Observations on *Botrychium virginianum* (Ophioglossaceae), A Fern Uncommon in the Eastern Andes of Peru

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Botrychium virginianum (L.) Sw. is a widely distributed terrestrial herb in the New World, Europe, and Asia. In numerous humid, mid-latitude forests, this fern species has been described as frequent or common in occurrence (e.g., Tryon et al., 1940; Massey, 1944; Cranfill, 1980; Theiret, 1980; Lellinger, 1985; Cody & Britton, 1989). Fewer records are known for the low-latitude sites of the New World (e.g., Proctor, 1985; Mickel & Beitel, 1988; Lellinger, 1989) and observations on population sizes have not been published. Widespread fern species that are common in mid-latitudes and uncommon in low latitudes would form a biogeographical element of great interest, if this can be shown to be a general pattern and not due to lack of information from the tropical sites.

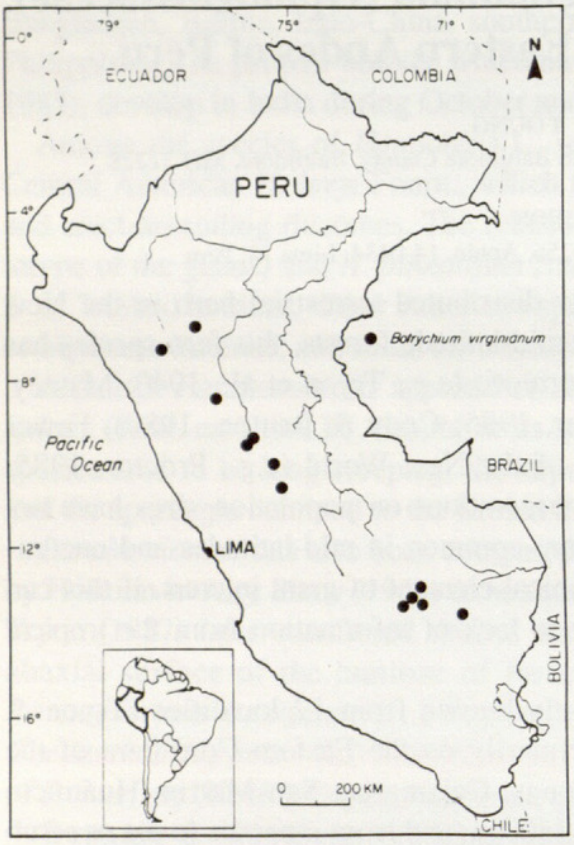
In Peru, *Botrychium virginianum* is currently known from 12 localities (Tryon & Stolze, 1989; our observations). These are primarily on the Eastern Cordillera of the Andes (Fig. 1), in the departments of Amazonas, Cajamarca, San Martín, Huánuco, Pasco, Junín, and Cusco, at elevations of 1800–3500 m, and from montane forest or scrub vegetation. Yet it was not the regional scarcity of *Botrychium virginianum* in Peru that first attracted our interest, but its local scarcity among the vegetation types we were studying in a national park in northern Peru (Young & León, 1988, 1990, 1991): of approximately 750 herbarium specimens made of pteridophytes from this park, only three were from *B. virginianum.* During the installation of a one hectare permanent tree plot in the park in June and July of 1988, we noticed this fern's presence within the demarcated area and decided to inventory it's sporophyte population.

In this study, we quantify *Botrychium virginianum's* presence on the forest plot, and then propose explanations for its local and regional distribution patterns.

STUDY AREA AND METHODS

The study area was in Chochos valley in the tropical subalpine zone of Rio Abiseo National Park, at approximately 3350 m elevation and 7°39'S, 77°29'W. Annual precipitation is probably at least 2500 mm, the mean annual temperature is approximately 5–8°C, and the climate is virtually aseasonal, with only a short dry season in July or August.

Young (1990: Chapter 3) chose a site within the timberline forest, but near the edge of that forest with high elevation grasslands (Fig. 2), and there he established a square one hectare plot that was gridded using stakes and meter tapes into 2500 contiguous 4-m^2 subplots. On each of these subplots, the identity, diameter, and height was recorded of every tree, shrub or tree fern with a minimum diameter of 2.5 cm at breast height (dbh). Each subplot was classified in terms of presence or absence of fallen trees or large branches, large boulders appearing above the soil surface, and canopy openings at least 1 m^2 in size and visible as projected vertically from a 2 m height (Brokaw, 1982). For *Botrychium virginianum,* we recorded the number of sporophytes in each subplot and the



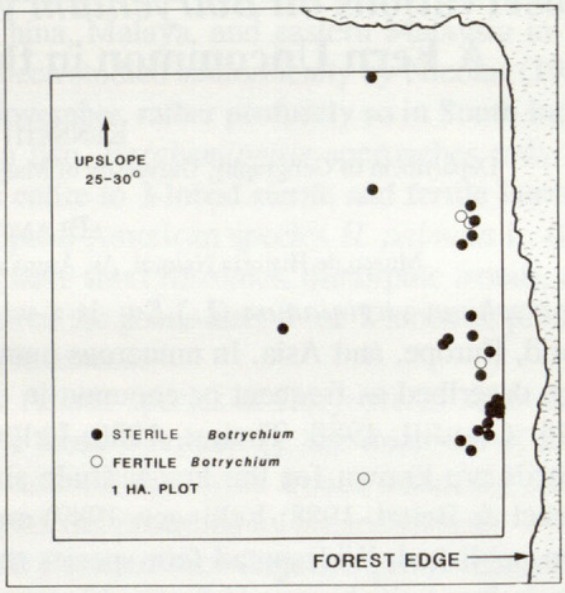


Fig. 1. Sites of herbarium collections of *Botrychium virginianum* in Peru, based on Tryon and Stolze (1989) and the authors' collections and observations.

Fig. 2. Locations of sporophytes of *Botrychium virginianum* on the 100 by 100 m plot made in a timberline forest bordering upon high elevation grasslands.

presence of any fertile leaves. Great care was taken during our fieldwork not to alter the understory by cutting or otherwise making trails, and no living plants were damaged or removed.

Young (1990: Chapter 3) described and analyzed the composition and abundance of the trees and shrubs on this plot, and offered some preliminary information on the tree ferns (Table 1). He found a significant positive association (Chi-square test, $p < 0.01$) between the presence of fallen trees or branches and the presence of canopy openings on the 4-m^2 subplots. Another noteworthy finding was a strong edge effect on the plot related to the presence of open subalpine grasslands 1–15 m from one of the plot's margins (Fig. 2).

Table 1. Site characteristics, and woody plant and tree fern diversity and abundance on the one ha forest plot sampled at 3350 m in the eastern Andes of Peru (Young, 1990).

Slope angles: 25– 30°.
Soils: acidic, with 5-20 cm organic matter on top of 20–100 cm of a black silt loan derived from glacial loess.
Trees and shrubs with diameters ≥2.5 cm:
46 species from 25 families and 32 genera.
Consisted of 1801 stems, with 38.8 m^2 of basal area.
Most common species were *Weinmannia auriculata* D. Don, Cunoniaceae;
Hedyosmum scabrum (R. & P.) Solms, Chloranthaceae;
Myrsine cf. *andina* (Mez) Pipoly, Myrsinaceae;
Ilex sp., Aquifoliaceae; *Ruagea hirsuta* (C.DC) Harms, Meliaceae.
Tree ferns with diameters ≥2.5 cm:
Two species: *Cyathea pallescens* (Sodiro) Domin, *Sphaeropteris atahuallpa* R. Tryon.
Consisted of 330 stems, with 3.1 m^2 of basal area.
Forest canopy height was 10 m (SD = 3).
Of 2500 contiguous 4-m^2 subplots, 78 had canopy openings, 682 had fallen logs or branches, and 12 had boulders.

This edge effect consisted of a lower forest canopy (8 m, instead of 10–11 m inside the forest), increased tree and shrub density (from about 1500 stems/ha to more than 2500 stems/ha on the edge), and the presence of eleven tree and shrub species restricted to forest edge habitat. He hypothesized that this was due only in part to the present-day environmental gradient of increased light on the forest edge (see also Young, 1993); there was also evidence that forest within about 40 m of the edge was not in compositional equilibrium and was, in fact, in a late successional stage, probably recovering from a grassland fire that may have entered and devastated the stand of trees many years previously. The subalpine grasslands of the study area do not burn naturally. Instead, grassland burning is a common tradition by local people, as it is in similar areas elsewhere (Horn, 1989; Laegaard, 1992).

Results

Twenty-nine plants of *Botrychium virginianum* were found on the one ha plot (Fig. 2). Four of these plants were fertile at the time of sampling.

Habitat affinities of *B. virginianum* on the plot were examined at two different spatial scales: that of the original 4-m^2 subplots and of those subplots aggregated into 625 16-m^2 subplots. There were no significant positive or negative associations (Chi-square tests, $p = 0.58–0.90$), at either of these scales, between presence of the fern and presence of canopy openings, fallen logs or branches, and boulders. The only microhabitat affinity we were able to document was the presence of most (89%) of the ferns inside the forest but within 20 m of the subalpine grasslands (Fig. 2).

Discussion

Botrychium virginianum was present in the sampled forest at a density of 29 plants/ha. However, it was even less conspicuous than these numbers would indicate because of its small stature (10–25 cm) and its spatial clustering near the forest edge (Fig. 2). In continuous montane forest (i.e., without edges) there would presumably be little suitable habitat. The tests of association indicate that rock outcroppings or small canopy openings associated with tree- or branchfalls do not provide a suitable habitat for this fern. Even in our study area, where forest edges were fairly common, a pteridologist penetrating more than 20 m within the forest would be unlikely to find this fern.

Botrychium virginianum was not an edge species in our study area in the same sense as *Hypolepis obtusata*, which was found only in the 2–3 m wide zone of shrubby growth that separated the grassland from the forest (Young & León, 1991). Rather it was mostly found in forest that bordered on an open edge. There might be a set of environmental characteristics unique to this location that could explain its presence there. Or the critical factor for this fern might be related to the time elapsed following a disturbance, suggesting that its spatial distribution on the plot was due to an association with forest in a late successional stage. The latter explanation receives some support from a recent study done in central Sweden: Stahl (1990) showed that the largest populations of *Botrychium virginianum* were found in 5–30 year old conifer stands, while only very sparse populations were present in conifer stands 70–100 year old; new establishment of sporophytes was limited to those stands that were 5–15 year old.

Plant species that are specialists on habitat edges for whatever reason are naturally uncommon, at least as long as edges make up a small percentage of the area of a vegetated landscape. Add to that the inconspicuousness of *Botrychium virginianum*, and it is now clear why we had thought this fern to be rare in Rio Abiseo National Park.

Based on these observations, we suggest that *Botrychium virginianum* is probably much more ubiquitous in montane habitats in Peru than the herbarium collections would seem to indicate. However, due to its habitat requirements, this will be an uncommon fern everywhere except where forest edges are abundant and successional forests predominate. As these are the very features that characterize most of the humid temperate forests of North America and Europe (Curtis, 1959; Burgess & Sharpe, 1981; Naveh & Lieberman, 1984; Turner, 1987), it would appear that the relative abundance there of *Botrychium virginianum* is to be expected.

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