

Increase of *Thysanothecium scutellatum* (Cladoniaceae, Ascomycota) in Japan

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Abstract *Thysanothecium scutellatum* is documented to be widely distributed from central to western Japan. In addition, field investigations in Miyajima-town on Miyajima Island, Hiroshima Prefecture, suggest that populations have increased in size when compared to the past. Although categorized as “Near Threatened (NT)” in the Red-list 2017 issued by the Ministry of the Environment of Japan, the current stable situation of the species with a wide distribution and increased populations suggest that this rank is no longer appropriate.

Key words: air pollution, lichen, red-list, sulfur dioxide, threatened species.

Introduction

Thysanothecium scutellatum (Fr.) D.J.Galloway belongs to the lichen family Cladoniaceae (Ascomycota). The diagnostic features of this species are 1) granular to squamulose or coralloid primary crustose thallus with whitish or pale green to green-yellow color, 2) swollen pseudopodetia (up to 10 mm high) with conspicuous grooves and corticate granules, and 3) the presence of divaricatic acid as a major lichen substance. It is distributed in Oceania, Southeast Asia, and East Asia (Galloway and Barlett, 1982; Wei *et al.*, 1994; Kashiwadani, 2008). In Japan, it has been found from central to western Honshu, Shikoku and Kyushu where it grows on barks of *Chamaecyparis obtusa*, *Cryptomeria japonica*,

Cycas revoluta, *Pinus densiflora*, *P. thunbergii*, *Washingtonia filifera*, plant debris on rocks and on decayed stumps at an elevational range of 5 to 700 meters (Asahina, 1956; Okamoto and Iwatsuki, 1992; Kurokawa and Kashiwadani, 1988; Kashiwadani, 1998, 2008; Okamoto, 2010; Hara *et al.*, 2011; Ohmura, 2011; Komine *et al.*, 2012; Kawakami *et al.*, 2014, 2015, 2016; Yamamoto *et al.*, 2016, 2017). In the past, the species has generally be considered rare and thus treated in the Red-list issued by the Ministry of the Environment of Japan (Environmental Agency of Japan, 2000; Ministry of the Environment, 2014). It was categorized as “Vulnerable (VU)” at first because only five localities were known. Later, the results of several field investigations confirmed that the known extant populations

were stable, and the red-list rank was revised and changed into “Near Threatened (NT)” which does not qualify for Critically Endangered, Endangered or Vulnerable now but is close to qualifying for or is likely to qualify for a threatened category in the near future following the IUCN (2001).

During the course of field investigations of threatened lichens in Japan, coupled with examination of herbarium specimens housed in the National Museum of Nature and Science (TNS), we obtained additional voucher specimens from 13 new localities. In addition, the existence of the species at 46 localities was also visually confirmed without collection within Miyajima-town, Miyajima Island, Hiroshima Prefecture. Here we provide an updated distribution map of *Thysanothecium scutellatum* and discuss its conservation status in light of the new records.

Materials and Methods

Field investigations were carried out by the following two methods: (1) investigation with voucher specimens collected from 1995 to 2017 in Japan by the authors and (2) investigation via photography and mapping without collection within Miyajima-town, Miyajima Island, Hiroshima Prefecture, Japan from 30 January to 8 October 2017 by the second author (M. C.). Identifications were made based on morphological study using the naked eye or a 10× hand lens in the field. The presence of divaricatic acid was confirmed in all voucher specimens examined by means of a microcrystal test (Asahina, 1936–1940) or thin layer chromatography with solvent B (Culberson and Kristinsson, 1970; Culberson and Johnson, 1982). All vouchers examined are housed in TNS otherwise indicated.

Results and Discussion

The distribution of *Thysanothecium scutellatum* in Japan ranges from central to western Honshu, Shikoku and Kyushu. Prior to 2011 *Thysanothecium scutellatum* was known in Japan

from only nine localities (Hara *et al.*, 2011; Ohmura, 2011). A total of 79 localities were documented by this study in addition to earlier published reports (Asahina, 1956; Okamoto and Iwatsuki, 1992; Kurokawa and Kashiwadani, 1988; Kashiwadani, 1998, 2008; Okamoto, 2010; Hara *et al.*, 2011; Ohmura, 2011; Komine *et al.*, 2012; Kawakami *et al.*, 2014, 2015, 2016; Yamamoto *et al.*, 2016, 2017) (Fig. 1). It should be noted that one locality for Tada Shrine, Kawanishi-city, Hyogo Prefecture (N34°51'40", E135°24'10") was destroyed as the habitat and the colonies disappeared with the substrate tree (Environment Agency of Japan, 2000). The species was frequently found growing on the trunks or stumps of acidic trees such as *Cryptomeria japonica*, *Pinus thunbergii* and *Washingtonia filifera* in open and sunny places.

The newly reported occurrences of *Thysanothecium scutellatum* may have resulted from two possible reasons: (1) the former investigations were insufficient or incomplete, and/or (2) the environmental condition of the habitat has improved from the past and the population as correspondingly increased in frequency and abundance. In fact, some of the occurrences reported here were already documented by herbarium records that had simply not been formally published. Concurrently evidence of locally abundant populations (Kurokawa and Kashiwadani, 1988; Kashiwadani, 1998, 2008) can serve as a guide to find other nearby populations (Komine *et al.*, 2012; Kawakami *et al.*, 2014, 2015, 2016; Yamamoto *et al.*, 2016, 2017), and basically says using known populations to search for new populations has proven to be effective (Bowering *et al.*, 2018).

In contrast, improvement of environmental conditions may also have facilitated successful colonization and establishment of the species. Several former and current investigations in Miyajima Island, Hiroshima, western Japan, have shown apparent increases of the species on the island. For instance, Nakanishi *et al.* (1975) reported on the the lichen flora of Miyajima Island (43 genera 131 species) but did not report

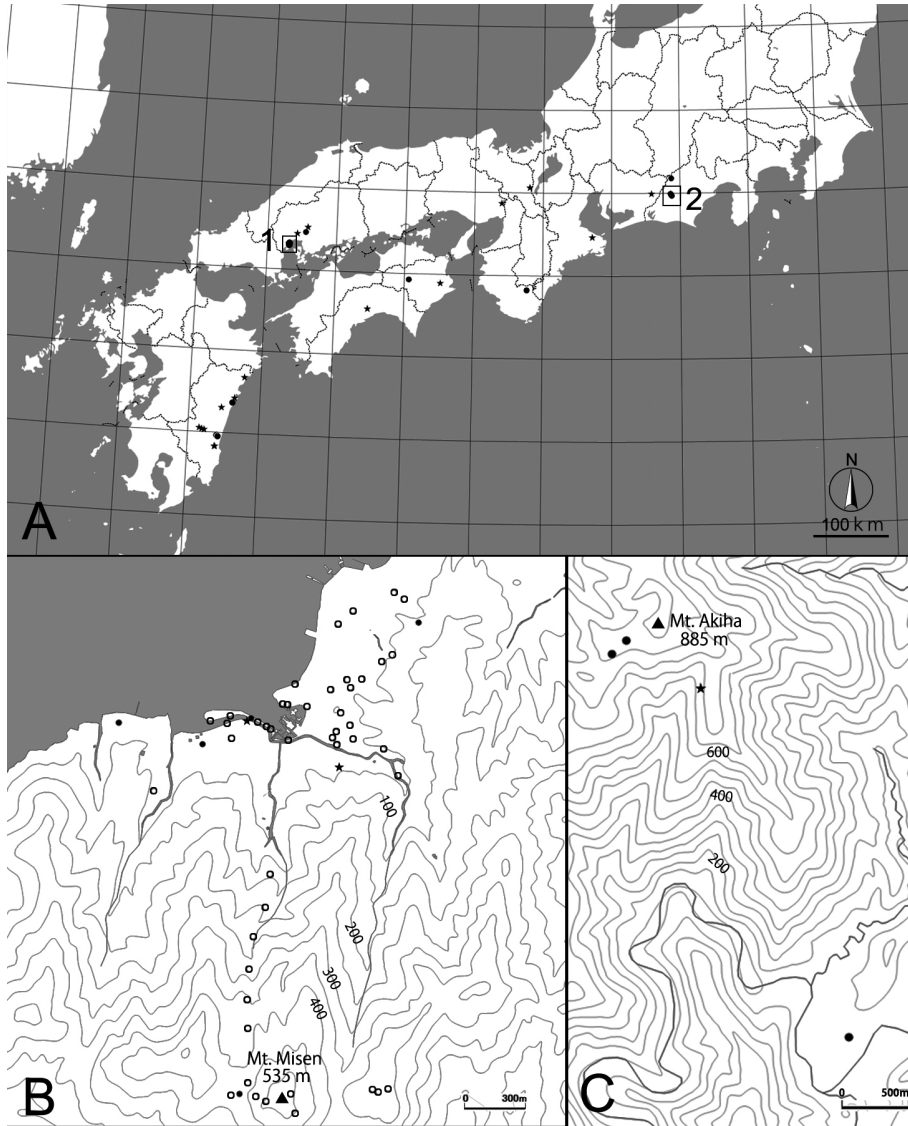


Fig. 1. Distribution of *Thysanothecium scutellatum* in Japan. ★: known localities, ●: new localities with voucher specimens, ○: new localities without voucher specimens. A. Whole map. B. Close-up map of box "1" in the whole map. C. Close-up map of box "2" in the whole map.

Thysanothecium scutellatum. In 1993, the first author (Y. O.) found one population only on a single tree on the island. In 2010, many colonies were found distributed across more than eight locations within the island. At present in 2017, a total of 53 localities (46 localities were only visually confirmed) was found on tree trunks and stumps of *Pinus* spp. and rarely *Pieris japonica*. Even if the potential for earlier authors to have

overlooked the species is taken into consideration, this documented increase is distinct. The increase could be related to improvement of environmental condition for the species from the past as lichens are well-known sensitive bioindicators for air pollution especially against sulfur dioxide and also known to recolonize into the formerly polluted area when the air quality has been improved (Rose and Hawksworth, 1981;

Hawksworth and McManus, 1989; Munzi *et al.*, 2007; Ohmura *et al.*, 2008, 2014). Before 1974, the vegetation of this island was seriously damaged by air pollution of sulfur dioxide and thousands of pine trees died and were cut down at that time (Nakanishi *et al.* 1975) but the current air quality has dramatically improved. Annual average of sulfur dioxide was 0.022 ppm in 1973 and it was 0.002 ppm in 2013 at the air pollution monitoring station located ca. 12 km SW of Miyajima-town (Ohtake City 2015).

As shown here, the population of *Thysanothecium scutellatum* in Japan is widely distributed geographically, locally abundant, and growth is stable at present. Therefore, we suggest that it is not threatened according to the categories in the Red-list 2017 issued by the Ministry of the Environment of Japan (Ministry of the Environment, 2017).

Specimens examined for the new localities (indicated as “●” in Fig. 1). JAPAN. Honshu. Prov. Tohomi (Pref. Shizuoka): Obata, Misakubocho, Iwata-gun (N35°09'57", E137°52'28"), on bark of *Cryptomeria japonica*, c. 200 m elev., 22 January 1995, H. Kashiwadani 38068; Mt. Akiha, Haruno-cho, Tenryu-ku, Hamamatsu-city (N34°58'47", E137°51'44"), on bark of *Cryptomeria japonica*, 810 m elev., 22 November 2010, Y. Ohmura 7753; ditto (N34°58'50", E137°51'48"), on bark of *Cryptomeria japonica*, 835 m elev., Y. Ohmura 7754; Shimosha, Nishiryoke, Haruno-cho, Shuchi-gun (N34°57'14", E137°52'54"), on bark of *Cryptomeria japonica*, c. 100 m elev., 24 January 1995, H. Kashiwadani 38047, 38064; ditto, on bark of *Zelkova serrata*, 21 January 1995, H. Kashiwadani 38071. Prov. Kii (Pref. Wakayama): Hongu, Hongu-cho, Tanabe-city (N33°50'19", E135°46'27"), on bark of *Cryptomeria japonica*, c. 80 m elev., H. Kashiwadani 50559. Prov. Aki (Pref. Hiroshima): Nishimatsubara, Miyajima Island, Hatsukaichi-city (N34°17'46", E132°19'04"), on bark of *Pinus thunbergii*, 2 m elev., 12 January 2010, M. Kono *et al.* 1; ditto, 14 January 2010, M. Kono 129, 130, 132 & Y. Ohmura; Omoto Park, Miyajima Island, Hatsukaichi-city (N34°17'42",

E132°18'55"), on stump, 7 m elev., 12 January 2010, M. Kono *et al.* 2; ditto, on bark of *Pinus thunbergii*, 14 m elev., 14 January 2010, M. Kono 144 & Y. Ohmura; Mt. Misen, Miyajima Island, Hatsukaichi-city (N34°16'47", E132°19'02"), on bark of decayed *Pinus* sp., 429 m elev., 12 January 2010, M. Kono *et al.* 67; Uguisu Path, Miyajima Island, Hatsukaichi-city (N34°18'02", E132°19'36"), on bark of *Pieris japonica*, c. 50 m elev., 20 August 2017, M. Chaki 14; ditto, on bark of *Pinus thunbergii*, M. Chaki 15; Mt. Takanojyo, Hiroshima-city (N34°26'26", E132°32'56"), on stump of *Pinus densiflora*, 410 m elev., 16 April 2017, Y. Ohmura 11264. Shikoku. Prov. Awa (Pref. Tokushima): Shimomiya Shrine, Nakano, Tsurugi-cho, Mima-gun (N33°54'49", E134°04'01"), on bark of *Cryptomeria japonica*, c. 400 m elev., 25 October 2011, S. Takeshita *et al.* 111025. Kyushu. Prov. Hyuga (Pref. Miyazaki): Miyazaki Ohmiya High school, Jingu, Miyazaki-city (N31°56'00", E131°25'30"), on bark of *Washingtonia filifera*, 8 m elev., 8 December 2017, S. Kurogi s.n. (herb. of Miyazaki Prefectural Museum of Nature and History; TNS); Heiwadai Park, Shimokitakata-machi, Miyazaki-city (N31°56'58", E131°24'53"), on bark of *Washingtonia filifera*, 30 m elev., 3 December 2017, S. Kurogi s.n. (herb. of Miyazaki Prefectural Museum of Nature and History; TNS); Hyuga San Park, Tohmi, Hyuga-city (N32°20'33", E131°37'27"), on bark of *Washingtonia filifera*, 20 m elev., 28 November 2017, S. Kurogi s.n. (herb. of Miyazaki Prefectural Museum of Nature and History; TNS).

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References

- Asahina, Y. 1936a. Mikrochemischer Nachweis der Flechtenstoffe (I). *Journal of Japanese Botany* 12: 516–525.
- Asahina, Y. 1936b. Mikrochemischer Nachweis der Flechtenstoffe (II). *Journal of Japanese Botany* 12: 529–536.
- Asahina, Y. 1937a. Mikrochemischer Nachweis der Flechtenstoffe (III). *Journal of Japanese Botany* 13: 529–536.
- Asahina, Y. 1937b. Mikrochemischer Nachweis der Flechtenstoffe. (IV). *Journal of Japanese Botany* 13: 855–861.
- Asahina, Y. 1938a. Mikrochemischer Nachweis der Flechtenstoffe. (V). *Journal of Japanese Botany* 14: 39–44.
- Asahina, Y. 1938b. Mikrochemischer Nachweis der Flechtenstoffe. (VI). *Journal of Japanese Botany* 14: 244–250.
- Asahina, Y. 1938c. Mikrochemischer Nachweis der Flechtenstoffe. (VII). *Journal of Japanese Botany* 14: 318–323.
- Asahina, Y. 1938d. Mikrochemischer Nachweis der Flechtenstoffe. (VIII). *Journal of Japanese Botany* 14: 650–659.
- Asahina, Y. 1938e. Mikrochemischer Nachweis der Flechtenstoffe. (IX). *Journal of Japanese Botany* 14: 767–773.
- Asahina, Y. 1939. Mikrochemischer Nachweis der Flechtenstoffe (X). *Journal of Japanese Botany* 14: 465–472.
- Asahina, Y. 1940. Mikrochemischer Nachweis der Flechtenstoffe (XI). *Journal of Japanese Botany* 16: 185–193.
- Asahina, Y. 1956. Lichenologische Notizen § 117–119. *Journal of Japanese Botany* 31: 65–70.
- Bowering, R., Wigle, R., Padgett, T., Adams, B., Cote, D. and Wiersma, Y. F. 2018. Searching for rare species: A comparison of Floristic Habitat Sampling and Adaptive Cluster Sampling for detecting and estimating abundance. *Forest Ecology and Management* 407: 1–8.
- Environment Agency of Japan (ed.). 2000. Threatened Wildlife of Japan—Red Data Book 2nd ed.—Vol. 9, Bryophytes, Algae, Lichens, Fungi. 429 pp. Japan Wildlife Research Center, Tokyo.
- Culberson, C. F. and Johnson, A. 1982. Substitution of methyl tert.-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. *Journal of Chromatography* 238: 483–487.
- Culberson, C. F. and Kristinsson, H. D. 1970. A standardized method for the identification of lichen products. *Journal of Chromatography* 46: 85–93.
- Galloway, D. J. and Bartlett, J. K. 1982. The lichen genus *Thysanothecium* Mont. & Berk., in New Zealand. *Nova Hedwigia* 36: 381–398.
- Hara, K., Komine, M., Kawakami, H., Kurogi, S., Yamamoto, Y. and Yoshimura, I. 2011. Materials for the study of distributions of lichenized fungi (24). *Thysanothecium scutellatum*. *Lichenology* 9: 45–48 (in Japanese).
- Hawksworth, D. L. and McManus, P. M. 1989. Lichen recolonization in London under conditions of rapidly falling sulphur dioxide levels, and the concept of zone skipping. *Botanical Journal of the Linnean Society* 100: 99–109.
- IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. Gland, Switzerland and Cambridge, U.K.
- Kashiwadani, H. 1998. Lichenes minus cogniti exsiccati. Fasc. V (Nos. 101–125). National Science Museum, Tokyo.
- Kashiwadani, H. 2008. Lichenes minus cogniti exsiccati. Fasc. XV (Nos. 351–375). National Science Museum, Tokyo.
- Kawakami, H., Hara, K., Komine, M., Kurogi, S., Iwakiri, K. and Yamamoto, Y. 2014. Lichens in riversides of Ayaminami-gawa and Ayakita-gawa, Aya-cho, Miyazaki-ken, Kyusyu, Japan. *Bulletin of the Miyazaki Prefectural Museum of Nature and History* 34: 73–81 (in Japanese with English summary).
- Kawakami, H., Watanuki, O., Hara, K., Komine, M., Kurogi, S., Iwakiri, K. and Yamamoto, Y. 2015. Lichens in seaside of Nichinan, Miyazaki-ken, Kyusyu, Japan. *Bulletin of the Miyazaki Prefectural Museum of Nature and History* 35: 41–46 (in Japanese with English summary).
- Kawakami, H., Watanuki, O., Hara, K., Komine, M., Kurogi, S., Iwakiri, K. and Yamamoto, Y. 2016. Lichens in Kaeda Valley, Miyazaki-shi, Miyazaki-ken, Kyusyu, Japan. *Bulletin of the Miyazaki Prefectural Museum of Nature and History* 36: 55–59 (in Japanese with English summary).
- Komine, M., Kawakami, H., Hara, K., Kurogi, S. and Yamamoto, Y. 2012. Materials for the study of distributions of lichenized fungi (32). New records of *Thysanothecium scutellatum* from Miyazaki-ken, Kyushu. *Lichenology* 10: 179–180 (in Japanese).
- Kurokawa, S. and Kashiwadani, H. 1988. Indices to Taxa Distributed under Lichenes Rariores et Critici Exsiccati. 114 pp. National Science Museum, Tokyo.
- Ministry of the Environment. 2014. Red Data Book 2014. —Threatened Wildlife of Japan—. Bryophytes, Algae, Lichens, Fungi. 580 pp. GYOSEI, Tokyo.
- Ministry of the Environment. 2017. Red-list 2017 issued by the Ministry of the Environment of Japan. <http://www.env.go.jp/press/files/jp/105449.pdf> (accessed on 14 December 2017).
- Munzi, S., Ravera S., and Caneva, G., 2007. Epiphytic lichens as indicators of environmental quality in Rome. *Environmental Pollution* 146: 350–358.

- Nakanishi, M., Oshio, M. and Inoue, M. 1975. Lichens of Itsukushima (Miyajima) Island Southwestern Japan. In: Committee for the Urgent Investigation of the Primeval Forest and Scenic Reserves of Itsukushima (Miyajima) Island (ed.) LAND AND LIFE IN ITSUKUSHIMA (Scientific studies of Itsukushima Island, Southwestern Japan), pp. 377–394, Hiroshima.
- Ohmura, Y. 2011. Notes on eight threatened species of lichens in Japan. *Bulletin of the National Museum of Nature and Science, Series B* 37: 57–61.
- Ohmura, Y., Kawachi, M., Ohtara, K. and Sugiyama, K. 2008. Long-term monitoring of *Parmotrema tinctorum* and qualitative changes of air pollution in Shimizu Ward, Shizuoka City, Japan. *Journal of Japan Society for Atmospheric Environment* 43: 47–54.
- Ohmura, Y., Thor, G., Frisch, A., Kashiwadani, H. and Moon, K. H. 2014. Increase of lichen diversity in the Imperial Palace Grounds, Tokyo, Japan. *Memoir of National Museum of Nature and Science* 49: 193–217.
- Ohtake City 2015. Ohtake-shi Kankyo Hakusyo. 71 pp. Ohtake City (in Japanese).
- Okamoto, T. 2010. New locality and substrate of *Thysanothecium scutellatum* (Fr.) D. J. Galloway (Cladoniaceae, lichenized Ascomycetes). *Hikobia* 15: 361–362.
- Okamoto, T. and Iwatsuki, Z. 1992. New localities of four rare lichens in Japan. *Hikobia* 11: 213–215.
- Rose, C. I. and Hawksworth, D. L. 1981. Lichen recolonization in London's cleaner air. *Nature* 289: 289–292.
- Wei, J., Jiang, Y. and Guo, S. 1994. Studies on the lichen family Cladoniaceae in China III. A new genus to China: *Thysanothecium*. *Mycosystema* 7: 23–27.
- Yamamoto, Y., Hara, K., Komine, M., Kurogi, S. and Iwakiri, K. 2016. Lichens in Mt. Osuzu, Miyazaki-ken, Kyusyu, Japan. *Bulletin of the Miyazaki Prefectural Museum of Nature and History* 36: 51–54 (in Japanese with English summary).
- Yamamoto, Y., Kawakami, H., Hara, K., Komine, M., Kurogi, S. and Iwakiri, K. 2017. Lichens in Nippo sea-side, Miyazaki-ken, Kyusyu, Japan. *Bulletin of the Miyazaki Prefectural Museum of Nature and History* 37: 37–40 (in Japanese with English summary).