it was collected again during the current investigations.
Specimen examined. K: YO&HM-7825

(on trunk of *Buxus microphylla* var. *japonica*).

4). **Cladonia fruticulosa** Kremp.
Specimens examined. G: YO&HM-7838 (on humus). N: YO&HM-7781 (on soil).

5). **Cladonia furcata** (Huds.) Schrad.
Specimens examined. J: YO&HM7809 (over humus on sloping road-bank). K: YO-8447 (over humus on sloping road-bank).

6). **Cladonia kurokawae** Ahti & S.Stenroos
This species was reported as *C. conistea* (Delise) Asahina (nom. illegit.) by Asahina (1955), and it was collected again during the current investigations.
Specimens examined. C: YO-8542, 8543 (over mosses on stone wall; 12/11/2011).

7). **Cladonia macilenta** Hoffm.
Specimen examined. N: YO&HM-7803 (on decayed stump).

8). **Cladonia merochlorophaea** Asahina
Specimen examined. L: YO&HM-7829 (on decayed wood).

9). **Cladonia ochrochlora** Flörke
Specimens examined. I: YO&HM-7830 (on decayed wood). N: YO&HM-7798 (on trunk base).

10). **Cladonia ramulosa** (With.) J.R.Laundon
Specimens examined. A: YO-8534, 8537 (on soil). C: YO-8541 (on soil on stone wall; 12/11/2011). J: YO&HM-7808, 7813 (on soil on sloping road-bank).

11). **Cladonia scabriuscula** (Delise) Leight.
Specimens examined. F: YO&HM-7839 (on soil; 21/12/2010). J: YO&HM-7807 (on soil on sloping road-bank).

12). **Cladonia submultiformis** Asahina
Specimen examined. J: YO&HM-7810 (on soil on sloping road-bank).

13). **Coccocarpia erythroxyli** (Spreng.) Swinscow & Krog
Specimens examined. C: YO&HM-7855 (on rock; 22/12/2010). L: YO&HM-7828 (on bark of *Pittosporum tobira*). N: YO&HM-7786 (on bark of *Ternstroemia gymnanthera*).

14). **Coccotrema porinopsis** (Nyl.) Imshaug ex Yoshim.
Specimens examined. H: YO&HM-7836 (on bark of *Prunus* sp.). I: YO&HM-7833 (on decayed wood).

15). **Collema japonicum** (Müll.Arg.) Hue
Specimen examined. C: YO&HM-7851 (on rock; 22/12/2010).

16). **Collema subflaccidum** Degel.
Specimens examined. C: YO-8548 (on stone wall; 12/11/2011), YO&HM-7847 (on bark of *Cinnamomum camphora*; 22/12/2010).

17). **Cresponea proximata** (Nyl.) Egea & Torrente
Specimens examined. C: YO&HM-7848 (on bark of *Castanopsis sieboldii*; 22/12/2010). D: YO-8561 (on bark of *Castanea crenata*).

18). **Dibaeis sorediata** Kalb & Gierl
Specimen examined. F: YO-8532 (on soil; 10/11/2011).

19). **Diorygma soozanum** (Zahlbr.) M.Nakan. & Kashiw.
Specimens examined. C: YO&HM-7849 (on bark of *Castanopsis sieboldii*; 22/12/2010). D: YO-8564 (on bark of *Castanea crenata*).

20). **Enterographa leucolyta** (Nyl.) Redinger
Specimens examined. A: YO-8538 (on rock). B: YO&HM-7845 (on rock).

21). **Fissurina inabensis** (Vain.) M.Nakan. & Kashiw.
Specimens examined. P: YO&HM-7796 (on bark of *Camellia japonica*). Without detailed locality, YD-s.n. (on bark of *Camellia japonica*; 29/9/1978).

22). **Graphis assimilis** Nyl.
This species has been confused with *G. intricata* Fée by Japanese lichenologists (Kurokawa and Kashiwadani, 2006). However, *G. intricata* has elongate lirellae and shorter spores (15–30 μm), while *G. assimilis* has short lirellae and longer spores (30–45 μm) (Lücking *et al.*, 2009).
Specimens examined. D: YO-8568 pr.

maj.p. (on bark of *Ginkgo biloba*). N: YO&HM-7791 (on bark of decayed wood). Along the route between Sato and Mt. Oyama, 250 m elev., MH-10252 (on trunk; 14/7/1981).

23). **Graphis cleistoblephara** Nyl.

Specimens examined. D: YO-8565 (on bark of *Castanea crenata*), YO8568 pr.p., YO8569 (on bark of *Ginkgo biloba*).

24). **Graphis hossei** Vain.

This species was known as *G. connectens* Zahlbr. for Japanese lichenologists (Kurokawa and Kashiwadani, 2006), which was synonymized into *G. hossei* by Lücking *et al.* (2009).

Specimens examined. K: YO&HM-7816 (on bark of *Prunus* sp.). Along the route between Sato and Mt. Oyama, 440 m elev., MH-10294A (on tree trunk; 14/7/1981).

25). **Graphis japonica** (Müll.Arg.) A.W.Archer & Lücking

This species was reported in Nakanishi (1966), but later, it was treated as a synonym of *G. fissofurcata* Leight. by Nakanishi (1974). According to Lücking *et al.* (2009), *G. japonica* contains 2–4 spores per ascus while *G. streblocarpa* (Bél.) Nyl. (syn. *G. fissofurcata*) contains one spore per ascus. These features are considered to be stable and *G. japonica* should be treated as a distinct species.

Specimens examined. N: YO&HM-7789 (on bark of *Ternstroemia gymnanthera*), YO&HM-7782 (on bark of *Daphniphyllum teijsmannii*). O: YO&HM-7799 pr.maj.p. (on bark of *Castanopsis sieboldii*).

26). **Graphis longiramea** Müll.Arg.

This species has been known as *Graphis awaensis* Vain. by Japanese lichenologists (Kurokawa and Kashiwadani, 2006). It was placed in synonymy with *G. longiramea* (Lücking *et al.*, 2009). The specimens collected in Mikura-jima Island have spores with 62–90 × 11–12 μm and 15–20-locules, which agree with the feature of *G. longiramea*.

Specimens examined. I: YO&HM-7831 (on decayed wood). Along the route between Sato and Mt. Oyama, 350 m elev., MH-10281 (on decaying wood; 14/7/1981).

27). **Graphis mikuraensis** Y.Ohmura & M. Nakan., **sp. nov.**

Mycobank No.: MB 815136

Type: Japan, Izu Islands (Tokyo Metropolis): along the route between Sato and Ienosawa, Mikura-jima Island, on tree branch, elevation 500 m, 15 July 1981, *M. Higuchi 10474* (Holotype, TNS).

This species is similar to *Graphis gonimica* Zahlbr. and *G. sapii* Zahlbr. but differs from *G. gonimica* in the larger spore and from *G. sapii* in lirella morphology.

[Fig. 2]

Thallus corticolous, off-white to pale fawn, smooth, dull. Ascomata conspicuous, numerous, crowded, sessile, erumpent, simple or sparsely branched, straight or curved, terminally rounded, with lateral thalline margin, up to 4 mm long, 0.3–0.4 mm wide; labia black, entire, disc concealed, non-pruinose. Proper exciple completely carbonized, 40–90 μm thick at the base. Hymenium 92–142 μm thick, inspersed with oil droplets. Ascospores, 8 per ascus, colorless, transversely 10–14-locular, (35–)43.7 ± 5.7(–54) × (6.7–)8.1 ± 0.8(–10) μm (n = 18).

Chemistry: norstictic acid and an unidentified substance (R*f* class 2, same position with stictic acid, in solvent B' and R*f* class 1, lower than salazinic acid, in solvent C; brownish yellow after heating, 110°C, 10 min. with 10% H_2SO_4) as the major substances.

Etymology: the epithet refers to the type locality, Mikura-jima Island.

This species is characterized by 1) the erumpent lirellae with black, entire and concealed labia and lateral thalline margin, which are up to 4 mm and simple to sparsely branched with rounded terminals ["*lineola*-morph" sense Lücking (2009) and Lücking *et al.* (2009)] (Fig. 2A), 2) the completely

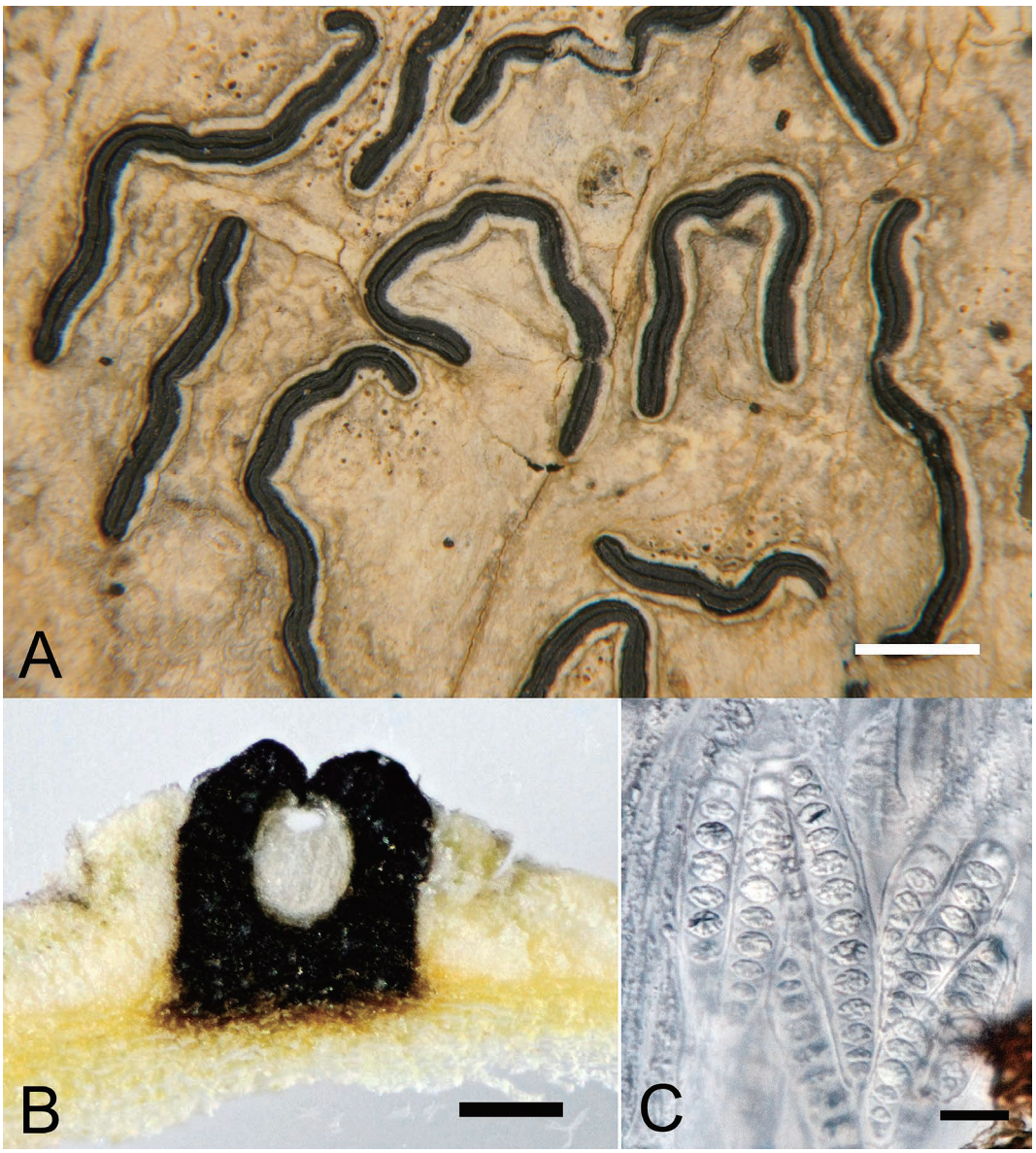

Fig. 2. *Graphis mikuraensis* Y.Ohmura & M.Nakan. (Holotype, TNS). A. Lirellae. B. Cross section of apothecium. C. Spores. Scales: A = 1 mm, B = 100 μm, C = 10 μm.

carbonized proper exciple (Fig. 2B), 3) the inspersed hymenium, 4) the transversely septate spores, 10–14-locular and 35–54 × 6.7–10 μm in length (Fig. 2C), and 5) the presence of norstictic acid.

Graphis mikuraensis resembles *G. gonimica* Zahlbr. (W-lectotype!) and *G. sapii* Zahlbr. (W-lectotype!), which were both described from China. However, *G. mikuraensis* is distinguished by lager spores than in *G. gonimica* [22–32 × 5–9 μm in length, 8 locules in Zahlbruckner (1932: 431)]; and by the *lineola*-morph lirellae with rounded terminals from *G. sapii* which has elongate and irregularly branched lirellae with acute terminals [“*deserpense*-morph” sense Lück-

ing (2009) and Lücking *et al.* (2009)] although the range of spore size and septation in *G. mikuraensis* entirely overlaps with that of *G. sapii* [40–44 × 6–7 μm in length, 12 locules in Zahlbruckner (1930: 40)]. It should be noted that Lücking *et al.* (2009) treated *G. sapii* as a synonym of *G. gonimica*, but we consider them as a distinct species according to the morphological differences mentioned above. *Graphis mikuraensis* is also similar to *G. desquamescens* (Fée) Zahlbr. which occurs in tropical and adjacent temperate regions including southern Japan. However, *G. mikuraensis* has a lateral thalline margin on the lirellae, while *G. desquamescens* lacks a lateral thalline margin ["*hossei*-morph" sense Lücking (2009)].

Graphis mikuraensis has been found only on Mikura-jima Island, and is possibly an endemic species to Japan. It was collected on tree bark at elevations between 440 and 500 m along a stream valley.

Specimen examined (except type). En route from Sato to Mt. Oyama, 440 m elev., MH-10294B (on tree trunk; 14/7/1981).

28). **Graphis scripta** (L.) Ach.

Specimens examined. D: YO-8563 (on bark of *Castanea crenata*). En route from Sato to Mt. Oyama, 140 m elev., MH-10227 (on trunk of *Camellia japonica*; 14/7/1981); the same locality, 250 m elev., MH-10252 (on trunk; 14/7/1981).

29). **Graphis tsunodae** Zahlbr.

Graphis tsunodae was described by Zahlbruckner (1916: 47) based on a specimen collected from Mt. Akagi in Japan. Nakanishi (1966) considered it as a synonym of *G. proserpens* Vain. However, Lücking *et al.* (2009) distinguished *G. tsunodae* from *G. proserpens* by having prominent sessile lirellae which lack thalline margins or have poorly developed thalline margins only at the base, while *G. proserpens* has erumpent lirellae with distinct lateral thalline margins. Moon *et al.* (2012) also reported *G. tsunodae* from Korea followed by Lücking *et al.* (2009). The features for the collections from Mikura-jima Island agree with *G. tsunodae*, although the occurrence of *G. proserpens* in Japan should be carefully revised by further research.

Specimens examined. L: YO&HM-7827 (on bark of *Pittosporum tobira*). O: YO&HM-7799 pr.p. (on bark of *Castanopsis sieboldii*). En route from Ohshimawake River to Nangou, 450 m elev., MH-10554 (on trunk of *Buxus microphylla* var. *japonica*; 16/7/1981).

30). **Hemithecium oshioi** (M.Nakan.) M.Nakan. & Kashiw.

Specimen examined. P: YO&HM-7794 (on bark of *Camellia japonica*).

31). **Herpothallon japonicum** (Zahlbr.) G.Thor

Specimen examined. E: YO-8560 (on bark of *Cryptomeria japonica*).

32). **Heterodermia diademata** (Taylor) D.D. Awasthi

Specimen examined. K: YO&HM-7814 (on bark of *Buxus microphylla* var. *japonica*).

33). **Heterodermia pandurata** (Kurok.) J.C.Wei

Specimens examined. Mt. Kurosaki-Takao-san, NS-s.n. (on twigs of *Buxus microphylla* var. *japonica*; 3/10/1963). Between Ienosawa River to Inane Shrine, 500 m elev., NN-8350 (on trunk; 17/7/1981).

34). **Hypotrachyna exsecta** (Taylor) Hale

This species was reported in Asahina (1955), and it was collected again during the current investigations.

Specimen examined. K: YO&HM-7821 (on bark of *Buxus microphylla* var. *japonica*).

35). **Hypotrachyna koyaensis** (Asahina) Hale

Specimen examined. K: YO&HM-7818, 7822 (on bark of *Buxus microphylla* var. *japonica*).

36). **Lecanora leprosa** Fée

D: YO-8567 (on bark of *Castanea crenata*).

37). **Lecanora mikuraensis** H.Miyaw.

This species was reported in Miyawaki (1988). It was collected at 380 m elev. without detailed locality (MH-10441, HIRO, not seen).

38). **Lecanora subimmergens** Vain.

Specimen examined. C: YO-8546 (on stone wall; 12/11/2011).

39). **Lepraria cupressicola** (Hue) J.R.Laundon

Specimen examined. C: YO-8554 (on bark of *Cryptomeria japonica*; 12/11/2011).

40). **Lepraria finkii** (de Lesd.) R.C.Harris, Evansia 2: 45. 1985.

Basionym: *Crocynia finkii* de Lesd., Bull. Soc. Bot. France 71: 334. 1924. Type: U.S.A., Iowa, Fayette Co., Fayette, 7. vii.1894, on moss and limestone, *B. Fink s.n.* (NY!, lectotype; COLO!, DUKE!, NY!, isolectotypes).

See description and illustrations in Lendemer (2013).

This species is characterized by the thick granular crustose thallus without crisped margins, and the presence of atranorin, zeorin, norstictic acid, stictic acid aggregate, and ± fatty acid.

The specimen from Mikura-jima Island agrees with the type specimens and description of Lendemer (2013). New to Japan.

Lepraria finkii has historically been confused with *L. lobificans* Nyl. which is a distinct and chemically variable species (Lendemer, 2013). As *L. finkii* was found together with *L. lobificans* Nyl. on Mikura-jima Island, the Japanese materials which were formerly identified as *L. lobificans* should be carefully revised in further researches.

Specimen examined. N: YO&HM-7800 (on bark of *Daphniphyllum teijsmannii*).

41). **Lepraria lobificans** Nyl., Flora 56: 196. 1873.

Type: France, Collioure, Pyrénées-Orientales, 4.vii.1872, on soil, *W. Nylander s.n.* (H-NYL-10864!, lectotype; H-NYL-10865!, isolectotype).

See synonyms in Lendemer (2013).

See descriptions and illustrations in Crespo *et al.* (2006), Saag *et al.* (2007), Tretiach *et al.* (2009) and Lendemer (2013).

This species is characterized by its thick granular thallus (*Leproloma*-like thallus) with crisped margins and the presence of atranorin and a chemosyndrome of stictic acid.

Seven chemotypes have been reported for the species (as *L. santosii*; Tretiach *et al.*, 2009): (1) atranorin, roccellic acid, zeorin, stictic and constictic acids; (2) atranorin, UV– vivid pink unknown, stictic and constictic acids; (3) atranorin, roccellic acid, stictic and constictic acids; (4) atranorin, roccellic acid, stictic and constictic acids (± or +), fumarprotocetraric or protocetraric acid; (5) atranorin, roccellic acid, protocetraric acid; (6) atranorin, roccellic acid, protocetraric acid, fumarprotocetraric acid; (7) atranorin, roccellic acid, fumarprotocetraric acid. The specimens collected from Mikura-jima Island are related to the "chemotype (1)", but they contain ± different fatty acid (not roccellic acid nor rangiformic acid).

Lepraria lobificans Nyl. in the sense of the type (Lendemer, 2013) is confirmed to occur in Japan. Previous occurrences of this species were in France and Canary Islands (Crespo *et al.*, 2006; Lendemer, 2013). The distribution is now extended to Japan but further careful examinations would expand the distribution. Given the difficulty involved in delimitation within *L. lobificans-L. isidiata* the identity of the Japanese populations should also be confirmed with molecular data in the future (Tretiach *et al.*, 2009).

Specimens examined. A: YO-8535 (on rock). C: YO-8557 (on stone wall; 12/11/2011).

42). **Leptogium azureum** (Sw.) Mont.

Specimens examined. C: YO&HM-7850, 7852 (on rock; 22/12/2010).

43). **Leptogium cyanescens** (Pers.) Körb.

Specimens examined. N: YO&HM-7788

(on bark of *Ternstroemia gymnanthera*), YO&HM-7801 (on bark of *Daphniphyllum teijsmannii*).

44). **Leptogium pichneum** (Ach.) Nyl.

This species was reported by Asahina (1955), but the voucher specimen was not found in TNS. In Japan, *Leptogium pichneum* is a common species at low elevations, and is usually found on stonewalls and tree trunks in humid habitats. It might occur in Mikura-jima Island, but was not collected during the current investigations.

45). **Lobaria discolor** (Bory) Hue

Specimens examined. H: YO&HM-7835 (on bark of *Trochodendron aralioides*). N: YO&HM-7787 (on bark of *Ternstroemia gymnanthera*).

46). **Lobaria retigera** (Bory) Trevis.

This species was reported in Asahina (1955), but the voucher specimen could not be found in TNS. *Lobaria retigera* is broadly distributed from Hokkaido to Ryukyu in Japan, and might occur in Mikura-jima Island. However, it was not found during the present investigations.

47). **Myelochroa entotheiochroa** (Hue) Elix & Hale

Specimens examined. C: YO&HM-7854 (on rock; 22/12/2010), YO-8547 (on stone wall; 12/11/2011).

48). **Nipponoparmelia laevior** (Nyl.) A.Crespo & al.

Although four voucher specimens are preserved in TNS, this species could not be found even at the same locality during this investigation.

Specimens examined. Between Ienosawa Riv. and Inane Shrine, ca. 500 m elev., NN-8349 (on trunk; 17/7/1981). Mt. Kurosaki-Takao-san, NS-s.n. (3/10/1963). Mt. Oyama (label as "Mt. Misen"), NS-s.n. (4/10/1963). Without detailed locality, NS-s.n. (7/10/1963).

49). **Normandina pulchella** (Borrer) Nyl.

This species was reported in Asahina (1955), and it was collected again during the current investigations.

Specimens examined. C: YO&HM-7853 (on mosses over rock; 22/12/2010). K: YO&HM-7823 (on bark of *Buxus microphylla* var. *japonica*).

50). **Ocellularia microstoma** (Müll.Arg.) Frisch

Specimen examined. I: YO&HM-7832 pr.maj.p. (on decayed wood).

51). **Ochrolechia parellula** (Müll.Arg.) Zahlbr.

Specimen examined. C: YO-8572 (on rock; 13/11/2011).

52). **Parmelinopsis minarum** (Vain.) Elix & Hale

Specimen examined. I: YO&HM-7834 (on decayed wood).

53). **Parmelinopsis spumosa** (Asahina) Elix & Hale

Specimens examined. C: YO&HM-7846 (on bark of *Cinnamomum camphora*; 22/12/2010), YO-8556 (on bark of *Cryptomeria japonica*; 12/11/2011). K: YO&HM-7817 (on bark of *Prunus* sp.), YO&HM-7826 (on trunk of *Trochodendron aralioides*).

54). **Parmotrema tinctorum** (Despr. ex Nyl.) Hale

Specimen examined. C: YO-8553 (on bark of *Cryptomeria japonica*; 12/11/2011).

55). **Peltigera dolichorrhiza** (Nyl.) Nyl.

This species was reported in Asahina (1955), but the voucher specimen could not be found in TNS. *Peltigera dolichorrhiza* is a common terricolous species in the temperate region and might occur in Mikura-jima Island. However, it could not be found during the current investigations.

56). **Peltigera pruinosa** (Gyeln.) Inumaru

Specimens examined. F: YO&HM-7840 (on humus with moss; 21/12/2010). J: YO&HM-7806, 7811 (over humus on sloping road-bank), YO&HM-7812 (over soil on sloping road-bank).

57). **Pertusaria multipuncta** (Turner) Nyl.

Specimen examined. C: YO-8539 (on stone wall; 12/11/2011).

58). **Phaeophyscia limbata** (Poelt) Kashiw.

This species is known as one of the commonest species of *Phaeophyscia* from lowland to montane regions in Japan, where it grows on tree bark with mosses or on rock with mosses (Kashiwadani, 1984). However, the taxonomic position of this taxon has been controversial and different treatments have been applied e.g. *P. hispidula* subsp. *limbata* by Poelt (1974) and Esslinger (1978), *P. limbata* by Kashiwadani (1984), Aptroot *et al.* (2002), Harada *et al.* (2004) and Kurokawa and Kashiwadani (2006), or as a synonym of *P. hispidula* var. *exornatula* by Moberg (1995). Although Kashiwadani (1984) excluded *P. hispidula* from the Japanese lichen flora, several of his subsequent publications reported *P. hispidula*, occasionally with *P. limbata*, from Japan (Kashiwadani *et al.*, 2000, 2002; Kurokawa and Kashiwadani, 2006; Shiba *et al.*, 2008; Ohmura *et al.*, 2012, 2014). Further taxonomic research based on molecular data in addition to the known morphological and chemical features are needed to solve the taxonomic problems among *P. hispidula* and related species. However, preliminary molecular data examined by Y. Ohmura seems to show that the Japanese populations of *P. hispidula* (s. lat.) have low genetic variation and form a different clade from those collected in other countries (unpublished data), which might support the observation of Kashiwadani (1984). Hence, this study tentatively applies the name of *P. limbata* to the species in the sense of Kashiwadani (1984).

Specimen examined. C: YO&HM-7858 (on concrete; 22/12/2010).

59). **Physciella melanchra** (Hue) Essl.

Specimen examined. C: YO&HM-7857 (on concrete; 22/12/2010).

60). **Physma radians** Vain.

This species was reported in Asahina (1955), and it was collected again during the current investigations.

Physma radians is widely distributed along the Pacific side of Honshu, Shikoku, Kyushu, and Ryukyu in Japan (Yoshimura, 1974), Philippines (Vainio, 1921), Taiwan (Wang-Yang and Lai, 1973) and Thailand (Magain and Sérusiaux, 2014). However, it seems to be relatively rare in Japan (Kashiwadani and Kurokawa, 1995). Mikura-jima Island is the northernmost locality for this species.

Specimen examined. C: YO-8540 (over mosses on stone wall; 12/11/2011).

61). **Porpidia albocaerulescens** (Wulfen) Hertel & Knoph

Specimen examined. C: YO-8551 (on stone wall; 12/11/2011).

62). **Pyrenula fetivica** (Kremp.) Müll.Arg.

Specimens examined. Without detailed locality, ca. 150 m elev., MH-32 (on trunks of *Shiia sieboldii*; 13/7/1981). Along the route between Ienosawa River and Inane Shrine, 500 m elev., NN-8348 (on trunk of *Camellia japonica*; 17/7/1981).

63). **Pyrenula leucostoma** Ach.

Specimen examined. Sato, ca. 150 m elev., MH-96 (on bark of *Camelia japonica*; 13/7/1981).

64). **Pyrenula platystoma** (Müll.Arg.) Aptoot

It was reported as *Anthracothecium oculatum* Müll.Arg. in Kashiwadani and Kurokawa (1981).

Specimen examined. Without detailed locality, YD-s.n. (on bark of *Camellia japonica*; 29/9/1978).

65). **Pyxine endochrysina** Nyl.

Specimen examined. C: YO-8549 (on stone wall; 12/11/2011).

66). **Ramalina litoralis** Asahina

Specimens examined. A: YO-8536 (on rock). B: YO-7843 (on rock).

67). **Rhabdodiscus crassus** (Müll.Arg.) Frisch

Specimens examined. H: YO&HM-7837B (on bark of *Prunus* sp.). N: YO&HM-7785 (on bark of *Camellia japonica*).

68). **Rhabdodiscus inalbescens** (Nyl.) Frisch, **comb. nov.**

Mycobank, no. 815287.

Basionym: *Thelotrema inalbescens* Nyl., Lich. Japon.: 57. 1890.

Type: Japan, Joumoto-Hakoné, corticola, 1879, *E. Almquist s.n.* (H-NYL-22453!, holotype).

[Fig. 3]

Rhabdodiscus inalbescens is characterized by the pustulate thallus, the pustules often bursting at the top to expose the fibrose to indistinctly granular-sorediate medulla, or developing a granular-sorediate surface; strongly emergent to adnate apothecia with reticulate columella; 1 seriate, brown, submuriform, 15–21 × 8–10 μm large, 4–6 × 1–2 loculate ascospores with rounded to subacute ends, I + purplish-blue; and psoromic acid.

This species has been frequently collected from Hokkaido to Kyushu up to 1,100 m elevation. It seems to be confined to coniferous trees including *Abies firma*,

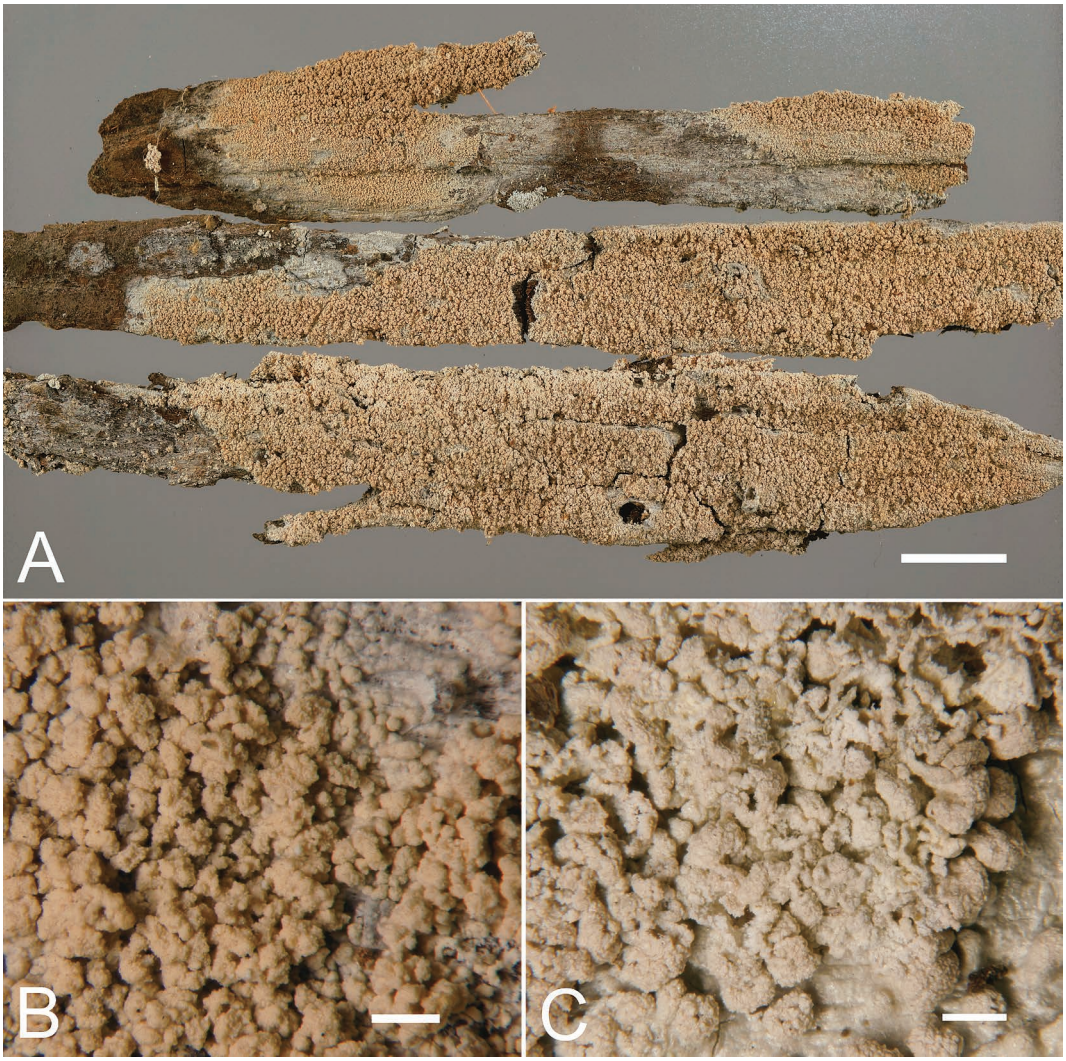

Fig. 3. *Rhabdodiscus inalbescens* (Nyl.) Frisch. A. Thallus (*Y. Ohmura 8555*, TNS). B. Granular-sorediate surface (*Y. Ohmura 8555*, TNS). C. Pustule bursting at the top with soredia (*H. Kashiwadani 49141*, TNS). Scale: A = 1 cm, B & C = 0.5 mm.

Cryptomeria japonica (Thunb. ex L.f.) D. Don, *Picea glehnii*, *Pinus densiflora* and *Tsuga sieboldii* Carrière, and shows a preference for older trees with fissured or flaky bark.

Although Mangold *et al.* (2009) considered *Thelotrema inalbescens* Nyl. as a synonym of *R. fissus* Vain., the investigation of the holotype and of numerous collections in TNS confirmed it as a separate species that, to present knowledge, is restricted to Japan. From *R. fissus* it is readily distinguishable by the pustulate thallus which is most distinct in the numerous sterile specimens, and by its distinct ecology.

Specimen examined. C: YO-8555 (on bark of *Cryptomeria japonica*; 12/11/2011).

Additional specimens examined. JAPAN. Hokkaido. Prov. Kushiro: along the trail from Taro-ko to the top of Mt. O-akan, Akan-cho, Akan-gun (43°26′N, 144°08′E), on bark of *Picea glehnii*, 430–700 m elev., 5/9/1995, *Y. Ohmura 1261 & H. Kashiwadani.* Honshu. Prov. Musashi (Tokyo Metropolis): Mt. Takao, Hachiohji-city, on bark of *Cryptomeria japonica*, 390 m elev., 13/12/1993, *H. Kashiwadani 44711*. Prov. Shinano (Pref. Nagano): Shimonakane, Minamishinano-mura, Shimoina-gun, on bark of *Abies firma*, ca. 550 m elev., 5/10/2000, *H. Kashiwadani 42593*; north western slope of Oyama mountain, Chichibu-Tama-Kai N. P., Kawakami-mura, Minamisaku-gun (N35°56′41.0″, E138°43′21.9″), on large *Tsuga diversifolia*, 1,658 m elev., 27/3/2013, *A. Frisch 13/Jp281 & Y. Ohmura.* Prov. Mikawa (Pref. Aichi): Mt. Iwagoya, Waichi, Shitara-cho, Kitashitara-gun (35°01′N, 137°39′E), on bark of *Pinus densiflora*, 780 m elev., 20/10/2003, *H. Kashiwadani 46140.* Prov. Ohmi (Pref. Shiga): Samegai Gorge, Maibara-city (N35°17′58.0″, E136°20′20.0″), on *Cryptomeria japonica*, 180 m elev., 13/7/2012, *A. Frisch 12/Jp340, Y. Ohmura & G. Thor*; ca. 2 km WNW of Mt. Amagoi, along Shibukawa River, Eigenji-cho, Kanzaki-gun, on bark of *Pinus densiflora*, ca. 400 m elev., 12/11/2009, *H. Kashiwadani 50010*. Prov. Kii (Pref. Wakayama): Nyu Shrine, Higashi, Ryujin-mura, Tanabe-city, on bark of *Cryptomeria japonica*, ca. 300 m elev., 29/3/2011, *H. Kashiwadani 49141*. Shikoku. Prov. Tosa (Pref. Kochi): None, Toyo-cho, Aki-gun, on bark of *Cryptomeria japonica*, ca. 5 m elev., 7/3/2011, *H. Kashiwadani 49059, 49066*. Kyushu. Prov. Buzen (Pref. Ohita): Mt. Hikosan, Soeda-cho, Tagawa-gun, on bark of *Cryptomeria japonica*, 1,106 m elev., 26/10/1996, *Y. Umezu 283*. Prov. Bungo (Pref. Ohita): en route from Notohge Pass to Mt. Ichino-dake, Yamakuni-cho, Shimoge-gun, on bark of *Tsuga sieboldii*, 720–910 m elev., 10/10/1996, *H. Kashiwadani 39994 & Y. Umezu*.

69). **Sarcographa tricosa** (Ach.) Müll.Arg.

Specimen examined. D: YO-8562 (on bark of *Castanea crenata*).

70). **Stereocaulon exutum** Nyl.

Specimen examined. M: YO&HM-7805 (on rock).

71). **Stereocaulon japonicum** Th.Fr.

This species was reported in Asahina (1955) with the recognition of *S. japonicum* var. *aogasimense* (Asahina) I.M.Lamb. occurring in another island, Aogashima Island. *Stereocaulon japonicum* is a common saxicolous species at lower to middle elevations of Japan, and might occur in Mikura-jima Island. However, it could not be found in the field investigations, and the voucher specimen was also not found in TNS.

72). **Stereocaulon japonicum** var. **aogasimense** (Asahina) I.M.Lamb.

Asahina (1969) reported the occurrence of this variety in this island. This taxon is characterized by 1) the minute size of the phyllocladia, which are cylindric-coralloid, not over 0.5 mm long and less than 0.1 mm in thickness; 2) the persistent primary thallus; and 3) the presence of atranorin, norstictic and stictic acids. It could not be

found during this investigation and no voucher specimen was found in TNS.

73). **Stereocaulon sorediiferum** Hue

This species was reported in Asahina (1955), and it was also collected by the first author during the current investigations and other collectors.

Specimens examined. K: YO&HM-7820 (on rock). M: YO&HM-7804 (on rock). Without detailed locality, JH-s.n. (17/7/1966). Mt. Kurosaki-Takao-san, NS-s.n. (on rocks; 3/10/1963). Mt. Oyama (label as "Mt. Misen"), NS-s.n. (on rocks; 4/10/1963).

74). **Stereocaulon verruculigerum** Hue

Specimens examined. F: YO&HM-7842 (on rock; 21/12/2010), YO-8446 (on rock; 10/11/2011). Along the route between Sato and Ohshimawake River, ca. 180 m elev., MH-10181 (on rock at cliff; 13/7/1981).

75). **Sticta gracilis** (Müll.Arg.) Zahlbr.

This species was reported in Asahina (1955). *Sticta gracilis* is usually found in humid forests of temperate to subtropical regions, and might occur in Mikura-jima Island. However, it could not be found during the current investigations, and the voucher specimen examined by Asahina (1955) was also not found in TNS.

76). **Thecaria montagnei** (Bosch) Staiger

In Japan, this species is rare but has been widely collected from various localities: i.e. Kohzu-shima Island that is one of Izu Islands (Kashiwadani, 1979), and warm-temperate to subtropical regions in southern Kyushu and Ryukyu Islands (Nakanishi, 1966, 1977). Additional examination of herbarium specimens in TNS revealed that this species is also distributed in Bonin Islands and Sulphur Islands in Japan.

Specimens examined. Along the route between Sato and Ohshimawake River, 140 m elev., MH-10169 (on trunk of *Camellia japonica*; 13/7/1981); the same locality, 180 m elev., MH-10187 (on trunk; 13/7/1981).

Additional specimens examined. JAPAN. Bonin Islands: Mt. Mikazuki, Chichijima-island, ca. 210 m elev., 10/6/1977, *H. Kashiwadani 13861*; en route from Kohshinzuka to Kitamura, Hahajima-island, 30/11/1977, *N. Amano s.n.* Sulphur Islands: Kita-iwo Island (N25°26′20″, E141°17′02″), on bark of *Eurya japonica* 430 m elev., 18/6/2009, *Y. Ohmura 6432*.

77). **Thelotrema similans** Nyl.

Specimen examined. I: YO&HM-7832 pr.p. (on decayed wood).

78). **Trapelia coarctata** (Turner ex Sm.) M.Choisy

Specimen examined. C: YO-8544 (on stone wall; 12/11/2011).

Phytogeographical notes

According to Kurokawa (2006), sixteen phytogeographical elements are recognized for the lichen flora of Japan on basis of their world distribution patterns, namely 1) holarctic, 2) bipolar, 3) alpine, 4) boreal, 5) Beringian, 6) eastern Asiatic-North American disjunctive, 7) northeast Asiatic, 8) pantemperate, 9) Sino-Japanese, 10) endemic, 11) pantropical, 12) paleotropical, 13) Indo-Malayan, 14) Pacific, 15) circum-Pacific, and 16) Australian. Among these elements, ten were recognized for the species occurring in Mikura-jima Island.

1. **Eastern Asiatic-North American disjunctive** (1 species, 1.3%): *Lecanora subimmergens* (see Kurokawa, 2006).

2. **Northeast Asiatic element** (3 species, 3.8%): *Cladonia kurokawae*, *Peltigera dolichorrhiza* (see Shiba *et al.*, 2008); *Nipponoparmelia laevior* (see Kurokawa, 2006).

3. **Pantemperate element** (25 species, 32.1%): *Cladonia furcata*, *C. scabriuscula*, *Porpidia albocaerulescens* (see Kurokawa, 2006); *C. merochlorophaea*, *Leptogium cyanescens*, *Parmelinopsis minarum*, *P. spumosa*, *Trapelia coarctata* [they were classified as cosmopolitan in Galloway (2007)]; *C. coniocraea*, *C. macilenta*, *C. ochrochlora*, *C. ramulosa*, *Coccocarpia erythroxyli*, *Collema japonicum*, *C. subflaccidum*, *Graphis scripta*, *Heterodermia diademata*,

Leptogium azureum, *Myelochroa entotheiochroa*, *Normandina pulchella*, *Physciella melanchra* (see Shiba *et al.*, 2008); *Lepraria finkii* (see Lendemer, 2013). Although *Agonimia pacifica* was suggested as Indo-Malayan (= Western Pacific) element by Galloway (2007) or boreal element by Shiba *et al.* (2008), it can be classified into the pantemperate element because of its wide distribution in Asia, Oceania and Brazil (Harada, 1993; Aptroot *et al.*, 1997, 2002; Moon, 1999; Aptroot, 2002, 2003; Galloway, 2007). *Lepraria lobificans* might be classified into this element because it is reported from Japan, France and Canary Islands (Crespo *et al.*, 2006). *Pertusaria multipuncta*, which is commonly found in the beech forests in Japan and the Northern Hemisphere (Oshio, 1968; Urbanavichus, 2010), can be classified into this element although Shiba *et al.* (2008) considered it as boreal element.

4. **Sino-Japanese element** (10 species, 12.8%): *Stereocaulon sorediiferum* (see Kurokawa, 2006); *Phaeophyscia limbata* (see Shiba *et al.*, 2008). The following species can be classified into this element: *Caloplaca spodoplaca*, which was only rarely collected in Japan (Nylander, 1890) and Korea (Kondratyuk *et al.*, 2012); *Diorygma soozanum*, distributed in warm temperate to subtropical regions of Japan, Taiwan, and China (Nakanishi, 1966; Meng and Wei, 2008); *Fissurina inabensis*, which is reported from Japan, Taiwan and Thailand (Nakanishi, 1966; Nakanishi *et al.*, 2001); *Hemithecium oshioi*, which is reported from Japan and China (Nakanishi, 1966; Jia *et al.*, 2011); *Ochrolechia parellula*, which is reported from Japan (Yoshimura, 1974) and Korea (Moon, 1999); *Ramalina litoralis*, which is reported from Japan, Korea and Taiwan (Kashiwadani *et al.*, 2006); *Stereocaulon exutum*, which is reported from Japan (Yoshimura, 1974) and Korea (Moon, 2013); *Thelotrema similans*, is distributed in temperate regions of Japan (Matsumoto, 2000) and Jeju Island in Korea (Joshi *et al.*, 2012).

5. **Endemic to Japan** (5 species, 6.4%): *Graphis mikuraensis*, only reported from Mikura-jima island (this study); *Herpothallon japonicum*, reported from the nemoral to subtropical region (Aptroot *et al.*, 2009); *Lecanora mikuraensis*, reported from Izu Islands, Shikoku and Kyushu (Miyawaki, 1988); *Rhabdodiscus inalbescens*, distributed in Hokkaido to Kyushu (this study); *Stereocaulon japonicum* var. *aogasimense*, reported from Izu Islands, Ryukyu Islands and Hirado Island (Asahina, 1969).

6. **Pantropical element** (11 species, 14.1%): *Enterographa leucolyta* (see Sparrius, 2004); *Graphis cleistoblephara*, *G. tsunodae* (see Lücking *et al.*, 2009); *Lecanora leprosa* (see Ryan *et al.*, 2004); *Pyrenula fetivica*, *P. leucostoma*, *P. platystoma* (see Aptroot, 2012). *Cresponea proximata* was suggested for this element by Egea *et al.* (1996). Although Galloway (1996) considered *C. proximata* as both Neotropical and Indo-Malayan elements, it is widely distributed in warm temperate and tropical regions of Asia and South America (Egea and Torrente, 1993; Breuss and Brunnbauer, 1997; Messuti and Ferraro, 2002). *Dibaeis sorediata* can also be classified into this element because it occurs in warm temperate to subtropical regions of Japan (Harada *et al.*, 2007), Nepal, Australia, and Réunion (Gierl and Kalb, 1993). *Leptogium pichneum* can be classified into this element because it occurs in warm temperate to subtropical regions of Japan, Taiwan, Southeast Asia, Australia, and South America (Zahlbruckner, 1925; Yoshimura, 1974). *Parmotrema tinctorum* belongs to this element with adjacent temperate regions (Nash and Elix, 2002) although Shiba *et al.* (2008) considered it as the pantemperate element.

7. **Paleotropical element** (10 species, 12.8%): *Cladonia fruticulosa* (see Galloway, 2007); *Graphis assimilis*, *G. japonica*, *G. longiramea* (see Lücking *et al.*, 2009); *Lobaria discolor* (see Shiba *et al.*, 2008); *L. retigera*, *Pyxine endochrysina* (see Kurokawa, 2006); *Rhabdodiscus crassus* (see Frisch and Kalb, 2006; Frisch and Ohmura, 2012). The following species can be classified into this element: *Graphis hossei*, which occurs in warm temperate regions of Japan, China (Nakanishi, 1966, 1974), Indonesia, Philippines, Thailand (Lücking *et al.*, 2009), and

Bolivia (Schiefelbein *et al.*, 2014); *Thecaria montagnei*, which occurs in tropical to subtropical regions of East and South-East Asia, Oceania, and West Africa (Staiger, 2002; Archer, 2006, 2009).

8. **Indo-Malayan element (= Western Pacific element)** (6 species, 7.7%): *Cladonia submultiformis*, *Stereocaulon verruculigerum* (see Kurokwa, 2006); *Hypotrachyna exsecta* (see Galloway, 2007). The following species can be classified into this element: *Heterodermia pandurata*, which occurs in warm temperate to subtropical regions of Japan, Taiwan, Thailand (Kurokawa, 1962), and India (Singh and Sinha, 2010); *Lepraria cupressicola*, which is reported from Japan, Australia, Norfolk Island, and Sri Lanka (Elix, 2009); *Sarcographa tricosa*, which is reported from southern Japan, Ceylon, Southeast Asia, and Australia (Nakanishi, 1966; Archer, 2009).

9. **Pacific element** (6 species, 7.7%): *Hypotrachyna koyaensis* (see Kurokawa, 1996), *Physma radians* (see Kurokwa, 2006). The following species can be classified into this element: *Ocellularia microstoma*, which is reported from Japan, Australia and the Philippines (Mangold *et al.*, 2009; Kraichak *et al.*, 2014); *Peltigera pruinosa*, which is reported from Japan, China, Taiwan, Australia (Yoshimura, 1974; Louwhoff, 2009), and Korea (Moon, 2013); *Stereocaulon japonicum*, which is reported from Japan, Taiwan, China, Java (Yoshimura, 1974), and Korea (Moon, 2013); *Sticta gracilis*, which is recorded from Japan, China and New Caledonia (Yoshimura, 1974).

10. **Circum-Pacific element** (1 species, 1.3%): *Coccotrema porinopsis* (see Messuti, 1996; Kurokawa, 2006).

Judging from the floristic composition outlined above, the lichen flora of Mikura-jima Island is characterized by the high percentage of pantemperate species in combination with tropical to subtropical species. Despite of the previous reports for vascular plants and bryophytes (Ohba, 1971; Higuchi and Nishimura, 2001), subalpine species of lichens could not be found in the investigated area. It should be also noted that *Nipponoparmelia laevior*, a conspicuous macrolichen which belongs to the northeast Asiatic element, could not be found during this study. The voucher specimens of *N. laevior* collected from various localities in this island before 1981 suggest that this species may have been common in former times but may have become extinct or drastically reduced in this island during the past 30 years.

Acknowledgments

We wish to express our sincere gratitude to M. Iwama, H. Miyakawa and Y. Miyakawa of Nonprofit Organization Nature center risen, S. Hirose and M. Hino of Mikura-jima Island for their kind help during the field surveys. We are also indebted to the village office for the coordination of this investigation and the residents of Mikura-jima Island for their warm encouragement regarding our exploration. Thanks are extended to H. Ebihara, Y. Mouri and K. Matsukura for their technical assistances in the laboratory experiments, M. Higuch of National Museum of Nature and Science for providing locality information of his collections, and an anonymous reviewer for the critical reading of this manuscript. This study is partly funded by the JSPS KAKENHI no. 24300314 to Y. Ohmura and JSPS Postdoctoral Fellowship for Foreign Researchers (no. 2301706) to A. Frisch.

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