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TAXOMETRICS CLASSIFICATION (HIERARCHICAL AND ORDINATION) OF AQUATIC AND SEMI-AQUATIC MOSSES: A PRELIMINARY MODEL TO BRYODIVERSITY MANAGEMENT

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ABSTRACT

Bryodiversity is naturally serving the ecosystems sustainably. It serves the environments by preventing natural disaster (flooding), maintaining the quality of the water body and filter or treats the pollutants naturally. Efficient bryodiversity management is needed for environmental cost cutting and have a cost-effective management strategy. To achieve this, cluster and principal component analyses (PCA) were manipulated to produce the linkage distance between the OTUs and identify the important groups of characters, respectively. In return, it becomes a guideline for bryoflora and environmental managements. In this study, 23 OTUs and 156 characters were analyzed. The output from the reliability and item analysis showed that the data set is highly reliable (Cronbach's alpha = 0.9627). From the cluster analysis, it showed that 5 clustered groups (manageable units) could be derived from the produced phenogram. This is based on the nearest neighbour amalgation rule and Euclidean distances. As for the principal component analysis, three factors were derived and explained 75.1064% of the variation with 56.0485%(PC1), 11.7346%(PC2) and 7.3233%(PC3), respectively. The ordination showed that 5 manageable units were derived from PC1 and 3 manageable units for PC2 and PC3, respectively. In conclusion, conservation should precede any biodiversity management plans.

Key words: aquatic mosses, semi-aquatic mosses, cluster analysis, principal component analysis (PCA), classification

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INTRODUCTION

Bryodiversity management is a new discipline in management science. Bryodiversity refers to the richness of bryophytes (mosses, liverworts and hornworts). Management signifies planning conservational strategy, organizing conservational plans, implementing organized conservational approach and controlling or sustaining the on-going of the implemented plan with the aim to conserve the nature (Raffield and Bingham 1994). Based on Stuessy (1990), biosystematics is crucial in understanding the biodiversity of a particular ecosystem. In this context the focus is on the richness of aquatic and semi-aquatic mosses. Without knowing the richness, no conservation plan will be implemented and thus, floral extinction is highly potential.

In this study, aquatic and semi-aquatic mosses were studied phenetically to find out the rarity and commonness among the studied populations. This is very crucial in conservation where rare species should be urgently conserved and less threatened spesies should be sustained too. Cost-effective is the success key in any management activities (Raffield and Bingham 1994). Phenetic analysis (cluster analysis and principal component analysis) will statistically group species with the most similar characters together (Scotland and Carine 2000; Komosinki *et al.* 2001; and Aguilar *et al.* 2004) and forms few manageable units. Instead of over-consuming time and costs for few related or familiar species and neglecting other populations, managing clustered group will be the solution in the successful bryodiversity management.

This new approach aims for conservation and at the same time continues serving the needs of the ecosystem. In term of costs, no artificial flood mitigator and barrier, no water quality tester and no waste water contamination might be required if aquatic and semi-aquatic mosses are present in the natural habitats (Ando and Matsuo 1984; Frahm 1996; Welch 1948; Conrad 1935; Whitehouse and McAllister 1954; Ando 1957; Grout 1912; Coupal and Lalancette 1976).

MATERIALS AND METHODS

Moss material and characterization

Twenty-three species or operational taxonomic units were selected and 156 characters with different level of character states (Table 1) were chosen for numerical classification. Further phenetic methodology referred to Stuessy (1990), Stotler and Stotler (2000), Frahm (2003), Smith (1978), Holmes (1998), Tsai *et al.* (2002); and Yamagishi *et al.* (2005). The main sources for analyses were morphological and anatomical data: vegetative (gametophyte) and reproductive (sporophyte) components. Both taxonomic sources were measured quantitatively and qualitatively.

Table 1. Characters and character states for the taxometric analyses

(1)Plant size(0-small,1-big/large,2-others); (2)Plant habitat and submergence (0-semi-aquatic,1-aquatic,2-not submerged,3-sometimes partly submerged,4-occasionally submerged,5-others); (3)Plant colour(0-greenish to blackish and rarely whitish,1-others); (4)Ephemerality of plant(0-no,1-yes,2-others); (5)Plant growth form(0-acrocarpous,1-pleurocarpous,2-others); (6)Plant covered by glaucous

Table 1. Continued

or bluish(0-no,1-yes,2-others); (7)Plant: prostate to erect(0-no,1-yes,2-others); (8)Plant branching form(0-simple to pinnately branched,1-others); (9)Rarity of plant(0-rare to common,1-others); (10)Plant: terete or julaceous form(0-no,1-yes,2-others); (11)Plant: means of asexual reproduction(0-without,1-with,2-without or with,3-others); (12)Plant: coarseness(0-not coarse,1-coarse,2-others); (13)Plant with flattened shoots(0-no,1-yes,2-others); (14)Autoicous (autoecious)(0-without archegonia and antheridia in separate influorescences,1-with archegonia and antheridia in separate influorescences,2-others); (15)Plant with innovative branches beneath inflorescences(0-no,1-rare,2-often,3-others); (16)Plant: more than 5mm(0-no,1-yes,2-others); (17)Rhizoids(0-obvious/with rhizodal tubers,1-not obvious,2-others; (18)Leaves unbordered by row of cells(0-no,1-yes,2-others); (19)Leaf bordered by(0-elongate cells,1-smooth cells,2-others); (20)Leaf sheathing(0-rarely,1-often,2-others); (21)Leaf costa ending below the apex to excurrent(0-no,1-yes,2-others); (22)Leaf without hair-points(0-no,1-yes,2-others); (23)Leaf hair-points(0-hyaline,1-others); (24)Leaves all of one kind(0-no,1-yes,2-others); (25)Leaves direction(0-homomallous,1-others); (26)Leaves arrangement(0-attached all around the stem,1-attached in two rows on opposite sides of the stem (distichous),2-others); (27)Leaf lamina(0-conspicious,1-others); (28)Leaf lamina unistratose(0-no,1-yes,2-others); (29)Leaf layer(0-unistratose,1-multistratose,2-unistratose to multistratose,3-others); (30)Leaves inconspiciously ranked(0-no,1-yes,2-others); (31)Leaves apex(0-ovate to spatulate,1-others); (32)Leaves tip(0-acuminate to acute (awned),1-others); (33)Leaves(0-various,1-undulate,2-straight or straight when dry,3-plicate or deeply plicate,4-plicate or not,5-concave,6-others); (34)Leaf (dorsal view)(0-keeled or flat,1-others); (35)Leaves position(0-at extreme apex,1-others); (36)Leaf alteration(0-little altered when dry,1-others); (37)Adaxial surface of the leaf costa(0-without lamellae or filaments,1-with lamellae or filaments,2-broadly channeled or flat,3-others); (38)Leaf without cancellinae(0-no,1-yes,2-others); (39)Spreading leaves(0-without,1-with,2-with and wide,3-others); (40)Differentiation of branch and stem leaves(0-strongly,1-weakly/scarcely,2-others); (41)Apical cells of branch leaves(0-about 1/2 length of those at midleaf,1-scarcely shorter than those at midleaf,2-others); (42)Leaf bases(0-without cancellinae,1-with cancellinae,2-others); (43)Leaf base with appear split(0-no,1-yes,2-others); (44)Sheathing base of leaves(0-without,1-rarely,2-with,3-others); (45)Concave leaf bases(0-not concave,1-not concave and with a narrow insertion,2-with,3-others); (46)Leaf longer than 1mm(0-no,1-yes,2-others); (47)Leaf cross-section(0-recurved only on one side,1-plane to recurved,2-recurved to revolute,3-revolute,4-others); (48)Leaf bases never or gradually expanded(0-no,1-yes,2-others); (49)Propagula in leaf apices(0-without,1-with,2-others); (50)Leaf apices at extreme apex(0-margins entire or papillose-crenulate,1-others); (51)Leaf apices(0-acuminate to bluntly acute,1-cuspidate,2-cuspidate to piliferous,3-without piliferous or aristate (awn),4-with piliferous or aristate (awn),5-others); (52)Channeled leaf apices(0-no,1-yes,2-others); (53)Leaf cell diametry(0-isodiametric,1-more or less isodiametric,2-others); (54)Leaf cell surface(0-flat, smooth and papillose,1-smooth, bulging or prorulose,2-smooth,3-papillose or prorulose,4-smooth and papillose,5-flat,6-papillose (uni to pluri) or prorulose,7-rarely with minute cuticular roughenings,8-others); (55)Leaf cell type(0-one type,1-others); (56)Leaf cell colour(0-green,1-others); (57)Size of leaf cells(0-shorts,1-longs,2-others); (58)Relative size of leaf cells(zero.1(-2):1,one.above about 3:1 or longer,two.4:1 or less,three.1-4(-5),four.more than 10:1,five.(3-)4:1 or longer,six.others); (59)Relative size of upper leaf cells(zero. more than 5:1,one. 2-6:1,two.others); (60)Leaf cell papillose(0-no,1-pluripapillose,2-closely set, simple to branched papillae/simple to branched papillae,3-unipapollose to pluripapillose,4-with papillae stellate from a stipitate base to C-shaped,5-others); (61)Leaf cells in obvious rows(0-no,1-yes,2-others); (62)Leaf cell shape(0-long-hexagonal,1-short-rectangular to linear,2-conic, clavate or branched and rarely C-shaped,3-rounded to quadrate,4-linear,5-merely rounded and not stellate,6-

Table 1. Continued

long, linear and hexagonal,7-rectangular,8-rectangular to long-hexagonal,9-others) ; (63)Upper leaf cells(0-smooth or with low and indistinct papillae,1-smooth,2-firm-walled and short-oblong to rhombic,3- prorulose,4-densely pluripapillose with C-shaped papillae,5-others); (64)Basal leaf cells(0-usually without thickened transverse walls,1-others); (65)Papillose over the lumina or prorulose in leaf cells(0-no,1-yes,2-only papillose over the lumina,3-others);(66)Mid leaf cells of stem leaf(0-40–120 µm long,1-others);(67)Branch and stem leaves scarcely differentiated(0-no,1-yes,2-others);(68)Leaf margin(0-single teeth or entire,1-entire,2-toothed,3-abruptly serrate at the shoulder,4-entire and denticulate,5-serrate margins whose teeth are often reflexed,6-entire or papillose-crenulate,7-with paired teeth,8-others);(69)Numbers of leaf margin(0-single,1-double,2-two to multilayered,3-others);(70)Near midleaf or below recurved to revolute(0-no,1-yes,2-others);(71)Upper leaf margins plane to revolute (with cells undifferentiated or paler than median cells)(0-no,1-yes,2-others);(72)Stomates(0-absent,1-present,2-others);(73)Leaf costa(0-without a costa or costa short and double, double or single with 2-3 lateral spurs,1-single,2-distinct throughout,3-others);(74)Adaxial surface of leaf along costa(0-broadly channelled or flat,1-others);(75)Single leaf costa to at least midleaf(0-yes,1-others);(76)Apical of leaf costa(0-subpercurrent,1-bluntly excurrent,2-excurrent to ending in the cusp,3-others);(77)Transverse section of leaf costa(0-2 stereid bands,1-single and dorsal stereid band,2-differentiated stereid bands,3-others);(78)Both dorsal and ventral stereid bands present(0-no,1-yes,2-others);(79)Cells of abaxial surface of costa(0-oblong and elongate,1-quadrate to short-oblong,2-others);(80)Dorsal part of leaf costa(0-smooth or toothed at back (ridged),1-not ridged,2-others);(81)Size of leaf costa(0-narrow or much narrower,1-wide or broad,2-others);(82)Lamellae or filaments on the adaxial surface of the costa(0-without,1-with,2-others);(83)Ventral costal epidermis(0-absent,1-present,2-others);(84)Cells of adaxial (upper) surface of costa similar to or smaller than laminal cells in transverse section(0-no,1-yes,2-others);(85)Costa more than 100µm wide at base(0-no,1-yes,2-others);(86)Costa ending in the leaf apex(0-no,1-yes,2-others);(87)Costa ending below the apex to excurrent(0-no,1-yes,2-others);(88)Costa ending in a spine(0-no,1-yes,2-others);(89)Costa occupying less than 1/4 the leaf base(0-no,1-yes,2-others);(90)Axilliary hairs(0-hyaline,1-brown,2-others);(91)Basal cells of axilliary hairs(0-slender,1-others);(92)Alar cells(0-scarcely differentiated,1-inflated in well marked groups,2-not at all inflated,3-alar group not extending more than 20 – 40 % up leaf,4-others);(93)Stem paraphyllia(0-no,1-no or lacking,2-abundant and filamentous,3-others);(94)Stem paraphyllia foliose(0-no,1-yes,2-others); (95)Foliate stem(0-sometimes complanate,1-foliate throughout and without rhizome-like connections between erect stems,2-symmetrical,3-sometimes flattened,4-others);(96)Stem form(0-erect,1-occasionally branched beneath influrouscences,2-others);(97)Stem branching(0-not branched,1-mostly prostrate with lateral branches,2-prostrate with erect branches bearing terminal sporophytes (cladocarpous),3-branching various (e.g. complanate-foliate, flattened-foliate, prostrate with lateral branches and ranches curved downwards),4-others);(98)Stem ranked leaves(0-without,1-with,2-others);(99)Stem: central strand(0-absent,1-present,2-others);(100)Stem: hyalodermis(0-absent,1-present,2-others);(101)Stem abundance(0-sparse to abundant,1-others);(102)Stem sclerodermis(0-clearly differentiated,1-not or weakly developed,2-others); (103)Stem size(0-up to 2.7mm long,1-others); (104)Stem epidermal cells(0-small,1-big/large,2-others); (105)Stems round in transverse section(0-no,1-yes,2-others); (106)Sporophytes(0-various types,1-terminal,2-not clustered,3-lateral,4-others);(107)Size of capsule(0-small,1-big/large,2-others);(108)Capsule projection(0-long-exserted,1-exserted,2-others); (109)Capsule symmetry(0-symmetric,1-asymmetric,2-others); (110)Capsule(0-operculate or cleistocarpous,1-others); (111)Capsule: valvate(0-never,1-always,2-others); (112)Capsule growth form(0-erect or straight,1-inclined to pendulous,2-horizontal to pendulous,3-never furrowed

Table 1. Continued

or strumose,4-globose and rugulose to furrowed when dry,5-horizontal or pendulous,6-others);(113)Neck of capsule(0-short and inconspicious/inconspicuous,1-others);(114)Surface of capsule(0-smooth,1-smooth or furrowed,2-others);(115)Capsule narrower than urn(0-no,1-yes,2-others);(116)Position of capsule(0-distinctly terminal/terminal,1-others);(117)Shape of capsule(0-cylindric to oval,1-others);(118)Capsule longer than 1mm(0-no,1-yes,2-others);(119)Capsule apex and unlobed at base(0-no,1-yes,2-others);(120)Calyptrae(0-cucullate,1-others);(121)Calyptrae: plicate(0-no,1-yes,2-others);(122)Covering of calyptrae(0-covering only operculum,1-covering only operculum and capsule apex,2-others);(123)Calyptrae unlobed at base(0-no,1-yes,2-others);(124)Size of calyptrae(0-small,1-large/big,2-others);(125)Peristome(0-absent,1-present,2-present with papillose,3-others);(126)Number of peristome(0-single,1-single or absent,2-single or double,3-double,4-others);(127)Peristome teeths(0-16,1-with teeth united in a high or rarely low,2-others);(128)Peristome state(0-not reflexed,1-spirally twisted above,2-with tubular basal membrane ,3-others);(129)Development of peristome(0-weakly developed,1-better developed,2-strongly developed,3-others);(130)Basal membrane of endostome(0-keeled,1-others);(131)Segments of endostome(0-keeled and perforate,1-others);(132)Endostome with cilia(0-no,1-yes,2-others);(133)Exostome(0-without or free of,1-with,2-others);(134)Operculum(0-conic to apiculate,1-others);(135)Projection of seta(0-exserted,1-others);(136)Size of seta(0-longer than 2mm,1-others);(137)Perichaetial position(0-terminal,1-usually low and simple to bifid,2-others);(138)Perichaetia with papillae(0-no,1-yes,2-absent to large,3-others);(139)Perichaetial surface(0-not scablike,1-scablike,2-others);(140)Perichaetial leaves (bract)(0-slightly or not differentiated,1-not differentiated,2-less differentiated,3-others);(141)Shape of bract(0-never long awned,1-others);(142)Propagula cup(0-absent,1-present,2-others);(143)Propagula(0-absent,1-present,2-with or without,3-sometimes present,4-never on leaf apices but sometimes elsewhere on leaves or in axils,5-others);(144)Axillary propagula(0-without,1-with,2-others);(145)Cells without nodulose-waxy walls(0-no,1-yes,2-others);(146)Cell characteristics(0-smooth, lax, thin-walled and hexagonal to rhombic,1-others);(147)Cells of old plants without colour change to bluish-green(0-no,1-yes,2-others);(148)Cell walls not thickened on abaxial side(0-no,1-yes,2-others);(149)Angular cells(0-not opaque,1-others);(150)End walls of basal cells not thickened(0-no,1-yes,2-others);(151)Hyaline basal cells (if present)(0-extending equal to costa,1-others);(152)Laminal cells surface view(0-obscure,1-well-defined,2-others);(153)Basal laminal cells(0-differentiated, hyaline and elongated,1-little differentiated, green and short-rectangular,2-others);(154)Tomentum (if present)(0-restricted to extreme base of stems,1-others);(155)Gemmae(0-without,1-with,2-others);(156)Nerve(0-(60-) 65 – 115µm wide near base,1-others).

Data analysis

Two analyses: cluster analysis (depicting similarities among OTUs) (Madeira *et al.* 1999; Ferguson *et al.* 2000; Sharma *et al.* 2004) and principal component analysis (PCA) (non-hierarchical relationships among OTUs) (McNulty 2004) were chosen and performed on the matrix data (Table 2-11). For cluster analysis, single linkage amalgation rule and Euclidean distances measure were manipulated for classification. STATISTICA 6.0 (by StatSoft, Inc. 2001) was utilized in this taxometric study (Mazak and Groves, 2006). Further numerical taxonomic methodology followed Luna *et al.* (2000); Romero *et al.* (2000); and Kim *et al.* (2003).

Data validation

Reliability and item analysis was performed to measure the overall representation of the data analyzed and degree of bias. This test was run with STATISTICA 6.0 (by StatSoft, Inc, 2001).

RESULTS AND DISCUSSIONS

The output from the reliability and item analysis showed that the data set is highly reliable (Cronbach's alpha = 0.9627). This means that more than 96% of the data analyzed were true score variability and reflecting the real situation. This value is higher than the standardized alpha (0.9612).

The character states (156 characters examined) for 23 OTUs (Table 2–11) were analyzed and produced 22 nodes for classification.

Table 2. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses

Operational Taxonomic Unit (OTU)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Barbula bolleana (Müll. Hal.) Broth.	1	0	0	0	0	0	1	0	0	2	3	2	2	2	3	2	1	1
Bryum caespiticium Hedw.	1	2	1	0	0	0	1	0	0	0	2	1	0	2	3	2	1	1
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	1	3	1	0	0	0	1	0	0	0	2	1	0	2	3	2	1	1
Cratoneuron filicinum (Hedw.) Spruce	2	0	1	2	2	2	1	0	1	2	3	2	2	2	3	2	2	2
Didymodon tophaceus (Brid.) Lisa	1	0	0	0	0	0	1	0	0	2	3	2	2	2	3	2	1	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	1	0	0	0	0	0	1	0	0	2	2	2	2	2	3	2	1	0
Eurhynchium speciosum (Brid.) Jur.	1	0	0	0	1	2	0	1	0	2	3	2	2	2	3	2	2	0
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	1	0	0	0	1	2	0	1	0	2	3	2	2	2	3	2	2	0
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	2	0	1	2	2	2	2	1	1	2	3	2	2	2	3	2	2	2
Fissidens grandifrons Brid.	2	4	1	2	2	2	2	1	1	2	3	2	2	2	3	2	2	2
Fontinalis antipyretica Hedw.	2	1	1	2	1	2	2	1	1	2	3	2	2	2	3	2	2	2
Fontinalis duriaei Schimp.	2	4	1	2	1	2	2	1	1	2	3	2	2	2	3	2	2	2
Gymnostomum calcareum Nees & Hornsch.	1	0	0	2	0	0	1	0	0	2	2	2	2	2	3	2	1	0
Hygroamblystegium tenax (Hedw.) Jenn.	1	1	0	0	1	2	1	0	0	2	3	1	2	2	3	2	2	1
Hymenostylium recurvirostrum (Hedw.) Dixon	2	0	1	2	2	2	2	1	1	2	3	2	2	2	3	2	2	2
Leptodictyum humile (P. Beauv.) Ochyra	2	0	0	0	1	2	1	0	0	2	3	2	1	1	3	2	2	0
Leptodictyum riparium (Hedw.) Warnst.	2	0	0	0	1	2	1	0	0	2	3	2	1	1	3	2	2	0
Palustriella commutata (Hedw.) Ochyra	2	0	0	2	2	2	1	0	1	2	3	2	2	2	3	2	2	2
Philonotis fontana (Hedw.) Brid.	1	4	0	0	0	0	1	0	0	2	3	2	2	2	2	2	1	2
Platyhypnidium riparioides (Hedw.) Dixon	1	1	0	0	1	2	1	0	0	2	3	2	2	2	3	2	2	0
Pohlia melanodon (Brid.) A.J. Shaw	1	0	0	0	0	0	1	0	0	0	3	1	2	2	3	1	1	1
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	1	0	0	0	0	0	1	0	0	0	3	1	2	2	3	1	1	1
Tortula marginata (Bruch & Schimp.) Spruce	1	0	0	0	0	0	1	0	0	2	2	2	2	2	3	2	0	0

Table 3. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Barbula bolleana (Müll. Hal.) Broth.	2	2	2	1	1	1	1	0	0	2	2	1	1	1	0	1	0	1
Bryum caespiticium Hedw.	0	2	1	1	1	1	2	0	0	2	3	2	0	0	0	1	1	1
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	0	2	1	1	1	1	2	0	0	2	3	2	0	0	0	1	1	1
Cratoneuron filicinum (Hedw.) Spruce	2	2	2	2	1	2	1	0	1	2	3	2	1	1	5	1	1	1
Didymodon tophaceus (Brid.) Lisa	2	2	2	0	1	1	1	0	0	2	1	1	1	1	0	1	0	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	2	2	2	1	1	1	1	0	0	2	0	2	1	1	0	1	1	1
Eurhynchium speciosum (Brid.) Jur.	0	2	2	1	1	1	2	0	0	2	3	2	1	1	3	1	1	1
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	0	2	2	1	1	1	2	0	0	2	3	2	1	1	4	1	1	1
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	2	2	2	2	1	2	1	1	1	2	3	2	1	1	6	1	1	1
Fissidens grandifrons Brid.	2	2	2	2	1	2	1	1	1	2	3	2	1	1	6	1	1	1
Fontinalis antipyretica Hedw.	2	2	2	2	1	2	1	0	1	1	3	2	1	1	6	0	1	1
Fontinalis duriaei Schimp.	2	2	2	2	1	2	1	0	1	1	3	2	1	1	6	0	1	1
Gymnostomum calcareum Nees & Hornsch.	2	2	2	1	1	1	1	0	0	2	0	2	1	1	0	1	0	1
Hygroamblystegium tenax (Hedw.) Jenn.	0	2	2	1	1	1	1	0	0	2	3	2	1	1	0	1	0	1
Hymenostylium recurvirostrum (Hedw.) Dixon	2	2	2	2	1	2	1	0	1	2	3	2	1	1	6	1	0	1
Leptodictyum humile (P. Beauv.) Ochyra	2	2	1	1	2	1	1	0	0	2	3	2	1	1	4	1	1	1
Leptodictyum riparium (Hedw.) Warnst.	2	2	1	1	2	1	1	0	0	2	3	2	1	1	4	1	1	1
Palustriella commutata (Hedw.) Ochyra	2	2	2	2	1	2	1	0	1	2	3	2	1	1	3	1	1	1
Philonotis fontana (Hedw.) Brid.	2	0	2	0	1	1	1	0	0	2	0	1	1	1	2	1	1	1
Platyhypnidium riparioides (Hedw.) Dixon	2	2	1	2	1	1	1	0	0	2	3	2	1	1	4	1	1	1
Pohlia melanodon (Brid.) A.J. Shaw	2	2	2	1	1	1	1	0	0	2	3	1	1	1	6	1	1	0
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	2	2	2	1	1	1	1	0	0	2	3	1	1	1	6	1	1	0
Tortula marginata (Bruch & Schimp.) Spruce	1	2	2	0	0	1	1	0	0	2	0	2	1	1	6	1	1	1

Table 4. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Barbula bolleana (Müll. Hal.) Broth.	0	2	3	2	2	1	2	0	3	2	1	1	0	0	5	2	0	0
Bryum caespiticium Hedw.	1	2	3	2	2	2	2	0	3	2	1	1	2	1	5	2	2	0
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	1	2	3	2	2	2	2	0	3	2	1	1	2	1	5	2	2	0
Cratoneuron filicinum (Hedw.) Spruce	0	2	3	2	2	2	2	3	3	2	4	2	2	1	5	2	2	8
Didymodon tophaceus (Brid.) Lisa	2	1	3	2	2	2	2	0	3	2	1	1	0	0	5	2	2	0
Eucladium verticillatum (Brid.) Bruch & Schimp.	3	1	3	2	2	2	2	0	3	2	1	2	2	1	5	2	2	6
Eurhynchium speciosum (Brid.) Jur.	3	2	1	0	0	2	2	0	0	2	1	2	2	1	0	2	2	2
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	3	2	1	0	0	2	2	0	0	2	1	2	2	1	0	2	2	2

Table 4. Continued

Operational Taxonomic Unit (OTU)	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	3	2	3	2	2	2	1	3	3	2	4	2	2	1	5	2	2	8
Fissidens grandifrons Brid.	3	2	3	2	2	2	1	3	3	2	4	2	2	1	5	2	2	8
Fontinalis antipyretica Hedw.	0	2	3	2	2	2	2	3	3	2	4	2	2	1	5	2	2	7
Fontinalis duriaei Schimp.	0	2	3	2	2	2	2	3	3	2	4	2	2	1	5	2	2	7
Gymnostomum calcareum Nees & Hornsch.	2	1	3	2	2	2	2	0	3	1	4	0	0	1	5	2	2	6
Hygroamblystegium tenax (Hedw.) Jenn.	0	2	2	2	2	2	2	0	3	2	1	2	2	1	0	2	2	8
Hymenostylium recurvirostrum (Hedw.) Dixon	3	2	3	2	2	2	2	3	3	2	0	2	2	1	5	2	2	7
Leptodictyum humile (P. Beauv.) Ochyra	1	2	2	1	1	2	2	0	1	2	1	2	2	1	0	0	2	2
Leptodictyum riparium (Hedw.) Warnst.	1	2	2	1	1	2	2	0	1	2	1	2	2	1	0	0	2	2
Palustriella commutata (Hedw.) Ochyra	0	2	3	2	2	2	2	3	3	2	4	2	2	1	5	2	2	7
Philonotis fontana (Hedw.) Brid.	0	2	3	2	2	2	2	0	3	2	1	1	2	1	5	2	2	3
Platyhypnidium riparioides (Hedw.) Dixon	1	2	3	2	2	2	2	0	3	2	1	2	2	1	5	2	2	2
Pohlia melanodon (Brid.) A.J. Shaw	0	2	3	2	2	2	2	3	3	1	1	0	2	1	5	2	2	4
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	0	2	3	2	2	2	2	3	3	1	1	0	2	1	5	2	2	4
Tortula marginata (Bruch & Schimp.) Spruce	0	1	3	2	2	0	2	1	3	2	4	0	0	1	2	2	1	0

Table 5. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Barbula bolleana (Müll. Hal.) Broth.	0	0	0	0	1	2	3	5	1	2	1	2	0	3	2	2	2	3
Bryum caespiticium Hedw.	0	0	2	1	2	5	0	0	0	1	3	1	2	1	0	2	2	1
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	0	0	2	1	2	5	0	0	0	1	3	1	2	1	0	2	2	1
Cratoneuron filicinum (Hedw.) Spruce	0	0	2	6	2	5	2	9	5	2	3	2	2	8	3	2	2	2
Didymodon tophaceus (Brid.) Lisa	0	0	0	3	2	2	2	2	5	0	2	1	2	0	3	2	2	2
Eucladium verticillatum (Brid.) Bruch & Schimp.	0	0	2	6	2	3	2	3	5	1	1	1	2	0	3	2	2	2
Eurhynchium speciosum (Brid.) Jur.	0	0	2	4	0	2	4	5	1	1	3	1	2	5	3	2	2	2
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	0	0	2	4	0	2	4	5	1	1	3	1	2	5	3	2	2	2
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	0	0	2	6	2	5	2	9	5	1	3	1	2	8	3	2	2	2
Fissidens grandifrons Brid.	0	0	2	6	2	5	2	9	5	1	3	1	2	8	3	2	2	2
Fontinalis antipyretica Hedw.	0	0	2	6	2	5	2	9	1	1	3	1	2	1	3	2	2	2
Fontinalis duriaei Schimp.	0	0	2	6	2	5	2	9	1	1	3	1	2	1	3	2	2	2
Gymnostomum calcareum Nees & Hornsch.	0	0	2	3	2	2	2	5	5	0	1	1	2	0	3	2	2	2
Hygroamblystegium tenax (Hedw.) Jenn.	0	0	2	6	0	5	2	9	2	1	2	1	2	5	3	2	2	2
Hymenostylium recurvirostrum (Hedw.) Dixon	0	0	2	6	2	1	2	9	5	1	3	1	2	6	3	1	2	2
Leptodictyum humile (P. Beauv.) Ochyra	0	0	1	4	0	5	2	6	5	1	2	0	1	4	2	2	2	2
Leptodictyum riparium (Hedw.) Warnst.	0	0	1	4	0	5	2	6	5	1	2	0	1	4	2	2	2	2

Table 5. Continued

Operational Taxonomic Unit (OTU)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Palustriella commutata (Hedw.) Ochyra	0	0	2	6	2	5	2	9	5	1	3	1	2	8	3	2	2	2
Philonotis fontana (Hedw.) Brid.	0	0	2	6	2	5	2	7	3	1	3	1	2	7	3	2	2	2
Platyhypnidium riparioides (Hedw.) Dixon	0	0	2	4	0	5	2	4	5	1	3	1	2	5	2	2	2	2
Pohlia melanodon (Brid.) A.J. Shaw	0	0	1	5	2	5	0	8	5	1	3	1	2	0	3	2	2	2
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	0	0	1	5	2	5	0	8	5	1	3	1	2	0	3	2	2	2
Tortula marginata (Bruch & Schimp.) Spruce	0	0	2	6	2	4	2	3	4	0	1	1	2	8	0	2	1	2

Table 6. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Barbula bolleana (Müll. Hal.) Broth.	1	1	0	0	2	0	0	0	1	2	2	3	3	3	3	3	3	0
Bryum caespiticium Hedw.	3	1	1	3	3	2	2	0	0	1	2	2	2	2	1	2	2	2
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	3	1	1	3	3	2	2	0	0	1	2	2	2	2	1	2	2	2
Cratoneuron filicinum (Hedw.) Spruce	3	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Didymodon tophaceus (Brid.) Lisa	1	0	1	3	2	2	1	0	0	0	1	2	2	2	2	2	2	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	3	1	0	3	2	1	2	0	0	2	2	2	2	2	2	2	2	2
Eurhynchium speciosum (Brid.) Jur.	3	1	1	3	3	2	2	2	0	2	2	2	2	2	2	2	2	2
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	3	1	1	3	3	2	2	2	0	2	2	2	2	2	2	2	2	2
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	3	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissidens grandifrons Brid.	3	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Fontinalis antipyretica Hedw.	0	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Fontinalis duriaei Schimp.	0	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Gymnostomum calcareum Nees & Hornsch.	1	0	0	3	1	2	2	1	0	0	1	2	2	2	2	2	2	2
Hygroamblystegium tenax (Hedw.) Jenn.	4	2	0	1	3	2	2	2	1	0	2	2	1	1	2	2	2	3
Hymenostylium recurvirostrum (Hedw.) Dixon	3	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Leptodictyum humile (P. Beauv.) Ochyra	2	1	0	3	3	2	2	2	0	1	2	2	2	2	1	2	2	2
Leptodictyum riparium (Hedw.) Warnst.	2	1	0	3	3	2	2	2	0	1	2	2	2	2	1	2	2	2
Palustriella commutata (Hedw.) Ochyra	3	1	0	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
Philonotis fontana (Hedw.) Brid.	3	1	0	3	3	2	2	0	0	2	2	2	2	2	2	2	2	2
Platyhypnidium riparioides (Hedw.) Dixon	3	1	0	3	3	2	2	2	0	2	2	2	2	2	1	1	2	2
Pohlia melanodon (Brid.) A.J. Shaw	3	1	0	3	3	2	2	0	0	2	2	2	2	2	2	2	1	2
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	3	1	0	3	3	2	2	0	0	2	2	2	2	2	2	2	1	2
Tortula marginata (Bruch & Schimp.) Spruce	1	1	0	2	1	2	2	0	0	2	2	1	2	2	2	2	2	2

Table 7. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
Barbula bolleana (Müll. Hal.) Broth.	1	0	1	2	0	1	0	0	1	0	1	2	1	2	2
Bryum caespiticium Hedw.	1	0	1	2	1	0	0	2	2	1	1	2	1	2	2
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	1	0	1	2	1	0	0	2	2	1	1	2	1	2	2
Cratoneuron filicinum (Hedw.) Spruce	2	1	1	1	2	2	4	2	2	2	0	2	1	2	2
Didymodon tophaceus (Brid.) Lisa	0	0	1	2	0	0	0	0	1	2	1	0	1	2	2
Eucladium verticillatum (Brid.) Bruch & Schimp.	1	0	1	2	4	0	0	2	2	2	1	2	1	2	2
Eurhynchium speciosum (Brid.) Jur.	1	4	1	2	4	2	1	2	2	2	1	2	1	2	2
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	1	4	1	2	4	2	1	2	2	2	1	2	1	2	2
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	1	4	3	2	4	2	4	2	2	2	1	2	1	2	2
Fissidens grandifrons Brid.	1	4	3	2	4	2	4	2	2	2	1	2	1	2	2
Fontinalis antipyretica Hedw.	1	4	3	2	3	2	4	2	2	2	1	2	1	2	2
Fontinalis duriaei Schimp.	1	4	3	2	3	2	4	2	2	2	1	2	1	2	2
Gymnostomum calcareum Nees & Hornsch.	1	0	1	2	3	1	0	0	1	0	1	1	0	0	2
Hygroamblystegium tenax (Hedw.) Jenn.	1	4	1	2	3	2	1	2	2	2	1	2	1	2	2
Hymenostylium recurvirostrum (Hedw.) Dixon	1	4	3	2	4	2	4	0	1	2	1	2	1	2	2
Leptodictyum humile (P. Beauv.) Ochyra	1	3	1	2	4	2	2	2	2	2	1	2	1	2	2
Leptodictyum riparium (Hedw.) Warnst.	1	3	1	2	4	2	3	2	2	2	1	2	1	2	2
Palustriella commutata (Hedw.) Ochyra	1	1	2	2	2	2	4	2	2	2	1	2	1	2	2
Philonotis fontana (Hedw.) Brid.	1	0	1	2	3	0	0	2	2	2	1	2	1	2	1
Platyhypnidium riparioides (Hedw.) Dixon	1	2	3	2	3	2	1	2	2	2	1	2	1	2	2
Pohlia melanodon (Brid.) A.J. Shaw	1	0	1	2	3	0	0	2	2	2	1	2	1	2	1
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	1	0	1	2	3	0	0	2	2	2	1	2	1	2	1
Tortula marginata (Bruch & Schimp.) Spruce	1	0	1	2	3	0	0	2	2	2	1	2	1	2	2

Table 8. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Barbula bolleana (Müll. Hal.) Broth.	0	0	0	0	0	0	0	0	0	1	1	1	2	2	0
Bryum caespiticium Hedw.	0	0	1	1	0	0	1	1	2	1	0	0	1	2	1
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	0	0	1	1	0	0	1	1	2	1	0	0	1	2	1
Cratoneuron filicinum (Hedw.) Spruce	0	2	2	2	0	0	6	1	1	2	1	1	2	2	1
Didymodon tophaceus (Brid.) Lisa	0	0	0	0	0	0	0	0	1	1	1	2	1	0	0
Eucladium verticillatum (Brid.) Bruch & Schimp.	0	2	2	2	1	2	6	1	2	2	0	1	2	2	1
Eurhynchium speciosum (Brid.) Jur.	3	2	2	2	0	2	6	1	2	1	1	1	2	2	1
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	3	2	2	2	0	2	6	1	2	1	1	1	2	2	1

Table 8. Continued

Operational Taxonomic Unit (OTU)	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	0	2	2	2	1	2	6	1	2	2	1	1	2	2	1
Fissidens grandifrons Brid.	0	2	2	2	1	2	6	1	2	2	1	1	2	2	1
Fontinalis antipyretica Hedw.	0	2	2	2	1	2	6	1	2	2	1	1	2	2	1
Fontinalis duriaei Schimp.	0	2	2	2	1	2	6	1	2	2	1	1	2	2	1
Gymnostomum calcareum Nees & Hornsch.	0	0	1	0	0	0	0	1	2	1	1	0	2	2	0
Hygroamblystegium tenax (Hedw.) Jenn.	3	2	2	2	0	0	6	1	2	1	1	1	2	2	1
Hymenostylium recurvirostrum (Hedw.) Dixon	3	2	2	2	1	2	6	1	2	2	1	1	2	2	1
Leptodictyum humile (P. Beauv.) Ochyra	3	2	2	2	0	0	6	1	2	1	1	1	2	2	1
Leptodictyum riparium (Hedw.) Warnst.	3	2	2	2	0	0	6	1	2	1	1	1	2	2	1
Palustriella commutata (Hedw.) Ochyra	0	2	2	2	0	0	6	1	2	2	1	1	2	2	1
Philonotis fontana (Hedw.) Brid.	1	0	1	0	0	0	4	1	2	1	1	1	2	2	1
Platyhypnidium riparioides (Hedw.) Dixon	3	2	2	2	0	0	6	1	2	1	1	1	2	2	1
Pohlia melanodon (Brid.) A.J. Shaw	4	0	1	0	0	0	0	0	2	1	0	1	2	2	1
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	4	0	1	0	0	0	2	0	2	1	0	1	2	2	1
Tortula marginata (Bruch & Schimp.) Spruce	1	0	1	0	0	0	6	1	1	1	1	0	2	1	0

Table 9. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
Barbula bolleana (Müll. Hal.) Broth.	0	2	2	2	1	0	0	3	3	1	1	2	2	1	0
Bryum caespiticium Hedw.	2	2	2	2	1	4	2	3	1	0	0	1	0	2	0
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	2	2	2	2	1	4	2	3	1	0	0	1	0	2	0
Cratoneuron filicinum (Hedw.) Spruce	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Didymodon tophaceus (Brid.) Lisa	0	2	2	0	1	2	2	3	1	1	1	2	2	1	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	2	2	2	2	3	4	2	3	3	1	1	2	2	2	1
Eurhynchium speciosum (Brid.) Jur.	2	2	2	2	3	4	2	3	2	1	1	2	2	1	1
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	2	2	2	2	3	4	2	3	2	1	1	2	2	1	1
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Fissidens grandifrons Brid.	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Fontinalis antipyretica Hedw.	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Fontinalis duriaei Schimp.	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Gymnostomum calcareum Nees & Hornsch.	2	1	1	2	1	1	2	3	3	1	1	2	2	1	1
Hygroamblystegium tenax (Hedw.) Jenn.	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Hymenostylium recurvirostrum (Hedw.) Dixon	2	2	2	2	0	4	2	3	3	1	1	2	2	1	1
Leptodictyum humile (P. Beauv.) Ochyra	2	2	2	2	3	2	2	0	3	1	1	2	2	0	1
Leptodictyum riparium (Hedw.) Warnst.	2	2	2	2	3	2	2	0	3	1	1	2	2	0	1

Table 9. Continued

Operational Taxonomic Unit (OTU)	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
Palustriella commutata (Hedw.) Ochyra	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Philonotis fontana (Hedw.) Brid.	2	2	2	2	3	4	2	3	1	1	1	2	2	1	1
Platyhypnidium riparioides (Hedw.) Dixon	2	2	2	2	3	4	2	3	3	1	1	2	2	1	1
Pohlia melanodon (Brid.) A.J. Shaw	2	2	2	2	3	3	2	3	3	1	1	2	2	1	0
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	2	2	2	2	3	3	2	3	3	1	1	2	2	1	0
Tortula marginata (Bruch & Schimp.) Spruce	2	0	2	0	1	4	1	2	3	1	1	2	2	1	1

Table 10. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	136	137	138	139	140	141	142	143	144	145	146
Barbula bolleana (Müll. Hal.) Broth.	0	0	1	0	0	0	0	5	2	1	1
Bryum caespiticium Hedw.	0	2	3	2	3	1	2	2	0	1	0
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	0	2	3	2	3	1	2	2	0	1	0
Cratoneuron filicinum (Hedw.) Spruce	1	2	3	2	3	1	2	5	2	2	1
Didymodon tophaceus (Brid.) Lisa	1	0	2	0	0	0	2	0	2	1	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	1	2	3	2	1	1	2	2	1	1	1
Eurhynchium speciosum (Brid.) Jur.	1	2	3	2	3	1	2	5	2	1	1
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	1	2	3	2	3	1	2	5	2	1	1
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	1	2	3	2	3	1	2	5	2	2	1
Fissidens grandifrons Brid.	1	2	3	2	3	1	2	5	2	2	1
Fontinalis antipyretica Hedw.	1	2	3	2	3	1	2	3	2	2	1
Fontinalis duriaei Schimp.	1	2	3	2	3	1	2	3	2	2	1
Gymnostomum calcareum Nees & Hornsch.	1	0	2	2	2	1	2	2	2	1	1
Hygroamblystegium tenax (Hedw.) Jenn.	1	2	3	2	3	1	2	5	2	2	1
Hymenostylium recurvirostrum (Hedw.) Dixon	1	2	3	2	3	1	2	5	2	2	1
Leptodictyum humile (P. Beauv.) Ochyra	1	2	3	2	3	1	2	0	2	1	1
Leptodictyum riparium (Hedw.) Warnst.	1	2	3	2	3	1	2	0	2	1	1
Palustriella commutata (Hedw.) Ochyra	1	2	3	2	3	1	2	5	2	2	1
Philonotis fontana (Hedw.) Brid.	1	2	3	2	1	1	2	2	2	1	1
Platyhypnidium riparioides (Hedw.) Dixon	1	2	3	2	3	1	2	5	2	1	1
Pohlia melanodon (Brid.) A.J. Shaw	0	2	3	2	3	1	2	2	1	1	1
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	0	2	3	2	3	1	2	2	1	1	1
Tortula marginata (Bruch & Schimp.) Spruce	1	2	3	2	1	1	2	2	2	1	1

Table 11. Matrix table showing the character states (156 characters) for the 23 OTUs of aquatic and semi-aquatic mosses.

Operational Taxonomic Unit (OTU)	147	148	149	150	151	152	153	154	155	156
Barbula bolleana (Müll. Hal.) Broth.	2	2	1	2	0	0	0	1	2	1
Bryum caespiticium Hedw.	1	1	1	2	0	2	2	1	2	1
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey & Scherb.	1	1	1	2	0	2	2	1	2	1
Cratoneuron filicinum (Hedw.) Spruce	2	2	1	2	1	2	2	1	2	1
Didymodon tophaceus (Brid.) Lisa	2	2	1	2	0	1	1	1	2	1
Eucladium verticillatum (Brid.) Bruch & Schimp.	2	2	1	2	0	2	2	1	2	1
Eurhynchium speciosum (Brid.) Jur.	2	2	1	2	1	2	2	0	2	1
Eurhynchium hians (Hedw.) Sande Lac. var. *hians*	2	2	1	2	1	2	2	0	2	1
Fissidens crassipes subsp. *warnstorfii* (M. Fleisch.) Brugg.-Nann.	2	2	1	2	1	2	2	1	2	1
Fissidens grandifrons Brid.	2	2	1	2	1	2	2	1	2	1
Fontinalis antipyretica Hedw.	2	2	1	2	1	2	2	1	2	1
Fontinalis duriaei Schimp.	2	2	1	2	1	2	2	1	2	1
Gymnostomum calcareum Nees & Hornsch.	2	2	1	2	0	2	2	1	2	1
Hygroamblystegium tenax (Hedw.) Jenn.	1	2	2	1	2	2	2	1	2	1
Hymenostylium recurvirostrum (Hedw.) Dixon	2	2	1	2	1	2	2	1	2	1
Leptodictyum humile (P. Beauv.) Ochyra	2	2	0	2	1	2	2	0	0	0
Leptodictyum riparium (Hedw.) Warnst.	2	2	0	2	1	2	2	0	0	0
Palustriella commutata (Hedw.) Ochyra	2	2	1	2	1	2	2	1	2	1
Philonotis fontana (Hedw.) Brid.	2	2	1	2	0	2	2	1	2	1
Platyhypnidium riparioides (Hedw.) Dixon	2	2	1	2	1	2	2	0	2	1
Pohlia melanodon (Brid.) A.J. Shaw	2	2	1	2	0	2	2	1	2	1
Pohlia wahlenbergii (F. Weber & D. Mohr) A.L. Andrews	2	2	1	2	0	2	2	1	2	1
Tortula marginata (Bruch & Schimp.) Spruce	2	2	1	1	0	2	2	1	2	1

The output of the analysis is presented in phenogram (Figure 1). In the first, second and third node, the linkage distance value is 1.0000 for *Bryum caespiticium* and *Bryum pseudotriquetrum, Eurhynchium speciosum* and *Eurhynchium hians* var. *hians*; and, *Leptodictyum humile* and *Leptodictyum riparium*, respectively. The distance linkage between *Pohlia melanodon* and *Pohlia wahlenbergii* is 2.0000 (node 4). As for node 5, the value is 3.0000 between *Fontinalis antipyretica* and *Fontinalis duriaei*.Two different genera of *Cratoneuron filicinum* and *Palustriella commutata* showed the value of 3.7417 in node 6. *Fissidens crassipes* subsp. *warnstorfii* and *Fissidens grandifrons* in the seventh node are distantly valued 4.0000.

At the eighth node (6.4807), *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii* and *Fissidens grandifrons* were linkaged. Next, *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii*, *Fissidens grandifrons* and *Hymenostylium recurvirostrum* were clustered under node 9 with linkage distance value of 8.0000. At the tenth node, *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii*, *Fissidens grandifrons*, *Hymenostylium recurvirostrum*, *Fontinalis antipyretica* and *Fontinalis duriaei* were distantly measured with value of 9.6954.

With distance linkage value of 10.2956, three species of *Leptodictyum humile*, *Leptodictyum riparium* and *Platyhypnidium riparioides* were linkaged under node 11. Next, *Eurhynchium speciosum*, *Eurhynchium hians* var. *hians*, *Leptodictyum humile*, *Leptodictyum riparium* and *Platyhypnidium riparioides* were analyzed to have distance linkage value of 10.3923 (twelfth node). Under node 13, there are *Eurhynchium speciosum*, *Eurhynchium hians* var. *hians*, *Leptodictyum humile*, *Leptodictyum riparium*, *Platyhypnidium riparioides* and *Philonotis Fontana* (11.3137). *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii*, *Fissidens grandifrons*, *Hymenostylium recurvirostrum*, *Fontinalis* antipyretica, *Fontinalis duriaei*, *Eurhynchium speciosum*, *Eurhynchium hians* var. *hians*, *Leptodictyum humile*, *Leptodictyum riparium*, *Platyhypnidium riparioides* and *Philonotis Fontana* are under one cluster group (node 14 and distance linkage equals to 11.5326).

Under node 15, *Didymodon tophaceus* and *Gymnostomum calcareum* were found with 11.7898 value. For the sixteenth node, *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii*, *Fissidens grandifrons*, *Hymenostylium recurvirostrum*, *Fontinalis antipyretica, Fontinalis duriaei*, *Eurhynchium speciosum*, *Eurhynchium hians* var. *hians*, *Leptodictyum humile*, *Leptodictyum riparium*, *Platyhypnidium riparioides*, *Philonotis Fontana* and *Hygroamblystegium tenax* were having distance value of 11.8743. With linkage distance value of 12.0831, *Didymodon tophaceus*, *Gymnostomum calcareum* and *Eucladium verticillatum* were grouped under node 17.

Node 18 showed the combination between node 16 and 17 with 12.4097. Distance linkage value of 12.4499 grouped all OTUs under node 18 and node 4 to become node 19. As for node 20, the combination is between node 19 and *Tortula marginata* (12.5300). *Barbula bolleana* and node 20 (12.8452) formed node 21. The distance linkage value for all OTUs is 12.8564.

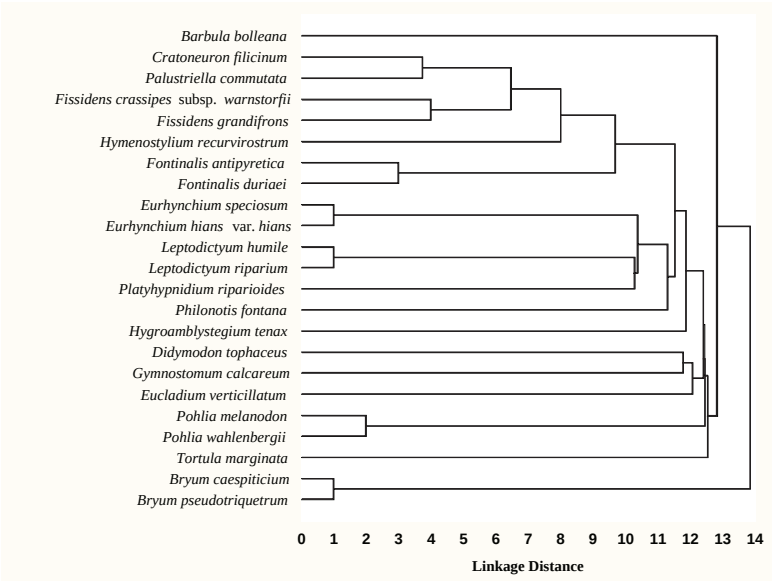

Figure 1. Dendogram showing the single linkage (nearest neighbours) clustering relationship based on Euclidean Distance among the 23 species of mosses

According to the principal component and classification analysis, the quality of representation value is 100% or most reliable. The first three components explained 75.1064% of the variation with 56.0485%(PC1), 11.7346%(PC2) and 7.3233%(PC3) respectively (Table 12). Components with eigenvalues lower than 1 were eliminated and not significant statistically. For PC1, the main variables are from the vegetative parts (plant and leaf) and major morphometric characters are numbered 3, 8, 9, 26, 27, 33 (negative loading), 51 (negative loading), 54 (negative loading), 55, 56, 58 (negative loading), 60 (negative loading), 63 (negative loading), 68 (negative loading) and 143 (negative loading). Less important on the reproductive part (capsule): 110, 112 (negative loading) and 126 (negative loading). PC2 showed the major variable is alar cells of leaf (92). The focal part is on the vegetative component of the bryophyte. Factor loading scores for PC3 were less correlated to the variables (characters) as compared to PC1 and PC2 . Any factor score lower than 5.0000 is considered insignificant and eliminated from the factor loading tables.

Table 12. Taxometric variables for the first three principal components

Component	*Eigenvalue*	*% Total Variance*	*Cumulative %*
1	12.89116	56.04853	56.0485
2	2.69895	11.73459	67.7831
3	1.68436	7.32332	75.1064

Figure 2. shows that mosses are skewed obviously to the negative side for PC1. PC1 grouped species obviously into three groups (i, j, o, d, r, n, k, l, p, q, h and g; s, v, u and f; and e, b and c) and 4 identical individual species (t, w, m and a). As for PC2 (Figure 2), 2 groups were segregated into the positive (i, j, o, d, r, n, k, l, p, q, h and g) and negative (s, v, u, f, m, a, e, b and c) sides; and 2 individual species near to the intermediary part (t and w).

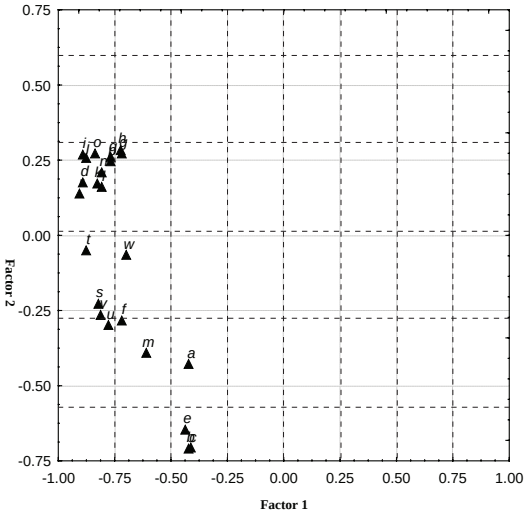

Figure 2. Scatter diagram between PC1 and PC2 from principal component analysis of 23 species of aquatic and semi-aquatic mosses using 156 characters

In Figure 3, PC3 grouped OTUs into one positive group of h, g, b, c, p, q, t, n and w; negative group of m, e, a, k, l, r, i,d, j, k, l, o, v and u; one species under intermediary line (f); and one species near to intermediary line (s). PC1 (Figure 3) segregated the individuals inconspicuously. Basically, individual species grouped under intermediary area is sharing characters from positive and negative sides.

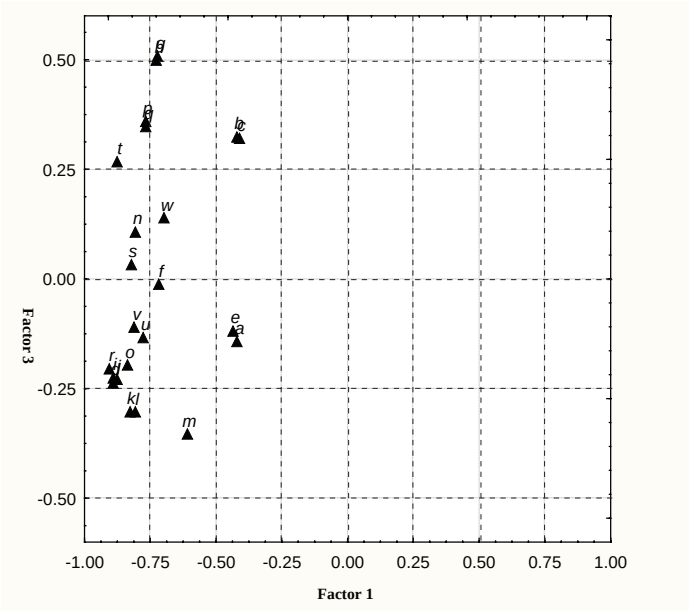

Figure 3. Scatter diagram between PC1 and PC3 from principal component analysis of 23 species of aquatic and semi-aquatic mosses using 156 characters

For cluster analysis, the algorithm chosen was hierarchical (aggromerative) (Tipirdamaz *et al.* 2006). This is because the main objective of this study is to group OTUs from smaller clusters into a larger groups (polythetic) (Stuessy 1990). The end result is to divide clustered groups for efficient aquatic and semi- aquatic bryodiversity management. The amalgation rule for analysis was single linkage (nearest neighbour) as the purpose to study the species relationship among OTUs and the measurement for distance between species was based on Euclidean distance. Euclidean distance is the most common and easy to interpret (Statistica 6.0, 2001). In this analysis, numbers of variables, cases and subcases analyzed were massive. Indirectly, biases and standard deviations were minimized. As the result, the reliability of the output is more than 96%.

On the other hand, clustering bryodiversity into few manageable units are very crucial and cost-effective. The relationship between a cluster of mosses reflects the generic, familial or higher taxonomic similarity. Genetically, they are sharing a closer gene pool (genotypes) and morphologically, the phenotypes are significant characters for identification and serving the ecosystem. Mosses are natural bioindicator for water quality, soil erosion controller and filtering the wastewater naturally (Ando and Matsuo 1984;

Frahm 1996; Welch 1948; Conrad 1935; Whitehouse and McAllister 1954; Ando 1957; Grout 1912; Coupal and Lalancette 1976). Thus, this approach can help bryodiversity managers to conserve the aquatic and semi-aquatic mosses in a collective way. In a simple manner, we efficiently manage all the clusters of mosses equally. Equality helps in balancing the habitat (ecosystem) for the benefits of human beings. Ironically, wrong management strategy can be bias to certain species, the other species will be neglected and the ecosystem will not be served naturally.

From the dendogram (Figure 1), there are 22 nodes. Thus, management strategy can be based on the nodes in the phenogram. For node 10, one management cluster can be formed from few subclusters which consists of *Cratoneuron filicinum*, *Palustriella commutata*, *Fissidens crassipes* subsp. *warnstorfii*, *Fissidens grandifrons*, *Hymenostylium recurvirostrum*, *Fontinalis antipyretica* and *Fontinalis duriaei*. Subclusters of node 13 (*Eurhynchium speciosum*, *Eurhynchium hians* var. *hians*, *Leptodictyum humile*, *Leptodictyum riparium*, *Platyhypnidium riparioides* and *Philonotis Fontana*), node 18 (*Didymodon tophaceus*, *Gymnostomum calcareum*, *Hygroamblystegium tenax* and *Eucladium verticillatum*), node 20 (*Tortula marginata*, *Pohlia wahlenbergii and Pohlia melanodon*) and node 22 (*Bryum caespiticium, Bryum pseudotriquetrum and Barbula bolleana).* In short, five management units of bryodiversity are proposed for management.

Under principal component analysis (PCA), management of clustered groups are strengthened (Tipirdamaz *et al.* 2006). Based on Statistica 6.0 (2001), PCA is reducing the numbers of variables and transform important variables into numbers of principal component. This is beneficial in management, where precise group of identifiable characters (in this context) are known for management and conservation. Furthermore, PCA is a very cost-effective tool for biodiversity management.

In cluster analysis, bryodiversity management is based on hierachical clustered manageable unit and PCA is based on group of related characters that forms one factor. In this case, we have three principal components. In the first principal component (Figure 2), we have three distinct groups and four independent OTUs (can form two minor groups). Thus, 5 managable units can be formed. All OTUs were skewed to the negative side. Statistically, it signifies all the OTUs were likely characterized differently from the common character states. This is very similar to the numbers of manageable units derived from cluster analysis, but with distinct species combination. As for the second component, 3 managable units were formed. It consists of a positive group that agrees with most of the common character states, a negative group that complies likely to the opposite character states and two intermediary individuals (skewed a bit to the negative side) where sharing both common and uncommon (more) character states. In Figure 3, three manageable units were observed: one positive-skewed group, one negative-skewed group and one individual in the intermediary line.

Comparing both taxometric classifications, cluster analysis is useful in hierachically linked OTUs for relationship-based management approach. All characters have the same weight and will be used totally. As for PCA, it groups OTUs on the scatter plot that refers to the group of important characters (principal component). Thus, only critical characters are used for efficient management. Relatively, both approaches to bryodiversity management are highly appreciated. Only through cluster analysis, the linkage distance will be known and important for future populational references. This means that populations are

evolving and further revisions will further change the taxonomic structure. For instance, PCA does not show this feature. In a nutshell, both approaches are supplementing each ones. Both combinations will help in solving managerial dilemma and problems.

CONCLUSION

Bryodiversity in the Mediterrean area of Spain is relatively lower (23 species of aquatic and semi-aquatic mosses) as compared to the 46 species recorded in the Tropical region of Sabah, Malaysia.Bryoflora conservation cum management have to be taken place. This is critical as the bryophytes are naturally serving the ecosystems continually and sustainably. The studied mosses were phenetically related and could be divided into 5 cluster groups through cluster analysis. The clustered group can be managed as a manageable unit. The rationale is that no single population will be overmanaged or neglected; and equal conservational plan to be implemented among the phenetically related units.

The manipulation of Principal Component Analysis (PCA) in this study reduced the least important characters used for management. The output produced three components with each group contain numbers of vital characters within. This is cost-effective for bryodiversity managers. This analysis allowed managers to identify, manage and conserve populations based on the components. From this study, output from cluster analysis will be an alternative to the results produced from the PCA. Nevertheless, both outputs are highly reliable and ready to be used for management. In a nutshell, it is more meaningful to conserve natural environmental regulator rather than creating man-made mitigator.

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