



Original Article

A preliminary study of bryophytes in the Khao Soi Dao wildlife sanctuary, Chanthaburi Province, Thailand

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Abstract

An investigation of bryophyte diversity of Khao Soi Dao wildlife sanctuary, Chanthaburi Province, Thailand was carried out in April 2013. In total, 387 specimens were enumerated, consisting of 103 species (45 liverworts, 1 hornwort, 57 mosses), 67 genera (25 liverworts, 1 hornwort, 41 mosses), and 38 families (14 liverworts, 1 hornwort, 23 mosses), excluding those as yet unidentified to species. Among these, four species of mosses, including *Clastobryum glabrescens* (Z.Iwats.) B.C.Tan, Z.Iwats. & D.H.Norris, *Macromitrium lorifolium* Paris & Broth., *Pterobryopsis gedehensis* M.Fleisch., and *Radulina borbonica* (Bél.) W.R.Buck, are newly reported to Thailand in this paper.

Keywords: bryophytes, Chanthaburi Province, Khao Soi Dao wildlife sanctuary

1. Introduction

Khao Soi Dao wildlife sanctuary is situated in Chanthaburi Province, Eastern Thailand, between 12°50'-13°20' N and 102°2'-102°16' E covering a total area of 745 square kilometers. According to phytogeographical regions of the country recently proposed by Van Welzen *et al.* (2011), Khao Soi Dao wildlife sanctuary is in Eastern region, which is influenced by the Central and Southern Indo-Chinese Flora (Cambodia and South Vietnam). The highest mountain in this wildlife sanctuary reaches 1,675 m a.s.l.

The latest moss checklist is by He (1998, 1995-2014) recorded 620 species and 31 subspecific taxa whereas the most recent hepatic checklist is by Lai *et al.* (2008) who recorded 376 species of liverworts and 12 of hornworts. However, the number of known bryophytes in Thailand keeps increasing due to a recent discovery of several new

species and many new records of bryophytes, especially from northern Thailand (Sukkharak and Chantanaorrapint, 2014, and references therein). In the framework of the 'Flora of Thailand' project, the vascular plant flora has been well-studied. In contrast, few studies of non-vascular plants have been conducted (Sukkharak and Chantanaorrapint, 2014). In addition, yet no study of bryophytes has been taken place in Khao Soi Dao wildlife sanctuary before. The aim of this study, therefore, was to investigate the diversity of bryophytes of Khao Soi Dao wildlife sanctuary.

2. Materials and Methods

The investigation of the bryophyte diversity of Khao Soi Dao wildlife sanctuary was carried out in April 2013. Both morphological and anatomical features were studied. Bryophyte specimens were identified using both keys and descriptions from various taxonomic literatures previously reported. The classification system of the families and genera used in this list are followed Crandall-Stotler *et al.* (2008), Renzaglia *et al.* (2008), and Goffinet *et al.* (2008) for liverworts,

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hornworts, and mosses, respectively. The specimens are kept in the Department of Biology, Faculty of Science, Burapha University.

3. Results and Discussion

Three hundred and eighty-seven specimens were collected. The following bryophyte list (Table 1) consists of 103 species, 67 genera, and 38 families (45 species, 25 genera, 14 families of liverworts; 1 species, 1 genus, 1 family of hornwort; 57 species, 41 genera, 23 families of mosses), excluding those that are not identified down to species level.

3.1 Species diversity

The most common families of mosses are Sematophyllaceae and Hypnaceae (6 species each) and families of liverwort are Lejeuneaceae (14 species). The results support that the Sematophyllaceae, Hypnaceae, and Lejeuneaceae are mainly tropical bryophyte families (Gradstein *et al.*, 2002; Tan *et al.*, 2007)

Most species found in this area commonly occur in lower mountain rain forests. The indicators of this forest type are the members of Calymperaceae, Fissidentaceae, Lejeuneaceae, Leucobryaceae, Lophocoleaceae, Meteoriaceae,

Table 1. Alphabetical list of bryophytes found in Khao Soi Dao wildlife sanctuary.

Taxa	Habitat (m)	Elevation (this study)	Collector No.
Marchantiophyta (Liverworts)			
Calypogeiaceae			
1. <i>Calypogeia arguta</i> Nees & Mont. ex Nees	s	1,523	274
Frullaniaceae			
2. <i>Frullania alstonii</i> Verd. (Figure 2B)	c	1,488-1,588	167, 168, 170, 175, 182, 183, 188, 205, 218, 231, 277, 278, 279, 281, 288, 291, 305, 306
3. <i>Frullania ericoides</i> (Nees ex Mart.) Mont.	c	510	8
4. <i>Frullania meyeniana</i> Lindenb.	c, r, l	869-1,675	110, 165, 171, 179, 282, 285, 287, 289, 327, 328, 329, 330, 332, 333, 360, 381
5. <i>Frullania serrata</i> Gottsche	c, r, l	1,000-1,675	141, 254, 331, 344, 351, 353
6. <i>Frullania vethii</i> Sande Lac.	c	1,400	346
Herbertaceae			
7. <i>Herbertus dicranus</i> (Taylor) Trevis.	c, s, t	1,000-1,590	115, 128, 159, 219, 243, 245, 247, 257, 319, 320, 366
8. <i>Herbertus ramosus</i> (Steph.) H.A.Mill	c, r, l, s, t	1,335-1,590	107, 132, 162, 169, 170, 193, 251, 258, 264, 291, 324
Lophocoleaceae			
9. <i>Heteroscyphus argutus</i> (Nees) Schiffn. (Figure 2C)	c, l	990-1,518	50, 76, 146, 231
10. <i>Heteroscyphus coalitus</i> (Hook.) Schiffn.	l	1,520	337
Jubulaceae			
11. <i>Jubula hutchinsiae</i> (Hook.) Dumort. subsp. <i>javanica</i> (Steph.) Verd.	c	1,520	340
Lejeuneaceae			
12. <i>Archilejeunea planiuscula</i> (Mitt.) Steph.	c	588	18
13. <i>Acrolejeunea pycnoclada</i> (Taylor) Schiffn.	c	1,090	74
14. <i>Cheilolejeunea ceylanica</i> (Gottsche) R.M.Schust. & Kachroo	c	869-1,090	70, 385
15. <i>Cololejeunea ocellata</i> (Horik.) Benedix	c	1,530	178
16. <i>Lopholejeunea horticola</i> Schiffn.	c	510-1,090	5, 9, 39, 40, 41, 55, 63
17. <i>Lopholejeunea nigricans</i> (Lindenb.) Steph.	c	510-1,400	3, 4, 11, 13, 139
18. <i>Lopholejeunea subfusca</i> (Nees) Schiffn.	c	510-1,545	6, 23, 24, 54, 57, 60, 73, 157, 158, 173, 174, 181, 208, 213
19. <i>Mastigolejeunea repleta</i> (Taylor) A.Evans	c	630	22

Table 1. (Continued)

Taxa	Habitat (m)	Elevation (this study)	Collector No.
20. <i>Ptychanthus striatus</i> (Lehm.) Nees	r	630-1,380	25, 32, 90, 96, 97, 98, 123, 368
21. <i>Spruceanthus polymorphus</i> (Sande Lac.) Verd.	c, l	510- 1,000	1, 2, 19, 42, 46, 56, 369, 371, 382
22. <i>Spruceanthus semirepandus</i> (Nees) Verd.	c, r	1,090-1,570	82, 99, 108, 129, 154, 262
23. <i>Thysananthus convolutus</i> Lindenb. (Figure 2F)	c	1,400	345
24. <i>Thysananthus spathulistipus</i> (Reinw., Blume & Nees) Lindenb.	c, r, l	1,000-1,588	311, 343, 354, 367, 370
25. <i>Tuzibeanthus chinensis</i> (Steph.) Mizut.	c	588	17, 19
Lepidoziaceae			
26. <i>Bazzania japonica</i> (Sande Lac.) Lindb.	c, s	1,420-1,590	149, 186, 227-1, 312, 323
27. <i>Bazzania cincinnata</i> (De Not.) Trevis.	c	1,570	269
28. <i>Bazzania praerupta</i> (Reinw., Blume & Nees) Trevis.	c, l	1,545-1,590	272, 318
29. <i>Bazzania recurvolimbata</i> (Steph.) N.Kitag.	c	1,545	210
30. <i>Bazzania tridens</i> (Reinw., Blume & Nees) Trevis. (Figure 2A)	c	700-1,590	35, 43, 52, 65, 69, 75, 84, 86, 102, 103, 130, 142, 206, 209, 229, 290, 304, 321, 322, 362
31. <i>Lepidozia parvula</i> N.Kitag.	t	1,340	356
Mastigophoraceae			
32. <i>Mastigophora diclados</i> (Brid. ex F.Weber) Nees	l, s, t	900-1,590	249, 318, 325, 374
Metzgeriaceae			
33. <i>Metzgeria furcata</i> (L.) Corda (Figure 2D)	c	1,420- 1,500	140, 143, 225
Plagiochilaceae			
34. <i>Plagiochila arbuscula</i> (Brid. ex Lehm. & Lindenb.) Lindenb.	c	1,160	83
35. <i>Plagiochila javanica</i> (Sw.) Nees & Dumort.	r, s	700-1,225	34, 100
36. <i>Plagiochila semidecurrrens</i> (Lehm.) Lindenb.	c, l, s	1,441-1,588	163, 203, 232, 266, 316
37. <i>Plagiochila trabeculata</i> Steph. (Figure 2E)	c, s	1,380-1,588	120, 151, 222, 248, 267, 315
38. <i>Plagiochilion oppositum</i> (Reinw., Blume & Nees) S.Hatt.	c	1,522-1,540	235, 238, 250
39. <i>Plagiochilion theriotianum</i> (Steph.) Inoue	l	1,540	255
Pleuroziaceae			
40. <i>Pleurozia gigantea</i> (F.Weber) Lindb.	c	1,489-1,675	216, 240, 253, 270, 286, 334
Porellaceae			
41. <i>Porella acutifolia</i> (Lehm.) Trevis.	c, s	1,535	191, 202
Radulaceae			
42. <i>Radula formosa</i> (C.F.W.Meissn. ex Spreng.) Nees	c	1,522- 1,570	234, 271
43. <i>Radula meyeri</i> Steph.	c, r	1,440-1,530	161, 189
44. <i>Radula perrottetii</i> Gottsche ex Steph.	c, s	700-1,588	33, 85, 93, 95, 117, 125, 150, 153, 190, 194, 308
Scapaniaceae			
45. <i>Plicanthus birmensis</i> (Steph.) R.M.Schust.	t	1,520	341
Anthocerotophyta (hornworts)Notothyladaceae			
46. <i>Phaeoceros carolinianus</i> (Michx.) Prosk. (Figure 2G)	t	1,400	347, 348, 349, 350
Bryophyta (mosses)Bryaceae			
47. <i>Rhodobryum roseum</i> (Hedw.) Limpr. (Figure 3H)	s	1,550	297
Calymperaceae			
48. <i>Calymperes afzelii</i> Sw.	c	510	7
49. <i>Calymperes lonchophyllum</i> Schwägr.	c	850	38
50. <i>Exostratum blumii</i> (Nees ex Hampe) L.T.Ellis	l	1,090	62
51. <i>Syrrhopodon japonicus</i> (Besch.) Broth.	c	869- 1,400	136, 384
52. <i>Syrrhopodon trachyphyllum</i> Mont.	l	869	378

Table 1. (Continued)

Taxa	Habitat (m)	Elevation (this study)	Collector No.
Daltoniaceae			
53. <i>Calypstrochaeta remotifolia</i> (Müll.Hal.) Z.Iwats., B.C.Tan & Touw (Figure 3A)	s	1,588	299
54. <i>Cyathophorella tonkinensis</i> (Broth. & Paris) Broth.	r, s, t	1,335-1,588	119-1, 293, 300
55. <i>Distichophyllum cirratum</i> Renauld & Cardot	l	1,340	358
Dicranaceae			
56. <i>Leucoloma molle</i> (Müll.Hal.) Mitt.	c, r, l	1,090-1,500	77, 88, 145, 227-2, 227-4
Diphysciaceae			
57. <i>Diphyscium longifolium</i> Griff. (Figure 3B)	c, s	869-1,420	144, 147, 379
Leskeaceae			
58. <i>Claopodium prionophyllum</i> (Müll.Hal.) Broth.	c	630	28
Leucobryaceae			
59. <i>Campylopus zollingerianus</i> (Müll.Hal.) Bosch & Sande Lac.	s, t	1,335-1,590	113, 259-2
60. <i>Dicranodontium uncinatum</i> (Harv.) A.Jaeger	s	1,540	246
61. <i>Leucobryum bowringii</i> Mitt.	l	869-1,400	137, 386
62. <i>Leucobryum javense</i> (Brid.) Mitt.	c, s	990-1,530	45, 79, 237, 275
63. <i>Leucobryum juniperoideum</i> (Brid.) Müll.Hal. (Figure 3E)	c, s	1,500-1,570	273, 283
Fissidentaceae			
64. <i>Fissidens crenulatus</i> Mitt.	c	1,225	102
65. <i>Fissidens hollianus</i> Dozy & Molk.	c	1,225	101
66. <i>Fissidens nobilis</i> Griff. (Figure 3D)	c	630-1,520	27, 342, 363
Hylcomiaceae			
67. <i>Macrothamnium macrocarpum</i> (Reinw. & Hornsch.) M.Fleisch.	s	1,545	211
Hypnaceae			
68. <i>Ectropothecium ohosimense</i> Cardot & Thér.	l	1,588	298
69. <i>Ectropothecium sikkimense</i> (Renauld & Cardot) Renauld & Cardot (Figure 3C)	s	1,489-1,588	215, 223, 314
70. <i>Gammiella ceylonensis</i> (Broth.) B.C.Tan & W.R.Buck	r	1,570	262
71. <i>Gammiella tonkinensis</i> (Broth. & Paris) B.C.Tan	c	543	16
72. <i>Hypnum submolluscum</i> Besch.	l	1,400	131
73. <i>Taxiphyllum taxirameum</i> (Mitt.) M.Fleisch.	s	1,588	317
Meteoriaceae			
74. <i>Cryptopapillaria feae</i> (Müll.Hal. ex M.Fleisch.) M.Menzel	c, r	1,335-1,570	109, 226, 227, 263, 364
75. <i>Meteorium speciosum</i> (Dozy & Molk.) Mitt. (Figure 3F)	c, r	1,335-1,540	112, 119-2, 228-1, 252
76. <i>Trachypodopsis serrulata</i> (P.Beauv.) M.Fleisch. var. <i>crispatula</i> (Hook.) Zanten	e, l, s	1,420-1,675	148, 214, 336
77. <i>Trachypus bicolor</i> Reinw. & Hornsch.	l	1,340	357
Mniaceae			
78. <i>Plagiomnium rhynchophorum</i> (Harv.) T.J.Kop.	t	1,520	341
Neckeraceae			
79. <i>Homaliodendron exiguum</i> (Bosch & Sande Lac.) M.Fleisch.	c	990	44-1
80. <i>Homaliodendron flabellatum</i> (Sm.) M.Fleisch.	c	1,160	80
81. <i>Homaliodendron montagneanum</i> (Müll.Hal.) M.Fleisch.	c	1,588	307
82. <i>Neckeropsis fimbriata</i> (Harv.) M.Fleisch.	c, s	543-990	14, 15, 31, 44-2
Orthotrichaceae			
83. <i>Macromitrium lorifolium</i> Paris & Broth. *	r	1,500	228-2
84. <i>Macromitrium sulcatum</i> (Hook.) Brid.	c, l	1,090-1,335	81, 111
Pilotrichaceae			
85. <i>Hookeriopsis utacamundiana</i> (Mont.) Broth.	s	1,380	127
Polytrichaceae			
86. <i>Pogonatum neesii</i> (Müll.Hal.) Dozy (Figure 3G)	l, s	1,340-1,600	335, 359

Table 1. (Continued)

Taxa	Habitat (m)	Elevation (this study)	Collector No.
Pterobryaceae			
87. <i>Calyptothecium wightii</i> (Mitt.) M.Fleisch.	s	1,160	94
88. <i>Pterobryopsis crassicaulis</i> (Müll.Hal.) M.Fleisch.	c	1,225	103
89. <i>Pterobryopsis gedehensis</i> M.Fleisch.*	c	850-1,570	37, 220, 239, 268, 387
Pylaisiadelphaceae			
90. <i>Clastobryum glabrescens</i> (Z.Iwats.) B.C.Tan, Z.Iwats. & D.H.Norris*	s	1,540	248
91. <i>Isopterygium minutirameum</i> (Müll.Hal.) A.Jaeger	l	1,090-1,520	71, 230
92. <i>Wijkia surcularis</i> (Mitt.) H.A.Crum	c, l	869- 1,500	280, 376, 380
Rhizogoniaceae			
93. <i>Pyrrhobryum spiniforme</i> (Hedw.) Mitt.	c, l	990- 1,225	49-1, 64, 66, 105
Sematophyllaceae			
94. <i>Acroporium downii</i> (Dixon) Broth.	l	990	53
95. <i>Acroporium hermaphroditum</i> (Müll.Hal.) M.Fleisch.	c	1,570	261
96. <i>Acroporium stramineum</i> (Reinw. & Hornsch.) M.Fleisch.	c	1,522- 1,590	244, 259-1
97. <i>Radulina borbonica</i> (Bél.) W.R.Buck*	c	528	13
98. <i>Radulina hamata</i> (Dozy & Molk.) W.R.Buck & B.C.Tan	c	869	383
99. <i>Trichosteleum boschii</i> (Dozy & Molk.) A.Jaeger	l	990	49-2
Stereophyllaceae			
100. <i>Entodontopsis anceps</i> (Bosch & Sande Lac.) W.R.Buck & Ireland	s	1,340	362
Symphyodontaceae			
101. <i>Symphyodon perrottetii</i> Mont.	c, r	1,550- 1,570	227-1, 260
Thuidiaceae			
102. <i>Thuidium cymbifolium</i> (Dozy & Molk.) Dozy & Molk.	s	630	21
103. <i>Thuidium pristocalyx</i> (Müll.Hal.) A.Jaeger	c, l	1,380- 1,530	121, 122, 156, 187

Notes

* new record to Thailand; Habitats: c = corticolous, e = epiphyllous, l = lignicolous, r = ramicolous, s = saxicolous, t = terricolous.

Neckeraceae, Porellaceae, Pterobryaceae, Radulaceae, and Thuidiaceae (Gradstein *et al.*, 2002; Gradstein and Culmsee, 2010).

One of endemic species of Thailand, *Lepidozia parvula* (Sukkharak and Chantanaorrapint, 2014) is also found in the study area. This species was previously collected from Khao Luang in Nakhon Si Thammarat Province, Southern Thailand (Kitagawa, 1978).

3.2 Habitats

Microhabitats of bryophytes were found in the area as shown in Table 1. The most common bryophytes in the area are epiphytes (69 species). According to Gradstein and Pócs (1989), epiphytes are divided into corticolous (growing on bark of trees), epiphyllous (growing on leaf surfaces), lignicolous (growing on rotten logs), and ramicolous (growing on branches). The most of epiphytic bryophytes in the area is corticolous. Terrestrial bryophytes are subdivided into saxicolous (growing on rocks) and terricolous (growing on soil) (Gradstein and Pócs, 1989). Most terrestrial bryophytes in the study area are saxicolous species.

3.3 Species composition

There are two different rain forest types, the lowland rain forest and the lower mountain rain forest that occurs on the slopes of the mountain.

Lowland rain forest occurs from the foot of the mountain to up to 700 m. Nineteen species (12 liverworts, 7 mosses) are found in this area. The result supports that in this type of forest liverworts is usually more numerous than mosses, the majority being members of the Lejeuneaceae (Gradstein *et al.*, 2002). Only *Archilejeunea planiuscula*, *Calymperes afzelii*, *Claopodium prionophyllum*, *Frullania ericoides*, *Gammiella tonkinensis*, *Mastigolejeunea repleta*, *Radulina borbonica*, *Thuidium cymbifolium*, and *Tuzi-beanthus chinensis* are restricted in this area.

Lower mountain rain forest is found from 700 m to 1,675 m, where the species composition differs among three sub-habitats, including 1) valley and hill slopes, 2) summit, and 3) swamp. Valley and hill slopes are characterized by humidity and shade. Ninety-two species were found in this sub-habitat. Of these, 80 species are restricted in this area. The summit is covered with trees with open canopy, and this



Figure 1. Study area of Khao Soi Dao wildlife sanctuary (A) trail to summit of Khao Soi Dao; (B-D) summit of Khao Soi Dao; (E) Seto swamp.

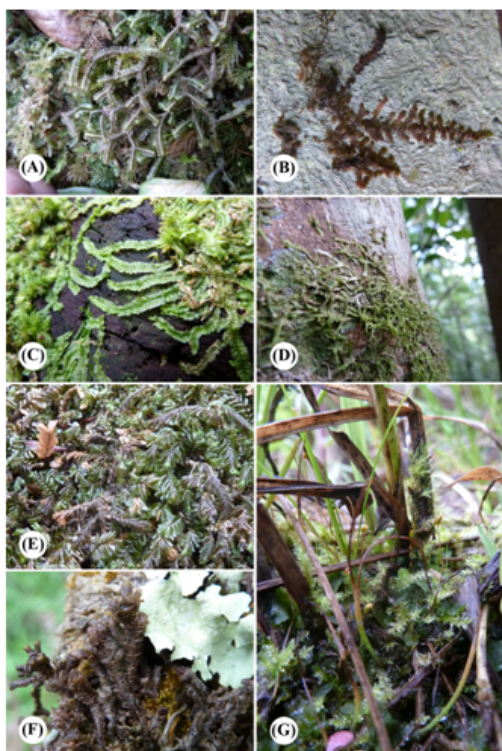


Figure 2. Some liverworts and hornwort found in Khao Soi Dao wildlife sanctuary (A) *Bazzania tridens* (Reinw., Blume & Nees) Trevis.; (B) *Frullania alstonii* Verd.; (C) *Heteroscyphus argutus* (Nees) Schiffn.; (D) *Metzgeria furcata* (L.) Corda; (E) *Plagiochila trabeculata* Steph.; (F) *Thysananthus convolutus* Lindenb.; (G) *Phaeoceros carolinianus* (Michx.) Prosk.



Figure 3. Some mosses found in Khao Soi Dao wildlife sanctuary (A) *Calyptrochaeta remotifolia* (Müll.Hal.) Z.Iwats., B.C.Tan & Touw; (B) *Diphyscium longifolium* Griff.; (C) *Ectropothecium sikkimense* (Renauld & Cardot) Renauld & Cardot; (D) *Fissidens nobilis* Griff.; (E) *Leucobryum juniperoideum* (Brid.) Müll.Hal.; (F) *Meteorium speciosum* (Dozy & Molke.) Mitt.; (G) *Pogonatum neesii* (Müll.Hal.) Dozy; (H) *Rhodobryum roseum* (Hedw.) Limpr.

area is subject to atmospheric clouds and mist to some extent. *Frullania meyeniana* is a common species there, whereas *Pleurozia gigantea*, *Pogonatum neesii*, and *Trachypodopsis serrulata* var. *crispatula* were found only once in one small group. In swamps, which are exposed to fully sun light, five species were collected. Of these, *Phaeoceros carolinianus* and *Thysananthus convolutus* were restricted to this area.

3.4 New records

The liverwort *Jubula hutchinsiae* subsp. *javanica* collected from Khao Soi Dao wildlife sanctuary has been reported as a new genus and species record to Thailand (Sukkharak, 2013). Four new records of mosses to Thailand including *Clastobryum glabrescens*, *Macromitrium lorifolium*, *Pterobryopsis gedehensis*, and *Radulina borbonica* are reported here: (1) *Clastobryum glabrescens*, previously known from China, Japan, Indonesia, Philippines (Wu Peng-Cheng and He, 2005), is distinguished by three-ranked leaves, serrate leaf margins in upper portion, and oval and colored alar cells. (2) *Macromitrium lorifolium*, previously found in Vietnam (Tan and Iwatsuki, 1993), is characterized by serrate leaf margins and percurrent costa. (3) *Pterobryopsis gedehensis*, is occurring in China and Philippines (Crosby *et al.*, 1999; Tan and Iwatsuki, 1991), and is essentially distinguished by entire leaf margins and non-costa. (4) *Radulina borbonica*, previously known from Réunion, Philippines, Indonesia, New Caledonia, Tahiti (O'Shea, 2006), is characterized by hamate leaves, laminal cells with pointed ends, and papillae on leaf cells. The data reveal that most of the new recorded species are previously reported from the Indo-Chinese flora. This supports that Khao Soi Dao wildlife sanctuary is influenced by the Indo-Chinese floristic region proposed by Van Welzen *et al.* (2011). Moreover, it indicates that the bryoflora of Thailand still remains poorly known, and that exciting discoveries may still be made in this area.

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