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One hundred and twenty years of bryology in the Vertizarana Valley (Navarra, North Spain)

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Abstract – The bryophytes collected in the years 1885, 1926-1935, 1972-1975 and 2006-2007 in Vertizarana Valley (Navarra, North Spain) have been studied, identifying or compiling 253 species. Fertility and Ellenberg's indicator values for light, temperature, substrate pH and nitrogen have been analysed. Results indicate that there have been small variations in Ellenberg's indicator values along the time span studied: the tendencies point at a decrease in light and increase in temperature and nitrogen, while substrate pH does not show a clear tendency. Regarding fertility, the overall number of species with sporophytes or sexual organs has decreased and several species seem to have lost fertility. All this suggests that changes in ecological conditions and air quality may have taken place in the Vertizarana Valley.

Bryophytes / Integrated Monitoring / ICP-IM / Navarra / Spain / Ellenberg's indicator values / fertility

INTRODUCTION

In 1885 J.M. Lacoizqueta published one of the earliest known Spanish bryological catalogues, referred to the Vertizarana Valley (Lacoizqueta, 1885), which was also the first for Navarra. Some decades later, P. and V. Allorge travelled through Spain. Allorge (1955) published the results from their collections between 1926 and 1935 (Heras Pérez & Infante Sánchez, 1997), among which there are many records from the Vertizarana Valley. Fuertes Lasala & Álvarez Orzanco (1982) provided more information on bryophytes collected in the Valley during the previous decade. Finally, Ederra Indurain (2001) revised the Lacoizqueta's herbarium and made some corrections to his 1885 catalogue.

The Suspiro Basin is a small lateral valley within the Vertizarana Valley that became the only Spanish location in the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems Network (ICP-IM) in 2006. One of the compulsory sub-programmes is "Soil

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Vegetation", where the bryological biodiversity has to be studied. This is the reason why we are again doing research on the bryological flora of Vertizarana, 120 years after the first Lacoizqueta catalogue.

The historic Lacoizqueta's herbarium and a lot of samples on which the publication of Fuertes Lasala & Álvarez Orzanco (1982) is based are kept at PAMP (University of Navarra Herbarium), so we have got easy access to them. The present paper intends to analyse the evolution of knowledge on the bryophytes species growing in the Vertizarana Valley and, to assess if bryophytes can indicate changes in air quality or ecological conditions in the valley for a long time span. To check these hypotheses, the presence of sporophytes or sexual organs and the Ellenberg's indicator values of each of the bryophytes collected there have been studied.

STUDY AREA

The Vertizarana Valley is located in NW Navarra (Northern Spain), near the Cantabrian Sea (Fig. 1). Since 1984 it has been a Natural Park of 2052 ha and has been recently declared site of Community importance for the Atlantic biogeographical region (with the name "Señorío de Bértiz") in accordance with the Directive 92/43/CEE (Anonymous, 2008), being part of the Natura 2000 network. The climate is oceanic, with a mean annual precipitation of 1697 mm and a mean temperature of 14.1 ºC. Altitude ranges from 110 to 830 m and substrate is very mixed, but predominantly acidic. The vegetation mainly consists in a beech wood (*Fagus sylvatica* L.), although there are some patches of oak woods (*Quercus robur* L.) and a few pastures.

MATERIAL AND METHODS

The main part of our collections was made in 2006-2007 in the Suspiro basin, the ICP-IM network point, but other places of the Vertizarana Valley have been prospected as well. Special attention has been paid to bryophytes growing on soil and trees, because saxicolous bryophytes are not the aim of the ICP-IM project.

The Lacoizqueta herbarium had been previously revised (Ederra Indurain, 2001), but several samples have been studied again. Likewise, almost all samples collected in the Señorío de Bértiz by Fuertes Lasala & Álvarez Orzanco (1982) and kept at PAMP have been revised. Besides the identification revision, all specimens have been examined to find sporophytes or sexual structures. As it is written on the herbarium labels, samplings corresponding to Lacoizqueta (1885) and Fuertes Lasala & Álvarez Orzanco (1982) took place over several years. Unfortunately, the Allorge herbarium is kept at PC, so the records given by Allorge (1955) are just bibliographical and data on fertility could not be provided.

The similarity between these catalogues, taken in pairs, trios or altogether, has been calculated with the Jaccard index of similarity:

$$J = 100\ c / a + b + d + ... + n - c$$

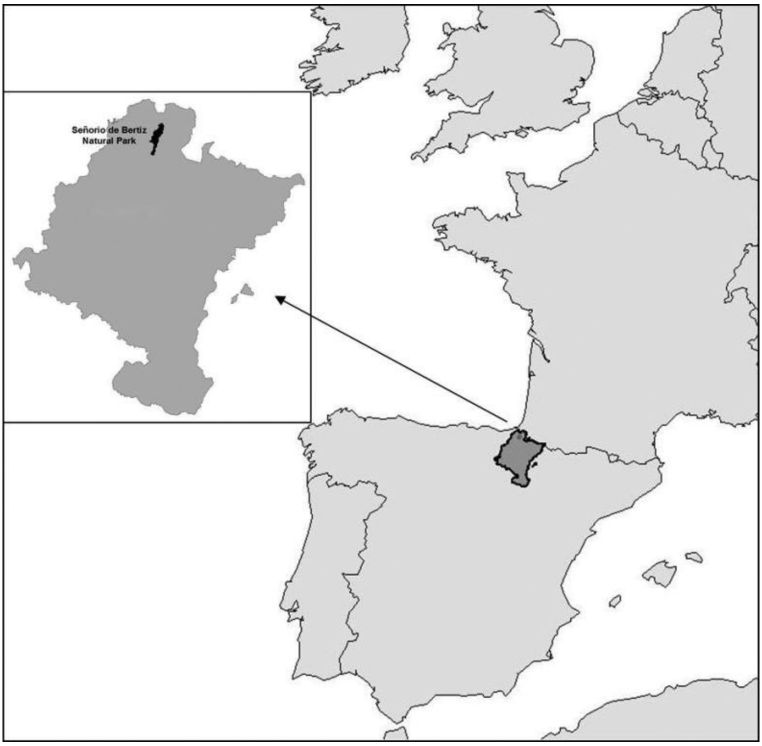

Fig. 1. Location of the Vertizarana Valley (Señorío de Bértiz) in Navarra and Spain.

where c is the number of species common to samples and a, b, d, n, are the number of species in the samples. The formula can be applied to two, three ...n, samples.

The Ellenberg's indicator values for light, temperature, substrate pH (acidity) and nitrogen have been consulted (Ellenberg *et al.*, 1992; Düll, 1992; Siebel, 1993; Mayor López, 1994; Hill *et al.*, 2007) and have been applied to as many species as possible. The Ellenberg's indicators values are numbers from 1 to 9 assigned to plants to indicate their relationships with environmental factors. For instance, a moss with Ellenberg's indicator value for light equal to 1 is indicating that the place where this moss has been collected is deep-shaded; on the contrary, Ellenberg's indicator value for light equal to 9 applies to species living in full light; values in the middle indicate intermediate ecological conditions. Ellenberg's indicator values for temperature, acidity and nitrogen work in the same way. Mean values of Ellenberg's indicator values of as many species as possible collected in one specific plant community are said to characterize accurately the environmental characteristics of that community, in such a way that communities with minor differences have different mean values, indicating different environmental conditions (Ellenberg *et al.*, 1992; Mayor López, 1994). Therefore, mean values of Ellenberg's indicator values of bryophytes collected at different times in the Vertizarana Valley may indicate if the ecological conditions have changed over a certain time span.

The catalogue of bryophytes collected in the Vertizarana Valley is presented in a table containing the species list and the Ellenberg's indicator values

(Table 1). Nomenclature and authors follow Hill *et al.* (2006) for mosses and Ros *et al.* (2007) for liverworts and hornworts. The following abbreviations have been used: **L&E**: species from Lacoizqueta (1885) and Ederra Indurain (2001). **All**: species from Allorge (1995). **F&Ál**: species from Fuertes Lasala and Álvarez Orzanco (1982). **IMPr**: species from the current Integrated Monitoring Project. **+**: presence of the species. **(*)**: species that have been identified on herbarium specimens, either correcting previous identifications or because they had been previously overlooked. **(?)**: unconfirmed species, due to lack of specimens in PAMP. §: with sporophytes (in few species, just with archegonia or antheridia). Ellenberg's indicator values: **L**, light; **T**, temperature; **R**, substrate pH (acidity); **N**, nitrogen; **x**, species indifferent to that ecological factor.

RESULTS AND DISCUSSION

Flora

The total number of species (Table 1) currently known from the Vertizarana Valley, including infraspecific taxa, is 253 (187 mosses and 66 liverworts and hornworts), and represent almost half of the bryoflora of Navarra (Huarte Irurzun, 2001; Juaristi Iranzo, 2005). This information has been built step by step, with every new study contributing, logically, fewer new records (Table 1). It seems unlikely to increase the number of bryophytes in the catalogue of the Vertizarana Valley significantly. Nine species have not been confirmed because there were no specimens in PAMP.

Like in Ederra Indurain (2001), where some species from Lacoizqueta (1885) were corrected and some others appeared, several species from Fuertes Lasala & Álvarez Orzanco (1982) have disappeared for having been misidentified: *Hygroamblystegium fluviatile* (Hedw.) Loeske is *Cratoneuron filicinum*; *Brachythecium velutinum* (Hedw.) Schimp. (*Brachytheciastrum velutinum*) is a mixture of *B. rutabulum* and *Kindbergia praelonga*; *Campylophyllum halleri* (Hedw.) M. Fleisch. is *Ctenidium molluscum*; *Campylopus pyriformis* (Schultz) Brid. is *Dicranella howei*; *Fissidens bryoides* var. *curnovii* (Mitt.) J. Amann (*F. bryoides* var. *caespitans* Schimp.) is *F. bryoides*; *Fissidens bryoides* subsp. *incurvus* (*F. viridulus* var. *incurvus* (Starke *ex* Röhl.) Waldh.) is *F. viridulus*; *Fissidens serrulatus* Brid. is *F. dubius*; *Isopterygium pulchellum* (Hedw.) A. Jaeger (*Isopterygiopsis pulchella* (Hedw.) Z. Iwats.) is *Pseudotaxiphyllum elegans*; *Plagiopus oederi* (Brid.) Limpr. (*Plagiopus oederianus* (Sw.) H.A. Crum *et* L.E. Anderson) is *Bartramia pomiformis*; *Plagiothecium denticulatum* (Hedw.) Schimp. is *P. nemorale*; *Pogonatum nanum* is *P. aloides*; *Rhytidiadelphus squarrosus* is *R. loreus*; *Schistidium apocarpum* is *S. crassipilum*; *Odontoschisma sphagni* (Dicks.) Dumort. is misidentified (Infante, 2000); *Southbya tophacea* (Spruce) Spruce is *Jungermannia hyalina*. As a result of corrections or additions of overlooked species we have added 18 species to Lacoizqueta (1885) and 9 to Fuertes Lasala & Álvarez Orzanco (1982); they have been marked **(*)** in Table 1.

The high number of species likely to be found and the different sampling methods used in the four studies yields different species lists and low similarity among them (Table 2). The Jaccard's index of similarity is lower when **All** is involved and vice versa. This may be due to the number of exclusive species (those that remain recorded in only one work) in Allorge (1955). It seems that P. and V. Allorge were prone to explore uncommon habitats and to collect and

Table 1. Bryophytes collected in Vertizarana Valley in 1885 (**L&E**), 1926-1935 (**All**), 1972-75 (**F&Ál**) and 2006-2007 (**IMPr**). The fertility (§) and the Ellenberg's ecological values (**L**, light; **T**, temperature; **R**, pH of the substrate; **N**, nitrogen) are shown. For more details see the text.

Species	*L*	*T*	*R*	*N*	*L&E*	*All*	*F&Ál*	*IMPr*
Mosses								
Aloina aloides (Koch ex Schultz) Kindb.	8	6	8	4	(*) §			
Amblystegium serpens (Hedw.) Schimp.	4	x	7	7	+ §	+		
Amphidium mougeotii (Schimp.) Schimp.						+		
Andreaea rothii F.Weber & D.Mohr	6	3	2	1	(*) §	+		
Anomodon viticulosus (Hedw.) Hook. & Taylor	3	3	8	4	+ §		+	
Antitrichia curtipendula (Hedw.) Brid.	4	3	6	3	+ §	+		+
Atrichum undulatum (Hedw.) P.Beauv.	4	x	5	5	+ §		+ §	+ §
Barbula convoluta var. *sardoa* Schimp.	8	x	6	4	(?)			
Barbula unguiculata Hedw.	7	x	7	x	+ §		+ §	
Bartramia pomiformis Hedw.	5	3	4	3	+ §		+ §	
Brachytheciastrum olympicum (Jur.) Vanderp. *et al.*								+ §
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	5	3	6	5				+
Brachythecium glareosum (Bruch ex Spruce) Schimp.	4	3	8	4		+		
Brachythecium rivulare Schimp.	4	3	6	4		+	+	+ §
Brachythecium rutabulum (Hedw.) Schimp.	5	x	x	8	+ §	+	+ §	+ §
Brachythecium tommasinii (Sendtn. ex Boulay) Ignatov & Huttunen						+		
Bryoerythrophyllum recurvirostrum (Hedw.) P.C.Chen	5	3	8	5	+ §			
Bryum alpinum Huds. ex With.	8	x	4	2		+		
Bryum argenteum Hedw.	7	x	7	8	+ §	+	+	+
Bryum dichotomum Hedw.	8	6	6	8	+ §			+ §
Bryum caespiticium Hedw.	8	x	6	4	+ §			
Bryum capillare Hedw.	5	x	7	3	+ §		+	
Bryum pseudotriquetrum (Hedw.) P.Gaertn. *et al.*	7	x	x	3	+ §	+	+ §	
Bryum rubens Mitt.	8	6	x	6	+ §			
Calliergionella cuspidata (Hedw.) Loeske	8	3	7	5	+ §		+	+
Calliergonella lindbergii (Mitt.) Hedenäs						+		
Campyliadelphus chrysophyllus (Brid.) R.S.Chopra	9	2	9	2		+		
Campylium stellatum (Hedw.) Lange & C.E.O.Jensen	8	2	7	3		+		
Campylophyllum calcareum (Crundw. & Nyholm) Hedenäs	4	5	9	2			(?)	
Campylopus flexuosus (Hedw.) Brid.	6	4	1	3		+	+	
Campylopus pilifer Brid.					+	+		
Ceratodon purpureus (Hedw.) Brid.	8	x	x	3	+ §		+ §	
Cirriphyllum crassinervium (Taylor) Loeske & M.Fleisch.	4	5	8	5		+		+ §

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Species	*L T R N*	*L&E*	*All*	*F&Ál*	*IMPr*
Cirriphyllum piliferum (Hedw.) Grout	5 3 7 6		+		
Climacium dendroides (Hedw.) F.Weber & D.Mohr	6 3 5 5		+		
Cratoneuron filicinum (Hedw.) Spruce	6 x 8 4		+	(*) §	
Crossidium squamiferum (Viv.) Jur.		+ §			
Cryphaea heteromalla (Hedw.) D.Mohr	7 6 7 5	+ §			
Ctenidium molluscum (Hedw.) Mitt.	x 4 8 2	+ §		+ §	+
Cynodontium bruntonii (Sm.) Bruch & Schimp.		+ §			
Dialytrichia mucronata (Brid.) Broth.	9 8 8 6		+		
Dichodontium pellucidum (Hedw.) Schimp.	4 3 7 5		+	+ §	+
Dicranella heteromalla (Hedw.) Schimp.	4 4 2 3	+		+ §	+ §
Dicranella howei Renauld & Cardot		(*) §	+	(*) §	
Dicranella varia (Hedw.) Schimp.	7 x 7 7			+ §	
Dicranum flagellare Hedw.	5 4 2 3		+		
Dicranum montanum Hedw.	5 3 2 2		+		+
Dicranum scoparium Hedw.	x x 3 2	+		+ §	+ §
Dicranum scottianum Turner ex R.Scott		+ §			
Didymodon fallax (Hedw.) R.H.Zander	8 x 8 4		+	+ §	
Didymodon spadiceus (Mitt.) Limpr.			+		
Didymodon tophaceus (Brid.) Lisa	7 x 8 5		+		
Diphyscium foliosum (Hedw.) D.Mohr	2 3 4 3	+ §	+	+ §	+ §
Encalypta streptocarpa Hedw.	5 x 9 3	+		+	
Entosthodon attenuatus (Dicks.) Bryhn		+ §		+ §	
Ephemerum minutissimum Lindb.	7 6 5 4				+ §
Epipterygium tozeri (Grev.) Lindb.				(*)	
Eucladium verticillatum (With.) Bruch & Schimp.	4 7 9 2	+ §	+	+ §	
Eurhynchiastrum pulchellum (Hedw.) Ignatov & Huttunen		(*) §			
Eurhynchium striatum (Hedw.) Schimp.	4 6 6 5	+ §		+	+ §
Fissidens adianthoides Hedw.	x 3 7 3	+ §	+	+ §	
Fissidens bryoides Hedw.	4 x 6 5	+ §	+	+ §	+ §
Fissidens bryoides var. *caespitans* Schimp.			+		
Fissidens dubius P.Beauv.	x 4 9 3		+	+ §	+ §
Fissidens exilis Hedw.	3 5 8 5				+ §
Fissidens grandifrons Brid.	2 4 8 4	+	+	+	
Fissidens monguillonii Thér.				(?)	
Fissidens polyphyllus Wilson *ex* Bruch & Schimp.		+ §	+	+	
Fissidens pusillus (Wilson) Milde				+ §	

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Species	*L*	*T*	*R*	*N*	*L&E*	*All*	*F&Ál*	*IMPr*
Fissidens rivularis (Spruce) Schimp.					(*) §	+		
Fissidens taxifolius Hedw.	x	4	7	5		+	+	+ §
Fissidens viridulus (Sw. ex anon.) Wahlenb.	7	5	8	5			+ §	+
Funaria hygrometrica Hedw.	8	x	6	8	+ §		+ §	+ §
Grimmia decipiens (Schultz) Lindb.						+		
Grimmia hartmanii Schimp.	5	2	2	4		+		
Grimmia laevigata (Brid.) Brid.	9	6	5	1		+		
Grimmia ovalis (Hedw.) Lindb.	9	4	5	1	+ §			
Grimmia pulvinata (Hedw.) Sm.	9	5	8	2	+ §		+ §	
Grimmia trichophylla Grev.	7	5	3	1	+ §	+		+
Hedwigia ciliata (Hedw.) P.Beauv.	9	x	2	1	+ §	+	+ §	
Hedwigia ciliata var. *leucophaea* Bruch & Schimp.					(*) §			
Hedwigia integrifolia P.Beauv.					+ §		+	
Heterocladium heteropterum (Brid.) Schimp.						+	+	+
Homalia trichomanoides (Hedw.) Brid.	2	3	7	4	+ §	+	(*) §	
Homalothecium sericeum (Hedw.) Schimp.	7	3	7	4	+ §		+	+
Hookeria lucens (Hedw.) Sm.	2	3	6	3	+ §	+	+ §	+ §
Hygrohypnum luridum (Hedw.) Jenn.	5	3	7	6		+		
Hylocomium splendens (Hedw.) Schimp.	5	3	5	2	+		+	+
Hyocomium armoricum (Brid.) Wijk & Margad.						+	+	+
Hypnum cupressiforme Hedw.	x	x	x	3	+ §		+ §	+ §
Hypnum cupressiforme var. *filiforme* Brid.					+ §		+ §	+
Isopterygiopsis muelleriana (Schimp.) Z.Iwats.						+		
Isothecium alopecuroides (Lam. ex Dubois) Isov.	4	4	6	4	+ §		+	+
Isothecium myosuroides Brid.	4	4	4	4	+ §		+ §	+ §
Kindbergia praelonga (Hedw.) Ochyra	5	4	5	6	+ §		+ §	+ §
Leptobryum pyriforme (Hedw.) Wilson	x	x	6	7		+		
Leptodon smithii (Hedw.) F.Weber & D.Mohr	4	8	7	4		+		
Leucobryum glaucum (Hedw.) Ångstr.	4	3	1	2	+ §	+	+ §	+
Leucobryum juniperoideum (Brid.) Müll.Hal.					(*) §		(*) §	+ §
Leucodon sciuroides (Hedw.) Schwägr.	8	5	7	4			+	+
Leucodon sciuroides var. *morensis* (Schwägr.) De Not.					+ §	+		
Loeskeobryum brevirostre (Brid.) M.Fleisch.	5	5	6	3		+		+
Mnium hornum Hedw.	3	3	3	4	+ §	+	+ §	+ §
Mnium lycopodioides Schwägr.							(?)	
Mnium marginatum (Dicks.) P.Beauv.	2	2	7	5			+	
Mnium stellare Hedw.	2	3	8	4		+	+	

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Species	*L*	*T*	*R*	*N*	*L&E*	*All*	*F&Ál*	*IMPr*
Neckera complanata (Hedw.) Huebener	3	x	7	4	+ §	+	+	+
Neckera crispa Hedw.	3	3	8	3	+ §	+	+	+
Neckera pumila Hedw.	4	3	6	4		+		+ §
Orthotrichum affine Schrad. ex Brid.	6	4	6	3		+	(?)	
Orthotrichum alpestre Bruch. & Schimp.								+ §
Orthotrichum anomalum Hedw.	9	3	8	3	+ §			
Orthotrichum lyellii Hook. & Taylor	6	4	5	3		+		+
Orthotrichum striatum Hedw.	4	3	6	3	+ §			+ §
Oxyrrhynchium hians (Hedw.) Loeske	5	4	7	7	+ §		+	+
Palustriella commutata (Hedw.) Ochyra	7	x	9	3	+ §		+	+ §
Paraleucobryum longifolium (Hedw.) Loeske						+		
Philonotis calcarea (Bruch & Schimp.) Schimp.	8	2	8	2		+		
Philonotis fontana (Hedw.) Brid.	8	x	4	3	+ §		+ §	
Philonotis marchica (Hedw.) Brid.	8	6	5	2	+ §			
Philonotis rigida Brid.					+ §	+	+ §	
Physcomitrium pyriforme (Hedw.) Bruch & Schimp.	7	4	7	7			(?)	
Plagiomnium affine (Blandow ex Funk) T.J.Kop.	5	4	5	5			+	+
Plagiomnium cuspidatum (Hedw.) T.J.Kop.	4	3	7	5			+ §	
Plagiomnium rostratum (Schrad.) T.J.Kop.	3	3	8	6		+		
Plagiomnium undulatum (Hedw.) T.J.Kop.	4	3	6	6	+ §		+	+
Plagiothecium cavifolium (Brid.) Z.Iwats.	2	2	6	6			+ §	
Plagiothecium nemorale (Mitt.) A.Jaeger	4	3	5	5	+	+	(*)	+
Plagiothecium undulatum (Hedw.) Schimp.	4	3	1	3	+		+	+
Platyhypnidium riparioides (Hedw.) Dixon	x	3	7	6	+ §		+ §	+ §
Pleurozium schreberi (Willd. ex Brid.) Mitt.	5	3	2	2				+
Pogonatum aloides (Hedw.) P.Beauv.	6	3	3	4	+ §	+	+ §	+ §
Pogonatum nanum (Hedw.) P.Beauv.	6	5	3	4	(?)			+ §
Pogonatum urnigerum (Hedw.) P.Beauv.	7	2	2	4		+	+ §	
Pohlia elongata Hedw.	2	2	3	3			+ §	
Pohlia nutans (Hedw.) Lindb.	x	x	2	3		+		
Pohlia wahlenbergii (F.Weber & D.Mohr) A.L.Andrews	5	x	7	3		+		
Polytrichastrum formosum (Hedw.) G.L.Sm.	4	2	2	4	+ §		+ §	+ §
Polytrichum commune Hedw.	6	2	2	2		+		
Polytrichum juniperinum Hedw.	8	2	2	1		+	(?)	
Polytrichum piliferum Hedw.	9	2	x	1	+ §	+	+	
Pseudocrossidium revolutum (Brid.) R.H.Zander	9	6	9	2	+ §			
Pseudoscleropodium purum (Hedw.) M.Fleisch.	5	4	5	5	+			+

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Species	*L*	*T*	*R*	*N*	*L&E*	*All*	*F&Ál*	*IMPr*
Pseudotaxiphyllum elegans (Brid.) Z.Iwats.	3	4	2	3		+	(*) §	+
Pterigynandrum filiforme Hedw.	5	2	4	4		+		
Pterogonium gracile (Hedw.) Sm.					+ §		+	+
Ptychomitrium incurvum (Schwägr.) Spruce					+ §			
Ptychomitrium polyphyllum (Dicks. ex Sw.) Bruch & Schimp.	6	5	3	2	+ §	+	+ §	
Racomitrium aciculare (Hedw.) Brid.	5	3	2	2	+ §	+		
Racomitrium heterostichum (Hedw.) Brid.	8	3	1	1	+	+	+ §	
Racomitrium lanuginosum (Hedw.) Brid.	8	x	3	1	+	+	+	
Rhizomnium punctatum (Hedw.) T.J.Kop.	3	3	4	4	+ §	+	+	+ §
Rhynchostegiella curviseta (Brid.) Limpr.	2	8	7	6	+ §			
Rhynchostegiella tenella (Dicks.) Limpr.	2	5	8	5		+		
Rhynchostegium confertum (Dicks.) Schimp.	4	5	6	6	+ §	+		
Rhytidiadelphus loreus (Hedw.) Warnst.	5	3	3	2	+ §	+	+	+
Rhytidiadelphus squarrosus (Hedw.) Warnst.	6	3	5	5		+		+
Rhytidiadelphus triquetrus (Hedw.) Warnst.	5	3	6	3	+		+	+
Schistidium apocarpum (Hedw.) Bruch	4	x	7	6	+ §			
Schistidium crassipilum H.H.Blom							(*) §	+ §
Sciuro-hypnum plumosum (Hedw.) Ignatov & Huttunen	5	3	6	5	+ §	+	+ §	+ §
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen	4	3	7	5	(*) §			
Sphagnum auriculatum Schimp.	8	3	2	2	(*)	+		
Sphagnum flexuosum Dozy & Molk.	7	3	2	4			(?)	
Sphagnum palustre L.	6	4	3	4		+		
Sphagnum quinquefarium (Braithw.) Warnst.	4	3	4	4		+		+
Sphagnum subnitens Russow & Warnst.	7	4	3	3	(*) §	+		
Syntrichia montana Nees	9	6	8	2	(*) §			
Taxiphyllum wissgrillii (Garov.) Wijk & Margad.	2	4	8	5		+		
Tetraphis pellucida Hedw.	3	3	1	4		+	+	
Thamnobryum alopecurum (Hedw.) Gangulee	3	4	7	7	+ §		+	+
Thuidium delicatulum (Hedw.) Schimp.						+		+
Thuidium tamariscinum (Hedw.) Schimp.	4	4	4	4	+ §		+	+
Timmiella anomala (Bruch & Schimp.) Limpr.							+	
Tortella nitida (Lindb.) Broth.						+		
Tortella tortuosa (Hedw.) Limpr.	5	x	8	3	+ §			
Tortula marginata (Bruch & Schimp.) Spruce	2	8	9	5		+		
Tortula muralis Hedw.	x	5	x	6	+ §		+ §	+
Trichostomum brachydontium Bruch					+			
Trichostomum crispulum Bruch	8	4	9	2	+ §		+	

Table 1. Bryophytes collected in Vertizarana Valley in 1885 (**L&E**), 1926-1935 (**All**), 1972-75 (**F&Ál**) and 2006-2007 (**IMPr**). The fertility (§) and the Ellenberg's ecological values (**L**, light; **T**, temperature; **R**, pH of the substrate; **N**, nitrogen) are shown. For more details see the text.

Species	*L*	*T*	*R*	*N*	*L&E*	*All*	*F&Ál*	*IMPr*
Ulota bruchii Hornsch. ex Brid.	4	3	4	3		+		
Ulota crispa (Hedw.) Brid.	4	3	3	3	+ §		+ §	+ §
Ulota hutchinsiae (Sm.) Hammar						+		
Weissia condensa (Voit) Lindb.					(?)			
Weissia controversa Hedw.	8	7	7	4	+ §		+ §	+ §
Weissia controversa var. *crispata* (Nees & Hornsch.) Nyholm	9	9	9	3			+ §	
Zygodon rupestris Schimp. ex Lorentz	4	6	7	5				+ §
TOTAL MOSSES					104 (3?)	96	99 (7?)	74
§ (% relative to confirmed species)					87 (86.1%)		52 (56.5%)	36 (48.6%)
Liverworts & Hornworts								
Anastrophyllum minutum (Schreb.) R.M.Schust.	5	2	2	2		+		
Aneura pinguis (L.) Dumort.	7	x	7	4		+		
Anthoceros punctatus L.					(?)	+		
Apometzgeria pubescens (Schrank) Kuwah.						+		
Bazzania trilobata (L.) Gray var. *trilobata*	5	4	2	2	+		+	+
Blepharostoma trichophyllum (L.) Dumort.					(?)		+ §	+
Calypogeia arguta Nees & Mont.	3	6	4	4		+	(?)	+
Calypogeia azurea Stotler & Crotz	3	3	3	4			+	+
Calypogeia fissa (L.) Raddi	4	4	3	4		+		+
Cephalozia bicuspidata (L.) Dumort.	x	x	3	3	+ §		+ §	+
Cephalozia lunulifolia (Dumort.) Dumort.	5	3	2	3		+		
Cephaloziella baumgartneri Schiffn.	9	3	9	2		+		
Cephaloziella turneri (Hook.) Müll.Frib.						+	+	
Chiloscyphus polyanthos (L.) Corda	4	4	6	4		+	+ §	+ §
Cololejeunea rossetiana (C.Massal.) Schiffn.						+		
Conocephalum conicum (L.) Dumort.	3	x	8	7	+ §		+ §	+
Diplophyllum albicans (L.) Dumort.	4	x	3	3	+ §		+ §	+ §
Dumortiera hirsuta (Sw.) Nees						+	+ §	
Fossombronia angulosa (Dicks.) Raddi)					(*) §			
Fossombronia pusilla (L.) Nees	7	7	5	3				+ §
Frullania dilatata (L.) Dumort.	6	3	6	3	+ §		(?)	+ §
Frullania fragilifolia (Taylor) Gottsche *et al.*	4	4	5	3		+		+
Frullania tamarisci (L.) Dumort.	4	3	5	2	+ §		+ §	+
Jubula hutchinsiae (Hook.) Dumort.						+	+	
Jungermannia atrovirens Dumort.						+	+ §	

Table 1. Bryophytes collected in Vertizarana Valley in 1885 (**L&E**), 1926-1935 (**All**), 1972-75 (**F&Ál**) and 2006-2007 (**IMPr**). The fertility (§) and the Ellenberg's ecological values (**L**, light; **T**, temperature; **R**, pH of the substrate; **N**, nitrogen) are shown. For more details see the text.

Species	*L T R N*	*L&E*	*All*	*F&Ál*	*IMPr*
Jungermannia gracillima Sm.	8 4 3 3	(*) §			
Jungermannia hyalina Lyell	4 3 4 3		+	(*) §	
Jungermannia pumila With.			+		
Jungermannia cf. *sphaerocarpa* Hook.		(*) §			
Leiocolea turbinata (Raddi) H.Buch			+		
Lejeunea cavifolia (Ehrh.) Lindb.	4 3 7 4			+ §	+
Lejeunea lamacerina (Steph.) Schiffn.			+		
Lepidozia reptans (L.) Dumort.	4 3 2 3		+		+
Lophocolea bidentata (L.) Dumort.	5 3 5 3	+ §	+	+ §	+ §
Lophocolea heterophylla (Schrad.) Dumort.	4 3 3 4		+		+
Lunularia cruciata (L.) Lindb.	4 8 7 8			+	+
Marchantia polymorpha L.	7 x x 8		+		
Marsupella emarginata (Ehrh.) Dumort.	6 3 2 2		+	+	+
Marsupella funckii (F.Weber & D.Mohr) Dumort.	8 3 2 2		+		+
Metzgeria conjugata Lindb.	3 4 5 3		+	+ §	
Metzgeria violacea (Ach.) Dumort.	4 5 6 4		+		
Metzgeria furcata (L.) Dumort.	4 3 6 4	+		+	+ §
Microlejeunea ulicina (Taylor) A.Evans	4 5 3 3		+		+
Nowelia curvifolia (Dicks.) Mitt.	4 4 1 3		+		
Odontoschisma denudatum (Mart.) Dumort.	6 4 1 3		+		
Pedinophyllum interruptum (Nees) Kaal.			+		+
Pellia endiviifolia (Dicks.) Dumort.	6 4 8 5			+ §	+ §
Pellia epiphylla (L.) Corda	4 4 3 4	+ §		+	+ §
Phaeoceros laevis (L.) Prosk.		(?)			
Plagiochila porelloides (Torrey ex Nees) Lindenb.	4 3 7 4	(*) §		+ §	+ §
Plagiochila punctata (Taylor) Taylor		(*)			
Porella arboris-vitae (With.) Grolle	3 4 7 3	+	+		
Porella platyphylla (L.) Pfeiff.	3 3 7 4	+ §			+
Preissia quadrata (Scop.) Nees	5 2 2 2	+ §			
Radula complanata (L.) Dumort.	4 3 7 4	(*)		+ §	+ §
Reboulia hemisphaerica (L.) Raddi	7 4 8 3	(?)			
Riccardia chamaedryfolia (With.) Grolle	6 4 4 4		+	+	+
Riccardia multifida (L.) Gray	7 4 4 4		+		
Saccogyna viticulosa (L.) Dumort.			+		
Scapania aspera Bernet & M.Bernet		(*)			
Scapania compacta (A.Roth) Dumort.	5 6 4 2	+			
Scapania nemorea (L.) Grolle	4 4 3 3	+ §		+ §	+

Table 1. Bryophytes collected in Vertizarana Valley in 1885 (**L&E**), 1926-1935 (**All**), 1972-75 (**F&Ál**) and 2006-2007 (**IMPr**). The fertility (§) and the Ellenberg's ecological values (**L**, light; **T**, temperature; **R**, pH of the substrate; **N**, nitrogen) are shown. For more details see the text.

Species	*L T R N*	*L&E*	*All*	*F&Ál*	*IMPr*
Scapania subalpina (Nees ex Lindenb.) Dumort.			+		
Scapania undulata (L.) Dumort.	3 3 4 3		+		
Southbya tophacea (Spruce) Spruce			+		
Trichocolea tomentella (Ehrh.) Dumort.	3 4 6 3		+	+	
TOTAL LIVERWORTS & HORNWORTS		25 (4?)	39	28 (2?)	30
§ (%relative to confirmed species)		14 (66.7%)		16 (61.5%)	10 (33.3%)
TOTAL (% over total nº of species) nº of ?		129 (51%) 7?	135 (53.4%)	127 (50.2%) 9?	104 (41.1%)
§ (% relative to confirmed species)		101 (82.8%)		68 (57.6%)	46 (44.2%)
New records for Bértiz		129 (7?)	94	22 (5?)	8
Accumulated number of species		129 (7?)	223 (6?)	245 (11?)	253 (9?)
Unique species		32 (4?)	53	14 (5?)	8

study mainly rare species. For example (Table 1), very common species like *Atrichum undulatum*, *Hypnum cupressiforme, Isothecium myosuroides*, *Polytrichastrum formosum* and others (Allorge, 1955), are sometimes said to be *"répandu dans tout le territoire"* but not precisely recorded for the Vertizarana Valley. On the other hand, although the species number in each work is quite similar (Table 1), the IM Project has fewer mosses, and consequently fewer total number of species, maybe due to fewer surveys in some habitats like rocks and walls, which are not necessary for the project (Finish Ministry Environment, 2008). Any comment or comparison should be taken with caution, especially when involving Allorge's (1955) species list or parameters that depend on substrate (pH, for example).

There are only 15 species that appear in all studies (but there could be more if Allorge's (1955) had been more precise). These may reflect either the standard environmental characteristics of the Vertizarana Valley or the continuity of some habitats: complete predominance of temperate and suboceanic species (Düll 1983, 1984 and 1985), photo-sciophytic and sciophytic species and meso-hygrophytic and hygrophytic species (Dierssen, 2001) (Table 3).

Some species recorded in the Vertizarana Valley are included in Sérgio *et al.* (2006): *Ptychomitrium incurvum* is RE (Regionally Extinct), *Timmiella anomala* is CR (Critically Endangered) and *Hedwigia integrifolia* is NT (Near Threatened).

Fertility

It is a common opinion that fertility relates to air pollution, which causes a decrease in sporophytes production or sexual organs in bryophytes (Bates & Farmer, 1992; Stewart, 1995; Church *et al.*, 2001). If the bryophytes living in certain areas have declined in fertility along a time span, we could suspect that air conditions have become worse.

Table 2. Jaccard index of similarity for groups of four, three or two studies made in Vertizarana Valley. **L&E**: Lacoizqueta (1885) revised by Ederra Indurain (2001); **All**: Allorge (1955); **F&Ál**: Fuertes Lasala & Álvarez Orzanco (1982); **IMPr**: ICP-IM current research. In bold, the highest numbers for trios and pairs.

GROUPS	*J*
L&E, All, F&Ál & IMPr	3
L&E, All & F&Ál	8
L&E, All & IMPr	5
L&E, F&Ál & IMPr	**18**
All, F&Ál & IMPr	8
L&E & All	18
L&E & F&Ál	**45**
L&E & IMPr	**36**
All & F&Ál	26
All & IMPr	22
F&Ál & IMPr	**47**

Table 3. Percentages of species found in all the four studies made in Vertizarana Valley according to distribution and light and humidity affinity.

		Percentage
Distribution	Temperate	53,3
	Suboceanic	46,7
Light	Sciophytic	33,3
	Photo-sciophytic	53,3
	Photophytic	6,7
	Indifferent	6,7
Humidity	Hygrophytic	33,3
	Meso-hygrophytic	33,3
	Mesophytic	6,7
	Meso-xerophytic	20
	Indifferent	6,7

Regarding fertility of the bryophytes from the Vertizarana Valley, those collected by Lacoizqueta (1885) were 82.8% fertile, while those collected by Fuertes Lasala & Álvarez Orzanco (1982) were 57.6% fertile, and those of IMPr were only 44.2% fertile (Table 1). This apparently suggests a dramatic decline, but data must be considered carefully. Although there is a clear tendency of the bryoflora, as a whole, to have decreased fertility and this can be related to an increase in air pollution, other factors have to be taken into account since the lack of sporophytes may be due to sampling differences, identification ability without sporophytes, and of course, to the fact that the species recorded in each study were different.

In order to clarify this problem, we only have considered the fertility of the species that have been recorded in more than one study (Fig. 2). Fertility can be the same if the species had (or did not have) sporophytes in all considered studies, or can have increased if the species did not have sporophytes in the first studies and do have them in the last ones, or can have decreased if the species had sporophytes in the first studies and do not have them in the last ones. For a few species it is impossible to know the tendency, either because there are not samples to check or because fertility in Fuertes Lasala & Álvarez Orzanco (1982) is different from that given in Lacoizqueta (1885) and IM Project.

One hundred and five species have been recorded in two or three studies (Table 1), of which 57 (54%) have the same fertility, 33 (31%) have decreased and only 7 (7%) have increased (Fig. 2). Among the 55 species recorded in three studies (Table 1) 25 (45%) show the same fertility, in 20 (36%) fertility has declined and only in 4 (7%) it has increased (Fig. 2). Therefore, it can be stated that bryophyte fertility of the Vertizarana Valley has declined and it is reasonable to attribute this decline partly to air pollution.

Bryophytes behave as qualitative bioindicators (something has happened, probably air pollution), but could be used as well as biomonitors because they can accumulate pollutants. This topic is the research aim of the ICP-IM subprogramme "Chemistry of Mosses" (Finish Ministry Environment, 2008), which is being developed by other researchers from the University of Navarra.

Ellenberg's indicator values

There are no Ellenberg's indicator values for all European bryophytes, but in this presentation we have been able to use quite a high number of species for each study in order to calculate the mean Ellenberg's indicator values (Table 4), making the results (Table 5 and Figs 3, 4, 5 and 6) reliable.

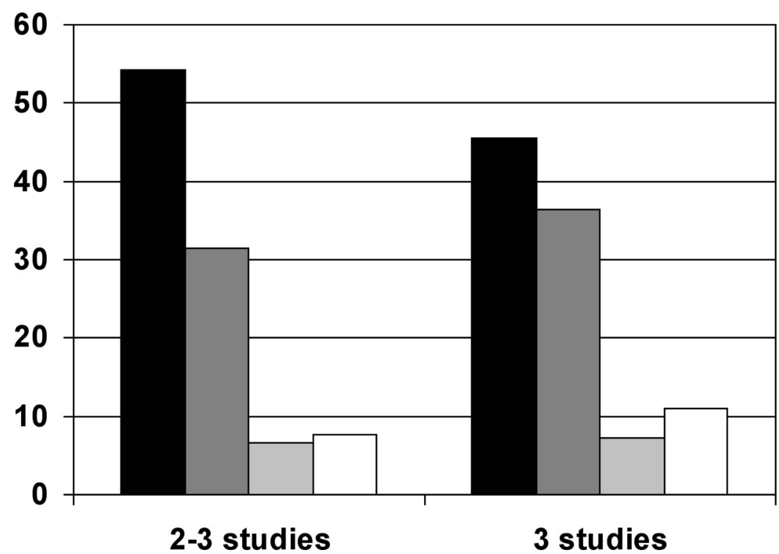

Fig. 2. Percentages of fertile bryophytes species collected in Vertizarana Valley in 2-3 studies and in three studies. In black, species whose fertility have not changed; in dark grey, species whose fertility has declined; in light grey, species whose fertility has increased; and in white, species of which it is not possible to deduce a tendency

Table 4. Number of bryophyte species collected in the Vertizarana Valley in Lacoizqueta (1885) (**L&E**), Allorge (1955) (**All**), Fuertes Lasala & Álvarez Orzanco (1982) (**F&Ál**) and the ICP-IM Project (**IMPr**) on which mean Ellenberg's indicator values for light (**L**), temperature (**T**), substrate pH (**R**) and nitrogen (**N**) have been calculated. In the first column, in brackets, are the numbers of species with data for each study.

Study (nº sp.)	*L*	*T*	*R*	*N*
L&E (103)	96	78	96	102
All (102)	97	85	98	102
F&Ál (106)	97	83	100	105
IMPr (93)	85	81	90	93

Table 5. Mean Ellenberg's indicator values for light (**L**), temperature (**T**), substrate pH (**R**) and nitrogen (**N**) for bryophytes collected in Vertizarana Valley for Lacoizqueta (1885) (**L&E**), Allorge (1955) (**All**), Fuertes Lasala & Álvarez Orzanco (1982) (**F&ÁI**) and the ICP-IM Project (**IMPr**).

Study	*L*	*T*	*R*	*N*
L&E	5.04	2.86	5.06	3.65
All	4.86	3.01	4.73	3.57
F&Ál	4.57	2.87	5.09	3.78
IMPr	4.31	3.33	4.94	4.05

Mean values for light have decreased from 5.04 in 1885 to 4.31 at the present time (Table 5), and percentages of species with values 4 and 3 are currently higher than in 1885 (Fig. 3). Gobierno de Navarra (2007) has reported that several uses of the Vertizarana forest, such as charcoal production, logging and cattle grazing, have been abandoned during the XX century, causing the growth of thicker schrubbery vegetation and more shaded environment. Although changes in Ellenberg's values for light are small, they coincide in indicating that the Vertizarana Valley has become shadier.

On the contrary, mean values for temperature and nitrogen have increased from 1885 to 2006-2007 (Table 5), and percentages of species with higher Ellenberg's values have also increased (Figs 4 and 6). Therefore, bryophytes are indicating that temperature and nitrogen are higher now than in the XIX century. Some colleagues are presently developing another ICP-IM subprogramme, Meteorology, to analyse historic climatic series, whose results will allow us to confirm whether there is correlation between temperature Ellenberg's indicator value and climate.

There are several studies connecting Ellenberg's indicator value for nitrogen in plants and in the environment (Pitcairn *et al.*, 2002 and 2005) and all of them conclude that Ellenberg's values correlate well with atmospheric N deposition, confirming the strength of the method in indicating enhanced N deposition, both by comparing plots or by following changes in a plot over time. It is very likely that the Vertizarana Valley has increased in nitrogen over the last century.

Substrate pH does not show a clear tendency (Table 5 and Fig. 5). Perhaps the data have been excessively affected by the different survey methods. For instance, in the IM Project we have made very few collections on rocks, which are likely to be rich in acidophilic species, since sandstones are very common in the Vertizarana Valley.

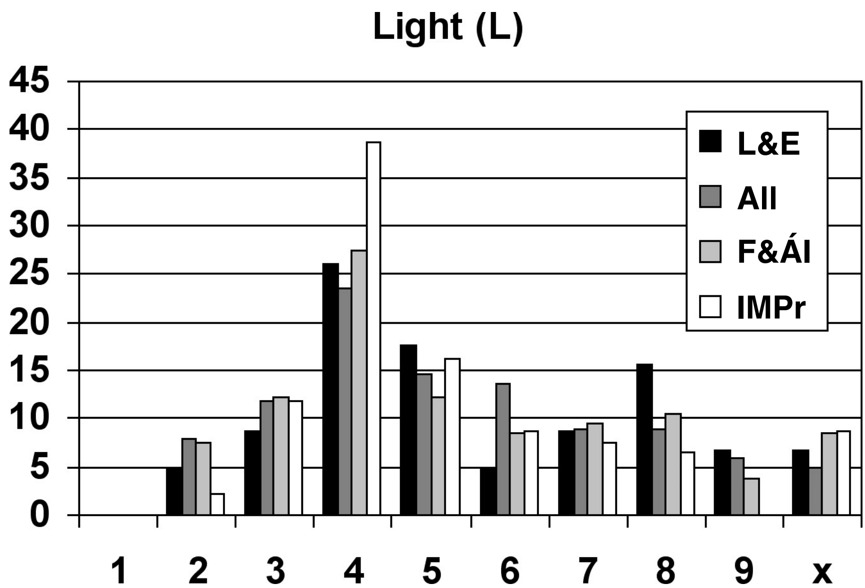

Fig. 3. Percentages of species collected in Vertizarana Valley along time according to Ellenberg's indicator values for light. **L&E**, Lacoizqueta (1885) revised by Ederra Indurain (2001); **All**, Allorge (1955); **F&Ál**, Fuertes Lasala & Álvarez Orzanco (1982); **IMPr**, current ICP-IM project. x, species indifferent to this ecological factor.

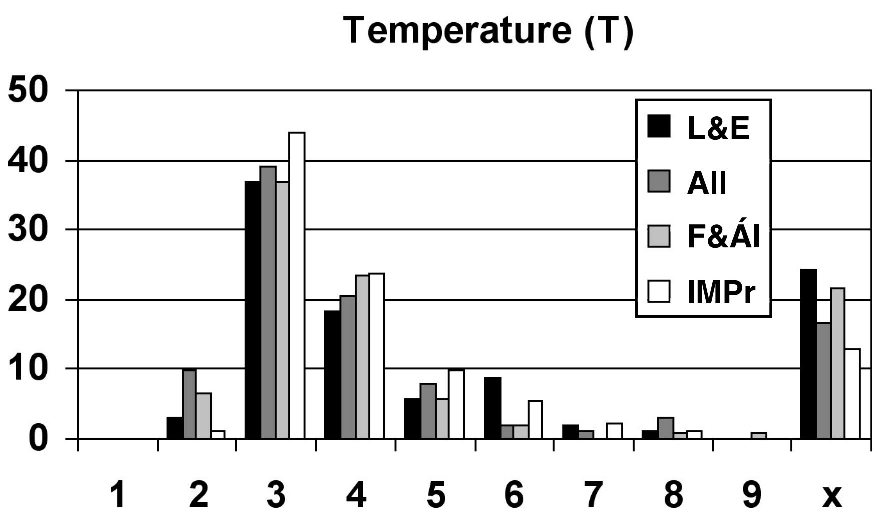

Fig. 4. Percentages of species collected in Vertizarana Valley along time according to Ellenberg's indicator values for temperature. **L&E**, Lacoizqueta (1885) revised by Ederra Indurain (2001); **All**, Allorge (1955); **F&Ál**, Fuertes Lasala & Álvarez Orzanco (1982); **IMPr**, current ICP-IM project. x, species indifferent to this ecological factor.

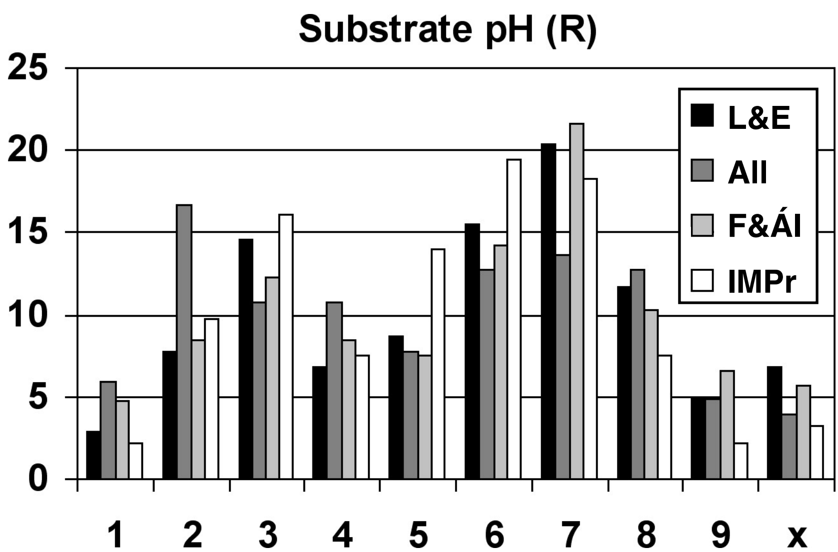

Fig. 5. Percentages of species collected in Vertizarana Valley along time according to Ellenberg's indicator values for substrate pH. **L&E**, Lacoizqueta (1885) revised by Ederra Indurain (2001); **All**, Allorge (1955); **F&ÁI**, Fuertes Lasala & Álvarez Orzanco (1982); **IMPr**, current ICP-IM project. x, species indifferent to this ecological factor.

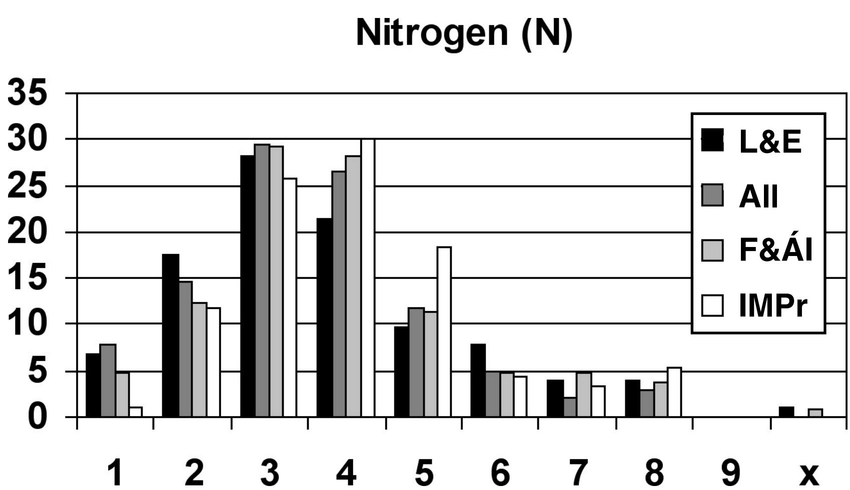

Fig. 6. Percentages of species collected in Vertizarana Valley along time according to Ellenberg's indicator values for nitrogen. **L&E**, Lacoizqueta (1885) revised by Ederra Indurain (2001); **All**, Allorge (1955); **F&ÁI**, Fuertes Lasala & Álvarez Orzanco (1982); **IMPr**, current ICP-IM project. x, species indifferent to this ecological factor.

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