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Biogeochemical Ecology of six Species of *Sphagnum* in Costa Rica

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There is very little information on the biogeochemical ecology of *Sphagnum* species in tropical regions. The majority of the ecological information on *Sphagnum* species in the tropics consists of general habitat information and pH values that are reported in new species descriptions and regional floras such as those of Crum (1980, 1989), Crum and Buck (1988), Karlin (1991), and McQueen (1989).

The few studies of *Sphagnum* habitats that have been published are restricted to the paramo habitats of northwestern South America. Cleef (1981) described four different kinds of *Sphagnum* bogs in the Cordillera Oriental of Colombia. The distinctions Cleef made between these bogs were based on vegetation, pH, altitude, and depth of the peat. The four major types are the *Sphagnum* bog with *Espeletia* and *Blechnum*, *Sphagnum* bog with *Swallenchloa*, *Sphagnum* bog with giant *Puya*, and the *Xyris-Sphagnum* bog. In addition, Cleef also described other kinds of *Sphagnum* habitats such as those found in wet seeps, along peaty lake shores, floating mats, and in boggy glacial valleys between 3600 and 3850 m.

Sanchez et al. (1989) examined the vegetation on peat deposits in the paramos around Bogota, Colombia. They concluded that bryophytes make up a major portion of the paramo vegetation and that several species of *Sphagnum* are dominant in some phases of succession from open water and small lakes to marshes. The six different paramo habitats that they examined have a high content of organic matter, moderate content of nitrogen, and low concentrations of Ca, Mg, K, and Na.

McQueen (1991) examined the niche breadth and overlap of four *Sphagnum* species in southern Ecuador. The pH, conductivity, and concentrations of Fe, K, Mg, Mn, Na, and P in the small peatlands that were examined were found to be similar to intermediate or transitional poor fens in the Northern Hemisphere.

The paucity of data on the biogeochemistry of *Sphagnum* species in the tropics is surprising. Based on field studies and herbarium specimens, we have found that there are at least 44 species of *Sphagnum* in the mountainous regions of Central America and northern South America. McQueen (1991) noted the destruction of peatland habitats by farmers in southern Ecuador. During the past year we observed the ongoing destruction of the type localities of *S. poasense* Crum in Costa Rica and *S. azuayense* Crum in Ecuador. The purpose of this study was to examine the biogeochemistry of some *Sphagnum* species and small peatlands in Costa Rica. It is our hope that this study will stimulate further interest in the

ecology of tropical *Sphagnum* species and provide a better understanding of tropical *Sphagnum* species.

Methods and Materials

Several sites in the mountainous regions of Costa Rica were selected for this study. Two of the sites can be referred to as peatlands. The largest of these peatlands is located near kilometer 70 of the Pan American Highway about halfway up the summit of Cerro del Muerte (3,491 m). *Sphagnum* forms extensive carpets in this peatland of about 40 ha. Species of *Blechnum*, *Vaccinium*, *Carex*, *Juncus*, and *Xyris* are the most noticeable vascular plants in this peatland. Karlin (1991) reported *S. sancto-josephense* Crum & Crosby, *S. lescurii* Sull. [= *S. subsecundum* var. *rufescens* (Nees & Hornsch.) Hub.], *S. magellanicum* Brid., and *S. platyphyllum* (Lindb.) Sull. We also found *S. alegrense* Warnst. and *S. sparsum* Hampe. Many of the older *Blechnum* trunks show evidence of being burned in the past and many of the young *Blechnum* exhibit evidence of recent burning in early 1991.

The second peatland, approximately half the size of the first peatland, is located near the summit of Volcan Poas (2,708 m). *Sphagnum sancto-josephense*, the most common species, forms carpets throughout the peatland with smaller populations of *S. poasense* Crum, *S. magellancium*, *S. recurvum* P. Beauv., and *S. sparsum*. *Vaccinium Carex*, *Isoetes*, *Juncus*, and *Xyris* are the most prominent vascular plants in this peatland. Several water courses up to 3 m deep traverse the peatland. In some of the drier portions of the peatland it was possible to observe a peat deposit of more than 2 m in depth in some places.

Additional sites of smaller populations of *Sphagnum* were examined on the slopes and summits of Cerro Chirripo (3,819 m) and Cerro del Muerte (3,491 m). *Sphagnum* forms small carpets and hummocks in the subalpine paramo forests of both these mountains. *Quercus*, *Arctostaphylos*, and *Lomaria* are the dominant vascular plants in these habitats. *Sphagnum* becomes common at an elevation of approximately 2,700 m on Cerro Chirripo and at 3,300 m on Cerro del Muerte. Cerro Chirripo is one of the few mountains in the region that was glaciated during the Pleistocene (Weber 1959). On Cerro Chirripo, *Sphagnum* is found around the margins of the numerous moraine lakes near the summit. According to the ranger, the water of the moraine lakes may recede by as much as 5 m during the dry season, leaving the *Sphagnum* populations very dry for several months of the year. On Cerro del Muerte, *Sphagnum* is found in the paramo just below the summit. *Sphagnum aureum* McQueen, *S. meridense* (Hampe) C.M., *S. cuspidatum* Hoffm., *S. gomezii* Crum, *S. perichaetiale* Hampe, *S. sparsum*, *S. magellanicum*, and *S. alegrense* are found on both of the mountains.

We examined only sites where there was surface water near a particular species. For this reason we were only able to examine the habitats of *S. alegrense*, *S. aureum*, *S. magellanicum*, *S. platyphyllum*, *S. sancto-josephense*, and *S. sparsum*. A total of 65 sites were visited with multiple samples at some sites, especially the two large peatlands. The water samples were kept cool until analyzed. The pH and conductivity (K_{corr}), corrected for H^+ concentration (Sjors 1950), were examined at a temperature of 20° C within 24 hours. The samples were kept frozen until analyzed for Ca, Fe, Mg, Mn, P, K, and Na by atomic adsorption spectrophotometry. Height above the water table and shade were not examined due to time constraints on our research time in Costa Rica and limitations on carrying equipment in the field.

Results

The two large peatlands on Volcan Poas and Cerro del Muerte are similar except for Fe, Na, and K which were many times higher in the Cerro del Muerte peatland (Table 1). There were many areas within both peatlands that were so dry that the *Sphagnum* plants crumbled when handled. The low pH of these peatlands is probably a result of the dry season. I previously visited these sites at the end of the wet season in 1988 and found more standing pools of water and recorded pH readings greater than 5.0.

The means for the various parameters for the species growing in all sites are similar (Table 2). The largest differences are for Fe and K. The pools of water surrounding *S. platyphyllum* were about 100 times higher in Fe than for any other species. The concentration of K in the pools

Table 1. Mean values of environmental parameters measured in two *Sphagnum* peatlands in Costa Rica. Ion concentrations are in ppm, conductivity in μmohs/cm, and n is the number of samples. Standard deviations are in parentheses.

Peatland	pH	K_{corr}	Ca	Mg	Fe	Mn	Na	K	P
Volcan Poas (n=12)	4.3 (0.8)	51.5 (9.8)	3.6 (0.6)	0.9 (0.08)	2.1 (0.1)	0.3 (0.01)	2.2 (0.1)	7.2 (1.3)	0.4 (0.2)
Cerro del Muerte (n=15)	3.8 (0.4)	48.5 (22.8)	5.8 (4.7)	3.3 (2.6)	14.1 (43.7)	0.8 (0.8)	39.7 (23.5)	72.5 (33.2)	1.9 (1.3)

Table 2. Mean values of environmental parameters measured for *Sphagnum* species from Costa Rica. Ion concentrations are in ppm, conductivity in μmohs/cm, and n is the number of samples. Standard deviations are in parentheses.

Species	pH	K_{corr}	Ca	Mg	Fe	Mn	Na	K	P
S. alegrense	3.9 (0.4)	51.5 (19.5)	6.5 (5.4)	3.5 (2.4)	8.1 (0.6)	0.9 (0.5)	46.8 (19.5)	79.3 (26.3)	2.5 (1.4)
S. aureum	3.4 (0.3)	63.3 (17.3)	7.5 (6.3)	3.2 (2.6)	0.4 (0.1)	1.5 (0.9)	30.6 (11.3)	132.5 (27.9)	3.2 (1.8)
S. magellanicum	4.3 (0.7)	41.3 (24.5)	7.8 (6.2)	2.9 (2.6)	0.9 (0.2)	0.9 (0.3)	24.6 (20.0)	71.2 (40.7)	1.8 (1.5)
S. platyphyllum	4.0 (0.6)	54.6 (26.7)	7.9 (0.2)	4.9 (0.1)	100.5 (75.5)	1.2 (0.2)	30.5 (3.9)	61.6 (33.4)	1.6 (0.5)
S. sancto-josephense	3.5 (0.5)	42.1 (18.7)	3.9 (4.2)	2.7 (3.1)	0.9 (0.1)	0.3 (0.3)	30.3 (24.3)	70.2 (31.7)	1.6 (1.4)
S. sparsum	4.1 (0.6)	44.9 (25.4)	5.6 (4.0)	2.6 (2.0)	1.2 (0.7)	1.0 (0.5)	24.9 (17.3)	82.0 (42.0)	1.7 (1.2)

around *S. aureum* were almost twice that of the other species examined.

Discussion

The values of the environmental parameters measured for the two peatlands examined in this study are similar to those reported by Sanchez et al. (1989) and Cleef (1981) in Colombia and McQueen (1991) for peatlands in southern Ecuador. The Cerro del Muerte peatland is most similar to the *Xyris-Sphagnum* bog type of Cleef (1981). In Colombia, Cleef describes these bogs as occurring between 3300 and 3700 m in upper subparamo and lower grass paramo. Common vascular plants, aside from *Xyris*, include *Blechnum, Hypericum* and *Halenia*. He described the soils as clayey to black peat with a pH range of 4.6- 5.3. The lower pH that we found in the Cerro del Muerte peatland may be attributed to the late date during the dry season when we examined this peatland. McQueen (1989) reported pH values closer to those of Cleef during a visit to a neighboring site at the end of the wet season a few years earlier. Both *S. magellanicum* and *S. sancto-josephense* are the dominant *Sphagnum* species in this peatland which also corresponds to Cleef's description of this type of peatland. One major deviation from Cleef's description is in the apparent greater diversity of *Sphagnum* species in the Costa Rican peatland on Cerro del Muerte compared to those reported by Cleef and Sanchez et al. (1989). Cleef reported only three species, *S. magellancium, S. sancto-josephense*, and *S. cuspidatum*, whereas, we found a total of at least six species.

The Volcan Poas peatland is most similar to a subtype of the *Xyris-Sphagnum* bog that Cleef (1981) refers to as the *Xyris acutifolia* bog. These bogs are described as forming on gentle slopes (3 - 5°), with a peaty clay depth of more than 120 cm, and a pH of about 5.0. In addition to *Xyris*, some common species in these types of peatlands include *Vaccinium* and *Isoetes*. Cleef reported that *S. magellanicum*, *S. sancto-josephense*, and *S. cuspidatum* are the most common species of *Sphagnum*. The Volcan Poas peatland has a similar vascular species composition, similar *Sphagnum* species, peat depth, and altitude. As mentioned earlier in the discussion the low pH of this Costa Rican peatland may be attributed to the season. In fact herbarium specimens collected by McQueen in December 1988 indicate that the pH ranged between 4.5 and 6.25 [*S. sancto-josephense*: McQueen 4060, 4061, 4062, 4067, 4074 (NY)]. It is also important to note that the Costa Rican peatland has more *Sphagnum* species in it. The pH and cation concentrations from the two Costa Rican peatlands are also similar to the values reported for the Colombian peat deposits examined by Sanchez et al. (1989). They reported a pH range of 4.2 to 5.3 for the sites that they examined which is not too different from what we found if one considers seasonal variation in pH. Their average values for Ca (3.9 meq/ 100 g) and Mg (2.0 meq/ 100 g), although not directly comparable, also suggest some similarities in these ion concentrations. However, the concentrations of K (1.06 meq/100 g) and Na (1.12 meq/100 g) that they reported from Colombia are much lower than the values we found for these cations (Table 2) and the concentration of P (22.8 ppm) is much greater. One explanation for the differences in K and Na is based on the fact that the ion concentrations in the Cerro del Muerte peatland were much higher for all ions (Table 1) and thus, may skew the averages reported for most of the species listed in Table 2.

The means of the environmental parameters for the individual species are similar to those reported for species in North America and South America with a few exceptions. Both the Na and K concentrations are in some cases ten times greater than values reported by Vitt and Slack (1975, 1984) and McQueen (1991). The Fe concentration for *S. platyphyllum* is approximately 100 times greater than the other species. High Fe concentrations in association with this species have also been reported by Sjors (1950). Sanchez et al. (1989) reported pH and cation concentrations for two species that were included in this study. They found the pH range of *S. magellanicum* to be between 4.2 and 4.9, and the concentration of Ca to be greater than the concentration of Mg. Likewise, for *S. sancto-josephense* they reported a pH range of 4.4 to 4.8 and a similar relationship between concentrations of Ca and Mg.

The species diversity in the paramo habitats of Costa Rica is greater than that reported for the paramo in Colombia. We found 13 species

in the sites we examined in Costa Rica compared to eight species reported for similar habitats in Colombia by Cleef (1981) and Sanchez et al. (1989). The four species that are in common to both regions are *S. magellanicum*, *S. sancto-josephense*, *S. recurvum*, and *S. cuspidatum*. We agree with Cleef (1981), Sanchez et al. (1989), and McQueen (1991) that the most common species in these paramo habitats of Central America and northwestern South America are *S. magellancium* and *S. sancto-josephense*. Of these species, only the latter species has a neotropical distribution, the other species have broad distributions throughout the Northern Hemisphere and portions of the Southern Hemisphere (Crum 1984).

Sphagnum alegrense, *S. aureum*, and *S. magellanicum*, which are all in the same section Sphagnum of the genus, also exhibit some interesting differences. *Sphagnum alegrense* was found in habitats with much greater concentrations of Fe and *S. aureum* was found in habitats with nearly twice the concentration of K as the other two species.

Differences such as these and the high Fe concentration for *S. platyphyllum* suggest niche diversification along microhabitat gradients and independent species utilization of the gradients as reported by Vitt and Slack (1984) and McQueen (1991). However, further comparisons cannot be made without calculation of niche breath and width for each species. In spite of this limitation the present study presents a more accurate representation of tropical *Sphagnum* biogeochemistry than reported by McQueen (1991) because many more diverse habitats and sites were sampled.

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