Table S1. Hypotheses and principles tested from global stoichiometric theory developed principally for tracheophytes, recent citations, variables affected, and specific predictions for tissue of bryophytes along the Mauna Loa matrix of soil ages and elevations. Abbreviations: CMA: canopy projected mass per area; MAP: mean annual precipitation, MAT: mean annual temperature; VPD: vapor pressure deficit.

Hypothesis / principle	**Citation**	**Variables affected**	**Specific predictions for bryophyte tissue**
(1) *Plants reflect the soil*	Elser *et al.*, 2010	N_{mass} P_{mass} N:P	Greater nutrient concentrations on better developed soils with greater nutrient supply, i.e., on older lava flows. Lower P_{mass} and greater N:P at increasing elevation and at decreasing MAT because of lower P availability (Vitousek *et al.*, 1992)
(2) *Leaf structure influences composition*	Niinemets, 1999, Shipley *et al.*, 2006	N_{mass} P_{mass} N_{area} P_{area} C:N C:P N:P CMA	Greater area-based nutrient concentrations in taller colonies with higher CMA, and lower mass-based concentrations and greater N:P corresponding to greater structural (cell wall) allocation for denser colonies with higher CMA. Higher CMA and area-based nutrient concentrations, and lower mass-based concentrations at higher elevation, VPD, and irradiance and on younger soil. Positive relationships of area-based concentrations, and negative relationships of mass-based concentrations, with CMA. Given thicker cell walls in bryophytes, C:N, C:P and N:P will be higher than typical for tracheophytes.
(3) *Stoichiometric homeostasis*	Elser *et al.*, 2010	N_{mass} P_{mass} N_{area} P_{area} N:P	N and P concentrations will vary in tandem and thus be positively correlated.
(4) *General scaling of N and P*	Reich *et al.*, 2010	N_{mass} P_{mass}	N will increase with P with scaling exponent of 2/3
(5) *Cold tolerance*	Reich and Oleksyn, 2004	P_{mass} C:P N:P	P_{mass} will increase, and C:P and N:P will decrease, at lower MAT and at higher elevation
(6) *Growth rate – RNA*	Elser *et al.*, 2010	P_{mass} C:P N:P	P_{mass} will be higher and N:P and C:P lower under conditions that promote more rapid growth, i.e., at greater MAP, irradiance, older soil and lower elevation. P_{mass} will be lower and N:P higher in slow-growing bryophytes than in tracheophytes.

Table S2a. Mean squares, degrees of freedom in parentheses and significance of analyses of variance (ANOVAs) for canopy structure and composition traits for bryophytes across the Mauna Loa matrix, Island of Hawaii. Results of a three-way ANOVA with factors species (Sp), elevation (E), and soil age (S); *** $P \leq 0.001$, ** $P \leq 0.01$. * $P < 0.05$; % of variation explained presented beneath.

Variable	**Elevation**	**Soil age**	**Species**	**E×S**	**E×Sp**	**S×Sp**	**E×S×Sp**
Canopy height	0.099(6)	1.341(1)*** 2	7.716(10)*** 90	0.160(2)* 0.4	0.083(25)* 2	0.085(3)	0.006(1)
Canopy mass per area	1.671(6)*** 22	3.057(1)*** 7	1.544(11)*** 38	0.188(2)	0.239(27)*** 14	0.157(3)	0.013(2)
Canopy density	1.349(6)*** 7	6.590(1)*** 6	8.393(10)*** 74	0.419(2)* 1	0.128(25)	0.373(3)* 1	0.008(1)
Nitrogen per mass	0.639(6)*** 32	0.254(1)** 2	0.286(11)*** 26	0.133(2)* 2	0.047(27)	0.013(3)	0.008(2)
Nitrogen per area	1.851(6)*** 24	1.549(1)*** 3	1.433(11)*** 34	0.520(2)** 3	0.293(27)*** 17	0.198(3)	0.032(2)
Phosphorus per mass	2.364(6)*** 40	0.995(1)*** 3	0.602(11)*** 19	1.017(2)*** 6	0.094(27)	0.103(3)	0.118(2)
Phosphorus per area	5.810(6)*** 41	0.564(1)	2.78(11)*** 27	1.464(2)*** 4	0.265(27)* 8	0.501(3)* 2	0.184(2)
Nitrogen:Phosphorus	1.411(6)*** 30	0.244(1)	0.653(11)*** 26	0.469(2)** 4	0.120(27)	0.112(3)	0.137(2)
Carbon:Nitrogen	0.6036(6)*** 32	0.3156(1)** 3	0.2755(11)*** 27	0.1131(2)* 2	0.0407(27)	0.0221(3)	0.0043(2)
Carbon:Phosphorus	2.321(6)*** 40	1.115(1)*** 3	0.568(11)*** 18	0.948(2)*** 6	0.102(27)	0.104(3)	0.140(2)

Table S2b. Mean squares, degrees of freedom in parentheses and significance of analyses of variance (ANOVAs) for canopy structure and composition traits for bryophytes across the Mauna Loa matrix, Island of Hawaii, for samples from the three elevations for which there were both young and old lava flows. Results of a three-way ANOVA with factors species (Sp), elevation (E), and soil age (S); *** $P \leq 0.001$, ** $P \leq 0.01$. * $P < 0.05$.

Variable	**Elevation**	**Soil age**	**Species**	**E×S**	**E×Sp**	**S×Sp**	**E×S×Sp**
Canopy height	0.0035(1)	0.206(1)***	0.650(9)***	0.0007(1)	0.0190(4)	0.0164(2)	0.0012(1)
Canopy mass per area	0.688(1)***	0.364(1)***	0.200(10)***	0.039(1)	0.074(5)***	0.032(2)	0.002(2)
Canopy density	0.289(1)***	0.723(1)***	0.823(9)***	0.0644(1)	0.0250(4)	0.0663(2)*	0.0016(1)
Nitrogen per mass	0.0039(1)	0.0586(1)**	0.0353(10)***	0.0207(1)	0.0018(5)	0.0031(2)	0.0015(2)
Nitrogen per area	0.796(1)***	0.130(1)**	0.186(10)***	0.116(1)**	0.085(5)***	0.037(2)	0.006(2)
Phosphorus per mass	0.113(1)*	0.464(1)***	0.087(10)***	0.131(1)*	0.011(5)	0.027(2)	0.022(2)
Phosphorus per area	1.36(1)***	0.01(1)	0.30(10)***	0.31(1)**	0.08(5)*	0.12(2)*	0.03(2)
Nitrogen:Phosphorus	0.075(1)*	0.193(1)**	0.048(10)**	0.047(1)	0.009(5)	0.031(2)	0.026(2)
Carbon:Nitrogen	0.0163(1)	0.0618(1)**	0.0336(10)***	0.0227(1)*	0.0018(5)	0.0051(2)	0.0008(2)
Carbon:Phosphorus	0.161(1)**	0.473(1)***	0.083(10)***	0.136(1)*	0.011(5)	0.027(2)	0.026(2)

Table S3. Slopes of relationships between variables significantly correlated for all data, or on young and/or old soils and/or within two or more taxa considered individually. The lower triangle contains the slopes for the relationships using all data (*y* from the column variables, *x* from row variables), determined by standard major axis (SMA) for trait-trait relationships and least squares regression for trait-climate relationships; italics denote slopes determined after log-log transformation;. The upper triangle are common slopes for the corresponding relationships from the lower triangle, with the data grouped by soil age (or data grouped by taxon if neither soil age had significant correlation for that trait pair); S denotes common slopes and intercepts for both soil types; Y and O for soil data traits pairs with common slope but higher intercept respectively for young and old soil; G for trait pairs for which two or more taxa had significant relationships with common slope and intercepts; **G** in bold type common slope across taxa but different intercepts, and **G*** in bold type when slopes differed between taxa. Trait symbols: CH = canopy height, CMA = canopy mass per area, CD = canopy density, N_{mass} = nitrogen concentration per mass, N_{area} = nitrogen concentration per canopy projected area, P_{mass} = phosphorus per mass, P_{area} = phosphorus per projected canopy area, N:P = nitrogen to phosphorus mass ratio, C:N = carbon to nitrogen mass ratio, C:P = carbon to phosphorus mass ratio, *OC* -= overstorey cover, MAT = mean annual temperature, MAP = mean annual precipitation, VPD = absolute vapor pressure deficit, molarVPD = mole fraction vapor pressure deficit.

	CH	**CMA**	**CD**	N_{mass}	N_{area}	P_{mass}	P_{area}	**N:P**	**C:N**	**C:P**	***OC***	**MAP**
CH	-		*-0.879* **S**								*1.42***S**	
CMA		-	*0.578* **S,G**		1.56**S**, **G**		17.3**S**, **G***	*-1.03*G			*-1.04***S**, G	
CD	*-0.888*	*0.583*	-		*1.75***S**, **G**		*0.578***G**				*-2.56***S**	
N_{mass}				-		*0.612***Y**, **G**			*-1.05***S**, **G**	*-0.616***Y**, **G**		
N_{area}		1.62	*1.72*		-		*0.763***Y**, **G**					
P_{mass}				*0.567*		-	*0.556***S**, **G**	*-1.20***S**, **G**	*-1.67***O**	*-1.02***S, G**		
P_{area}		16.8	*1.23*		*0.751*	*0.582*	-	*-2.15***Y,** G		*-1.82***S**, **G**		
N:P		*-1.51*				*-1.18*	*-2.03*	-		*0.856***S**, **G**		*0.484***G**
C:N				*-1.04*		*-1.84*			-	0.0177**Y**, **G**		
C:P				*-0.58*	*-1.32*	*-1.02*	*-1.75*	*0.866*	0.0155	-		
OC	*1.34*	*-1.70*	*-2.09*		*-1.71*		-0.40				-	
MAP								*0.979*				-

*Slopes differed between species/genera; *M. microstomum* with lowest and *Campylopus* spp. with highest slope (*A. fuscoflavum* and *B.* cf. *trilobata*, the other taxa with significant correlation, were intermediate).

Table S4. Partial correlation analysis using all data for the correlations of traits in the first row with variables in the first column. For each test, the partial correlation coefficients are presented for the relationships between the row and the column traits after controlling for the effects of the other row variables in the test. When the original correlation (in Table 3) was stronger for log-transformed data, the partial correlation analysis was also conducted using log-transformed data (italics). Trait symbols as in Table S3. Significance: * $P < 0.05$; ** $0.01 \geq P > 0.001$; *** $P \leq 0.001$.

Test		**CH**	**CMA**	**CD**	N_{area}	P_{mass}	P_{area}	**N:P**	**C:P**
(1)	***OC***	***0.48****	***-0.44****	***-0.65****	***-0.36***	0.08	**-0.30***	-0.03	-0.14
	MAT	-0.12	*-0.20*	-0.03	-0.11	*-0.03*	*-0.16*	*0.24*	*0.01*
	MAP	0.10	0.19	0.02	0.09	*-0.13*	*0.00*	*0.00*	0.24
(2)	**MAT**	-0.07	*-0.22*	-0.12	-0.16	*-0.02*	*-0.18*	*0.23*	*0.00*
	MAP	0.08	0.19	0.05	0.10	*-0.14*	*0.01*	*0.00*	0.25
(3)	**CMA**				**0.89*****		**0.84*****		
	OC				*0.11*		0.08		
(4)	**CMA**					0.07	***0.81****	*-0.16*	-0.05
	MAT					***-0.32****	***-0.32****	***0.48****	***0.33***
(5)	**CMA**							***0.65****	
	P_{area}							***-0.81****	
(6)	**CMA**							***0.65****	
	P_{area}							***-0.81****	
	MAT							***0.40***	

Table S5. Partial correlation analysis using young soil and old soil data separately for the correlations of traits in the first row with variables in the first column. For each test, the partial correlation coefficients are presented for the relationships between the row and the column traits after controlling for the effects of the other row variables in the test. When the original correlation (in Table 3) was stronger for log-transformed data, the partial correlation analysis was also conducted using log-transformed data (italics). Trait symbols as in Table S3. Significance: * $P < 0.05$; ** $0.01 \geq P > 0.001$; ***$P \leq 0.001$.

Soil	**Test**		**CH**	**CMA**	**CD**	N_{area}	P_{mass}	P_{area}	**N:P**	**C:P**
Young	**(1)**	***OC***	***0.56****	*-0.49*	***-0.69*****	*-0.46*	-0.28	*-0.42*	0.19	0.13
		MAT	-0.20	-0.23	-0.06	-0.07	0.05	-0.17	*0.16*	-0.27
		MAP	-0.12	0.37	0.00	0.19	***-0.61****	0.01	*0.43*	***0.62****
	(2)	**MAT**	0.00	-0.42	-0.33	-0.26	-0.09	-0.34	*0.25*	-0.24
		MAP	-0.19	0.41	0.12	0.25	***-0.59****	0.08	*0.40*	***0.60****
Old	**(1)**	***OC***	***0.45****	*-0.31*	***-0.64******	*-0.18*	0.27	-0.12		
		MAT	-0.12	-0.05	0.12	-0.02	-0.22	*0.07*		
		MAP	0.12	0.04	-0.11	0.01	0.2	*-0.09*		
	(2)	**MAT**	-0.08	-0.10	0.02	-0.05	-0.18	*0.11*		
		MAP	0.10	0.08	-0.04	0.03	0.16	*-0.13*		

Table S6. Partial correlation analysis using individual taxon data for the correlations of traits in the first row with variables in the first column. For each test, the partial correlation coefficients are presented for the relationships between the row and the column traits after controlling for the effects of the other row variables in the test. When the original correlation (in Table 4) was stronger for log-transformed data, the partial correlation analysis was also conducted using log-transformed data (italics). Trait symbols as in Table S3. Significance: * $P < 0.05$; ** $0.01 \geq P > 0.001$; ***$P \leq 0.001$.

Species	Test		**CMA**	**CD**	N_{area}	P_{mass}	P_{area}	**N:P**	**C:P**
A. fuscoflavum	**(1)**	**OC**	-0.60*	-0.61*					
		MAT	0.32	0.17					
		MAP	-0.42	-0.45					
	(2)	**MAT**	-0.07	-0.22					
		MAP	-0.47	-0.49					
Campylopus spp.	**(1)**	**OC**	-0.77*		-0.63*		-0.84*		
		MAT	-0.49		-0.61		-0.42		
		MAP	0.53		0.63		0.46		
	(2)	**MAT**	-0.74		-0.80		-0.72		
		MAP	0.77		0.81		0.74		
M. microstomum	**(1)**	**OC**				-0.11	-0.17	0.29	0.08
		MAT				*-0.52**	*-0.59**	*0.72**	*0.49**
		MAP				*0.11**	0.12	*-0.26**	*0.06**
	(2)	**MAT**				*-0.51**	*-0.56**	*0.70**	*0.50**
		MAP				*0.05**	0.08	*-0.17**	*0.09**
R. lanuginosum	**(1)**	**OC**					0.34	0.5	
		MAT					-0.37	-0.67	
		MAP					*-0.54**	0.79*	
	(2)	**MAT**					-0.18	-0.68	
		MAP					*-0.69**	**0.89**	

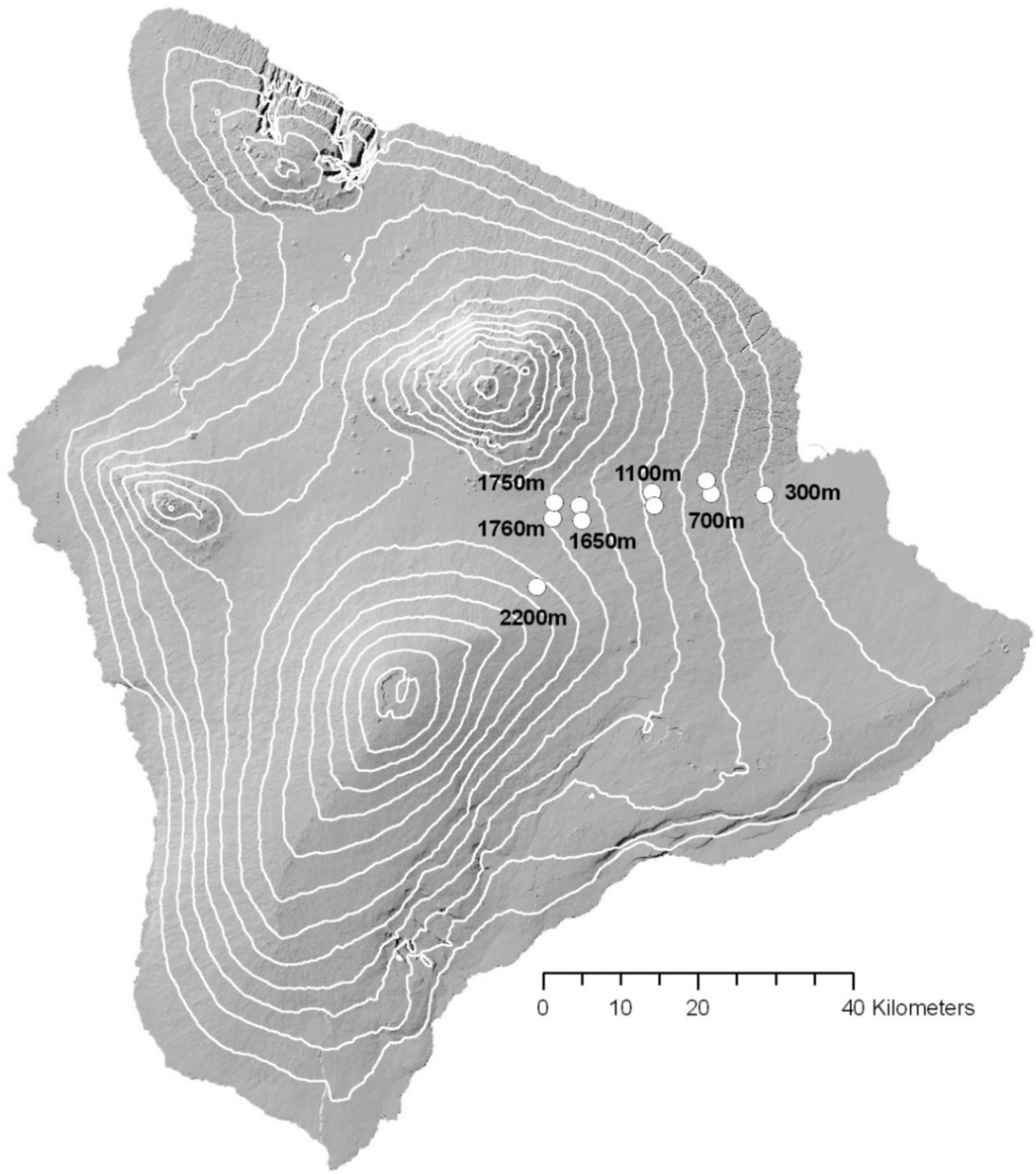

Figure S1. Topographic map of the Hawaii Island with 300 m elevational contour lines and sampling locations with elevations.

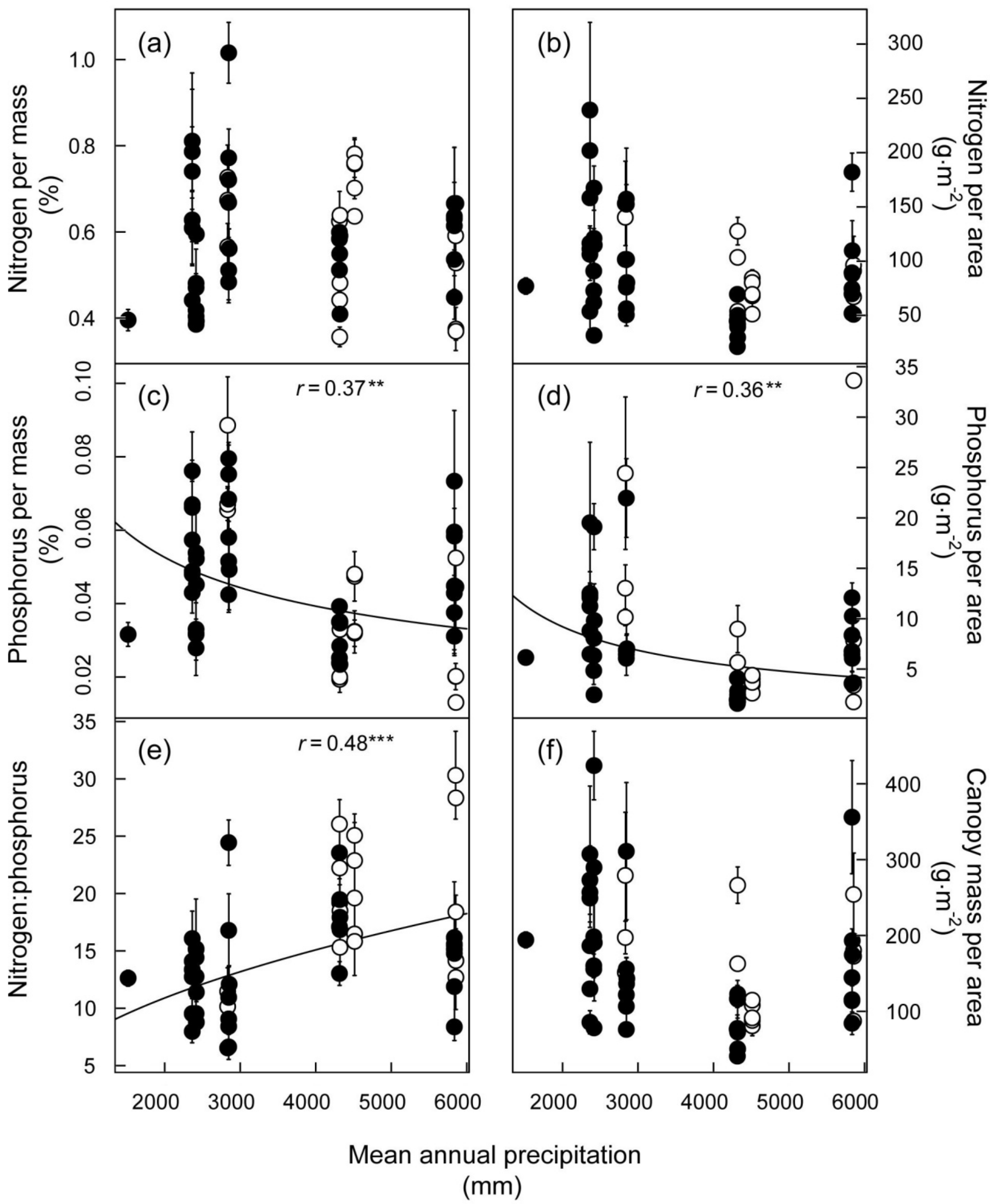

Figure S2. Relationships of bryophyte nutrient concentrations and stoichiometric ratios with mean annual precipitation (MAP): (a) nitrogen per dry mass (N_{mass}), (b) nitrogen per area (N_{area}), (c) phosphorus per dry mass (P_{mass}), (d) phosphorus per area (P_{area}), (e) nitrogen:phosphorus dry mass ratio (N:P), (f) canopy mass per area (CMA). Open and closed circles respectively indicate species averages from young and old lava flow sites. Fitted lines were determined by fitting ordinary least squares regression to log-transformed data [log y = log b + a × log(MAP) for C,D and E; C: a = 0.125 (95% CI: -0.947 to 1.20), b = -0.425; D: a = 3.35 (1.49 to 5.21), b = -0.724; E: a = -0.524 (-1.38 to 0.334), b = 0.473. Error bars = 1 SE. Significance levels: * P <0.05; **0.01 ≥ P > 0.001; ***P ≤ 0.001.