Ecography

E7877
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Supplementary material

Appendix 1

Environmental variables and chytridiomycosis as correlates of amphibian threat risk

Principle component analyses (PCA) using raw environmental variables to visualize overlap of environmental conditions between species extinction risk categories, genera and chytridiomycosis. These analyses were performed without species records of *Pristimantis*:

The first axis (40.2% variation explained) of the PCA that included raw variables described extreme or limiting temperatures and elevation. The following variables were important in defining axis 1: maximum temperature of warmest month, mean temperature of warmest quarter, mean temperature of wettest quarter and annual mean temperature (Table A1-3). The second PCA axis (18.8% of the variation explained) was based on precipitation, primarily precipitation during driest periods and coldest quarter (Table A1-3). Occurrences of critically endangered species and points derived from the chytridiomycosis environmental niche tended to occur in high elevation, cool areas, as well as in dry areas (Fig. A1-a).

Principle component analyses (PCA) using variables where the influence of altitude was removed to visualize overlap of environmental conditions between species extinction risk categories, genera and chytridiomycosis. These analyses were performed without species records of *Pristimantis*:

The first axis (36.9% variation explained) was mainly defined by temperature variables: maximum temperature of warmest month, temperature annual range, mean diurnal range and annual mean temperature (Table A1-3, Fig. A1-b). This axis showed an inverse pattern relative to the first PCA axis generated from raw environmental variables; the most threatened species' occurrences (i.e. critically endangered) and chytridiomycosis model points tended to be in areas that were either warmer or similar to that expected based on their altitude (Fig. A1-b). The second PCA axis (23.5% variation explained) was defined by precipitation variables, mainly precipitation of driest month, precipitation of driest quarter and precipitation of coldest quarter (Table A1-3). Along this axis, most critically endangered species' occurrences and the chytridiomycosis model tended to be in areas close to the expected precipitation conditions (Fig. A1-b).

References

Merino-Viteri, A. 2001. Análisis de posibles causas de las disminuciones de poblaciones de anfibios en los Andes del Ecuador. Licenciatura Thesis, Pontificia Universidad Católica del Ecuador, Quito.

Proaño-Bolaños, C. et al. 2007. A midaltitude report of Batrachochytrium dendrobatidis in Ecuador. — Froglog 82: 3–4.

Ron, S. R. 2005. Predicting the Distribution of the Amphibian Pathogen Batrachochytrium dendrobatidis in the New World. — Biotropica 37: 209–221.

Ron, S. R. et al. 2011. Biodiversity and Conservation Status of Ecuadorian Amphibians. — In: Heatwole, H. et al. (eds), Amphibian Biology. Surrey Beatty & Soons PTY Limited, Baulkham Hills, Volume 9, Part 2. pp. 129–170.

Table A1-1. Positive occurrences for the presence of chytrid fungus *B. dendrobatidis* on Ecuadorian amphibian species. It also includes information of IUCN categories that are as follows: Critically Endangered (CR), Endangered (EN), Data Deficient (DD). These 10 unique occurrence locations of *B. dendrobatidis* were obtained from literature (Ron et al. 2011b) and were used to generate a predictive model of chytridiomycosis distribution. This table is an updated version of Ron et al. (2011b).

Species	**Red list category**	**Province: Locality**	**Altitude (m.a.s.l.)**	**Source**
Atelopus balios	CR	Cañar: Río Patul	350 - 450	A. Blasco-Zuñiga, P. A. Menéndez-Guerrero, C. Proaño-Bolaños (unpublished)
Atelopus sp.	CR	Chimborazo:	3505	Merino-Viteri (2001)

Table A1-1. Continuation

Gastrotheca pseustes	EN	Lagunas de Atillo		Ron et al. (2011)
Atelopus pastuso	CR	Imbabura: 9 km E Cuicocha	2813	Merino-Viteri (2001)
Atelopus pastuso	CR	Carchi: 42 km O Tulcán	2564	Merino-Viteri (2001)
Atelopus sp.	CR	Pichincha: Otongoro	3432	Ron et al. (2011)
Atelopus sp. (*spumarius* complex)	DD	Morona-Santiago: 6.6 km N from Limón	1035	Proaño et al. (2007)
Hyalinobatrachium pellucidum	CR			Ron (2005)

Gastrotheca pseustes	EN	Azuay: 4 km O		Merino-Viteri (2001)
Telmatobius niger	CR	Laguna La Toreadora	3961	Merino-Viteri (2001)
Gastrotheca pseustes	EN	Bolívar: Cashca-Totoras	2718	Merino-Viteri (2001)
Gastrotheca pseustes	EN	Cotopaxi: Limpiopungo	3870	Ron et al. (2011)
Telmatobius niger	CR	Azuay: 10 km S from Cutchil	3065	Merino-Viteri (2001)

Table A1-2. Basic information of the 109 species analyzed. Including extinction risk (based on the IUCN categories), number of unique records (*n*), species whose distribution data were used to generate niche models, information from area under the Receiver Operating Characteristic curve (AUC) and binomial tests used for models evaluation, range size in km^2. IUCN categories are as follows: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data Deficient (DD). It is also included values of Morisita's overlap index C_m (Hurlbert, 1978) to analyze the overlap between the environmental niche of the chytridiomycosis and amphibian species, values of environmental niche properties (position and breadth) to estimate marginality and niche breadth, and estimated percentage of the reduction in geographic range size due to habitat degradation for each amphibian species.

Species	Red list category	*n*	Niche Model	Jacknife success rate	*p-value*	AUC Training Data	AUC test data	Training omission rate	Test omission rate	*p-value*	Range size (km^2)

Allobates fratisenescus	DD	2	no			
Allobates insperatus	NT	4	no			
Allobates kingsburyi	DD	9	yes	0.667	0.000	15812.849
Atelopus arthuri	CR	3	no			
Atelopus balios	CR	3	no			

Table A1-2.

Continuation

Atelopus bomolochos	CR	6	yes	0.667	0.001	3045.572
Atelopus boulengeri	DD	5	yes	0.800	0.010	1253.552
Atelopus coynei	EN	5	yes	0.800	0.000	7957.256
Atelopus exiguus	CR	6	yes	0.833	0.000	6068.743
Atelopus guanujo	CR	2	no			
Atelopus halihelos	DD	1	no			
		1				
Atelopus ignescens	CR	6	yes	0.875	0.000	17339.511

		1									
Atelopus longirostris	CR	1	yes	0.909	0.000						9382.256
		1									
Atelopus mindoensis	EN	2	yes	0.917	0.000						4139.737
Atelopus nanay	CR	2	no								
Atelopus nepiozomus	DD	6	yes	0.667	0.001						5028.855
		1									
Atelopus petersi	CR	1	yes	0.778	0.001						7049.184
Atelopus planispina	EN	5	yes	0.800	0.001						9215.115
		1									
Colostethus fugax	NT	0	yes	0.500	0.058						3395.360
Table A1-2.											
Continuation		3									
Epipedobates machalilla	NT	3	yes			0.976	0.928	0.000	0.143	0.039	43712.351
Epipedobates tricolor	NT	8	yes	0.625	0.000						4416.294

Hyloxalus anthracinus	CR	84	yes	1.000	0.000						8234.674
Hyloxalus awa	VU	4	yes			0.979	0.986	0.000	0.000	0.000	24106.969
Hyloxalus bocagei	EN	6	yes	0.833	0.000						4405.956
Hyloxalus cevallosi	DD	7	yes	0.714	0.000						10469.529
Hyloxalus delatorreae	CR	5	yes	0.500	0.012						688.377
Hyloxalus exasperatus	DD	3	no								
Hyloxalus fallax	DD	2	no								
Hyloxalus fuliginosus	EN	55	yes	0.800	0.000						2535.535
Hyloxalus infraguttatus	VU	14	yes			0.967	0.925	0.083	0.273	0.001	27289.527
Hyloxalus jacobuspetersi	CR	4	yes			0.980	0.987	0.065	0.000	0.000	10628.915
Hyloxalus maquipucuna	DD	1	no								
Hyloxalus marmoreoventris	EN	1	no								

Table A1-2.

Continuation

Hyloxalus mystax	DD	1	no								
Hyloxalus peculiaris	VU	1	no								
Hyloxalus pumilus	CR	1	no								
Hyloxalus sauli	LC	2 5	yes			0.956	0.957	0.000	0.000	0.013	40780.504
Hyloxalus shuar	NT	1 5	yes	0.800	0.000						19057.438
Hyloxalus toachi	EN	1 5	yes	0.867	0.000						14324.956
Hyloxalus vertebralis	EN	6 8	yes			0.984	0.976	0.000	0.083	0.000	9137.576
Hyloxalus whymperi	DD	2	no								
Pristimantis acerus	EN	3	no								

Pristimantis actites	NT	3	no			
Pristimantis atratus	EN	4	no			
Pristimantis balionotus	EN	1	no			
Pristimantis baryecuus	EN	8	yes	0.875	0.000	9087.606
Pristimantis condor	VU	2	no			

Table A1-2.

Continuation

Pristimantis cremnobates	EN	4	no			
		1				
Pristimantis crenunguis	EN	7	yes	0.941	0.000	21337.093
		1				
Pristimantis crucifer	EN	1	yes	0.818	0.000	5051.255
Pristimantis cryophilius	EN	7	yes	0.857	0.000	7906.424
		2				
Pristimantis devillei	NT	2	yes	0.909	0.000	3689.148

Pristimantis dissimulatus	EN	2	no			
Pristimantis ernesti	DD	1	no			
Pristimantis eugeniae	EN	6	yes	0.833	0.000	2149.562
		1				
Pristimantis festae	LC	4	yes	0.857	0.000	11433.601
		1				
Pristimantis floridus	EN	0	yes	0.800	0.000	22162.456
Pristimantis ganonotus	DD	1	no			
Pristimantis gentryi	EN	6	yes	0.833	0.000	775.393
Pristimantis gladiator	EN	7	yes	0.714	0.001	5287.319
		1				
Pristimantis glandulosus	EN	3	yes	0.923	0.000	1207.890

Table A1-2.

Continuation

Pristimantis hamiotae	DD	2	no

Pristimantis huicundo	DD	1	no			
Pristimantis ignicolor	EN	3	no			
Pristimantis incanus	EN	3	no			
Pristimantis incomptus	NT	5	yes	0.800	0.000	4943.561
Pristimantis inusitatus	EN	6	yes	0.833	0.000	12501.920
Pristimantis katoptroides	EN	1	no			
Pristimantis kirklandi	EN	1	no			
Pristimantis librarius	DD	3	no			
Pristimantis lividus	EN	6	yes	0.667	0.000	7803.039
Pristimantis luteolateralis	NT	16	yes	0.875	0.000	3546.992
Pristimantis modipeplus	EN	11	yes	0.909	0.000	3176.527
Pristimantis muricatus	VU	3	no			
Pristimantis nigrogriseus	NT	1	yes	0.909	0.000	15132.226

		1				
Table A1-2.						
Continuation		1				
Pristimantis nyctophylax	VU	6	yes	0.938	0.000	2912.893
Pristimantis ocreatus	VU	2	no			
Pristimantis orcesi	VU	6	yes	0.667	0.000	7998.610
		1				
Pristimantis orestes	EN	7	yes	0.941	0.000	10429.036
		1				
Pristimantis ornatissimus	VU	5	yes	0.867	0.000	13797.688
Pristimantis orphnolaimus	DD	2	no			
Pristimantis ortizi	DD	2	no			
Pristimantis pastazensis	EN	2	no			
Pristimantis paululus	LC	5	yes	0.600	0.050	40714.165
Pristimantis perlcutus	EN	1	no			

Pristimantis philipi	DD	2	no								
Pristimantis prolatus	EN	8	yes	0.750	0.000						7670.360
Pristimantis proserpens	EN	6	yes	0.941	0.000						13447.038
Pristimantis pteridophilus	EN	6	yes	0.667	0.000						3510.807

Table A1-2. Continuation

Pristimantis pycnodermis	EN	17	yes	0.882	0.000						3558.192
Pristimantis pyrrhomerus	VU	13	yes	0.846	0.000						12111.639
Pristimantis riveti	NT	30	yes			0.973	0.980	0.000	0.000	0.001	5887.818
Pristimantis rubicundus	EN	7	yes	0.857	0.000						2825.877
Pristimantis ruidus	DD	1	no								
Pristimantis simonbolivari	EN	5	yes	0.800	0.000						184.371
Pristimantis sobetes	DD	3	No								

Pristimantis spinosus	EN	8	yes	0.750	0.001						10706.455
		1									
Pristimantis surdus	VU	1	yes	0.001	0.000						4147.491
Pristimantis tenebrionis	VU	6	yes	0.667	0.000						17799.578
Pristimantis thymalopsoides	VU	1	no								
		1									
Pristimantis trachyblepharis	LC	5	yes	0.800	0.000						15104.656
		1									
Pristimantis truebae	EN	4	yes	0.929	0.000						7724.638
Pristimantis versicolor	EN	9	yes	0.778	0.003						3134.311
Table A1-2.											
Continuation		1									
Pristimantis vertebralis	VU	0	yes	0.800	0.000						8319.967
Pristimantis vidua	EN	3	no								
Pristimantis walkeri	LC	4	yes			0.982	0.972	0.000	0.000	0.000	35828.327

		1									
Telmatobius cirrhacelis	CR	3	no								
		2									
Telmatobius niger	CR	8	yes			0.965	0.982	0.048	0.000	0.000	11874.714
Telmatobius vellardi	DD	6	yes	0.833	0.000						2663.044

Table A1-2. Continuation

Species	Morisita's overlap index C_m on temperature	Morisita's overlap index C_m on precipitation	Marginality	Niche breath on temperature B'–T	Niche breath on precipitation B'–P	% reduction in range size due to habitat degradation
Allobates fratisenescus						
Allobates insperatus						
Allobates kingsburyi	0.040	0.004	1.775	0.201	0.163	17.162
Atelopus arthuri						
Atelopus balios						
Atelopus bomolochos	0.445	0.804	2.941	0.065	0.130	49.844
Atelopus boulengeri	0.000	0.000	1.776	0.077	0.137	31.821
Atelopus coynei	0.330	0.487	2.049	0.198	0.458	62.560
Atelopus exiguus	0.674	0.857	3.071	0.102	0.141	40.119
Atelopus guanujo						
Atelopus halihelos						
Atelopus ignescens	0.915	0.970	3.682	0.106	0.255	35.134
Atelopus longirostris	0.028	0.031	1.102	0.308	0.631	55.528

Table A1-2.

Continuation

Atelopus mindoensis	0.000	0.016	1.644	0.095	0.378	78.564
Atelopus nanay						
Atelopus nepiozomus	0.316	0.485	2.186	0.145	0.321	17.406
Atelopus petersi	0.822	0.713	4.045	0.062	0.214	20.093
Atelopus planispina	0.000	0.004	1.590	0.121	0.344	35.873
Colostethus fugax	0.000	0.000	1.377	0.141	0.312	11.596
Epipedobates machalilla	0.000	0.570	1.850	0.553	0.452	75.678
Epipedobates tricolor	0.000	0.000	2.476	0.371	0.517	80.999
Hyloxalus anthracinus	0.821	0.975	3.167	0.133	0.184	36.074
Hyloxalus awa	0.003	0.010	1.556	0.599	0.492	75.083
Hyloxalus bocagei	0.014	0.148	1.707	0.133	0.471	22.448
Hyloxalus cevallosi	0.000	0.000	2.113	0.192	0.075	34.356
Hyloxalus delatorreae	0.582	0.861	2.924	0.145	0.183	31.790

Hyloxalus exasperatus						

Table A1-2.

Continuation

Hyloxalus fallax						
Hyloxalus fuliginosus	0.012	0.085	1.950	0.100	0.489	30.513
Hyloxalus infraguttatus	0.001	0.808	1.695	0.443	0.314	62.545
Hyloxalus jacobuspetersi	0.720	0.927	3.120	0.148	0.305	69.377
Hyloxalus maquipucuna						
Hyloxalus marmoreoventris						
Hyloxalus mystax						
Hyloxalus peculiaris						
Hyloxalus pumilus						
Hyloxalus sauli	0.000	0.000	0.822	0.331	0.180	15.061
Hyloxalus shuar	0.217	0.349	1.726	0.179	0.602	27.920
Hyloxalus toachi	0.000	0.001	1.589	0.538	0.533	62.074

Hyloxalus vertebralis	0.756	0.941	3.066	0.128	0.178	36.922
Hyloxalus whymperi						
Table A1-2.						
Continuation						
Pristimantis acerus						
Pristimantis actites						
Pristimantis atratus						
Pristimantis balionotus						
Pristimantis baryecuus	0.369	0.545	2.142	0.195	0.442	29.769
Pristimantis condor						
Pristimantis cremnobates						
Pristimantis crenunguis	0.014	0.023	1.637	0.501	0.554	78.466
Pristimantis crucifer	0.010	0.002	1.613	0.132	0.402	67.986
Pristimantis cryophilius	0.983	0.965	3.781	0.096	0.181	19.516
Pristimantis devillei	0.569	0.280	2.789	0.152	0.193	2.312

Pristimantis dissimulatus						
Pristimantis ernesti						
Pristimantis eugeniae	0.119	0.141	2.201	0.081	0.355	92.625

Table A1-2.

Continuation

Pristimantis festae	0.866	0.683	3.363	0.128	0.238	28.453
Pristimantis floridus	0.222	0.375	1.567	0.432	0.716	81.037
Pristimantis ganonotus						
Pristimantis gentryi	0.707	0.610	1.864	0.040	0.081	12.667
Pristimantis gladiator	0.723	0.631	4.202	0.050	0.164	5.377
Pristimantis glandulosus	0.284	0.446	2.642	0.086	0.166	2.354
Pristimantis hamiotae						
Pristimantis huicundo						
Pristimantis ignicolor						
Pristimantis incanus						

Pristimantis incomptus	0.000	0.033	1.781	0.103	0.190	10.335
Pristimantis inusitatus	0.239	0.288	1.630	0.267	0.220	28.888
Pristimantis katoptroides						
Pristimantis kirklandi						

Table A1-2.

Continuation

Pristimantis librarius						
Pristimantis lividus	0.876	0.648	3.769	0.087	0.172	21.906
Pristimantis luteolateralis	0.011	0.004	1.770	0.114	0.326	30.702
Pristimantis modipeplus	0.788	0.822	3.360	0.128	0.140	70.816
Pristimantis muricatus						
Pristimantis nigrogriseus	0.204	0.291	1.450	0.216	0.724	31.878
Pristimantis nyctophylax	0.030	0.023	1.885	0.096	0.322	89.559
Pristimantis ocreatus						
Pristimantis orcesi	0.747	0.875	4.380	0.049	0.173	38.119

Pristimantis orestes	0.890	0.946	3.297	0.151	0.177	40.107
Pristimantis ornatissimus	0.003	0.004	1.944	0.420	0.538	52.407
Pristimantis orphnolaimus						
Pristimantis ortizi						
Pristimantis pastazensis						

Table A1-2.

Continuation

Pristimantis paululus	0.000	0.000	1.487	0.544	0.271	22.968
Pristimantis perlcutus						
Pristimantis philipi						
Pristimantis prolatus	0.000	0.021	1.742	0.110	0.231	13.625
Pristimantis proserpens	0.018	0.066	1.164	0.183	0.662	32.528
Pristimantis pteridophilus	0.147	0.384	2.443	0.083	0.366	79.926
Pristimantis pycnodermis	0.373	0.386	2.320	0.129	0.290	24.552
Pristimantis pyrrhomerus	0.755	0.904	3.090	0.168	0.355	30.893

Pristimantis riveti	0.712	0.922	3.051	0.097	0.158	38.484
Pristimantis rubicundus	0.000	0.000	2.189	0.070	0.079	39.329
Pristimantis ruidus						
Pristimantis simonbolivari	0.659	0.710	3.310	0.071	0.088	50.467
Pristimantis sobetes						
Pristimantis spinosus	0.205	0.329	1.614	0.223	0.676	30.796

Table A1-2.

Continuation

Pristimantis surdus	0.304	0.599	2.561	0.114	0.373	84.794
Pristimantis tenebrionis	0.000	0.003	2.386	0.469	0.490	91.002
Pristimantis thymalopsoides						
Pristimantis trachyblepharis	0.000	0.000	1.925	0.203	0.114	18.766
Pristimantis truebae	0.946	0.855	3.726	0.116	0.152	99.041
Pristimantis versicolor	0.141	0.688	2.140	0.112	0.205	11.655
Pristimantis vertebralis	0.203	0.763	2.351	0.101	0.425	78.233

Pristimantis vidua						
Pristimantis walkeri	0.002	0.234	1.453	0.479	0.624	45.987
Telmatobius cirrhacelis						
Telmatobius niger	0.966	0.839	3.602	0.127	0.140	54.016
Telmatobius vellardi	0.545	0.873	2.892	0.104	0.142	32.126

Table A1-3. Loadings of 19 environmental variables (Bio's) from Principal component analyses (PCA's), applied to amphibian occurrence records (109 species, 1,000 unique records) and 4,000 randomly generated points within the range of predictive model of chytridiomycosis. PCA's were conducted using raw environmental variables and variables where the influence of altitude was removed to visualize overlap of environmental conditions between species extinction risk categories, genera and chytridiomycosis. Analyses were performed with and without species records of *Pristimantis* (see text for further explanation). The last column shows loadings from a PCA using environmental rasters instead of occurrence points. As before, we controlled for the effect of elevation.

Code	Variables	Raw environmental variables and geographic variables		Raw environmental variables and geographic variables without *Pristimantis*		Variables where the influence of altitude was removed		Variables where the influence of altitude was removed without *Pristimantis*		Altitude-free environmental rasters from Ecuadorian Andes	
		PC I	**PC II**	**PC I**	**PC II**	**PC I**	**PC II**	**PC I**	**PC II**	**PC I**	**PC II**
Geog.	Longitude	-0.13	0.58	-0.15	0.56						
Geog.	Latitude	-0.04	0.07	-0.07	0.11						
Geog.	Altitude	-0.93	-0.08	-0.95	-0.03						
BIO1	Annual Mean Temperature	0.97	0.08	0.97	0.02	0.92	-0.02	0.92	-0.05	-0.98	0.11
BIO2	Mean Diurnal Range(Mean(period max-min))	0.48	-0.10	0.49	-0.13	0.92	-0.20	0.92	-0.24	-0.68	-0.33

Table A1-3. Continuation

BIO3	Isothermality	-0.22	0.07	-0.19	0.03	0.24	0.10	0.26	0.03	-0.30	-0.23
BIO4	Temperature Seasonality (Coefficient of Variation)	0.17	0.18	0.16	0.21	-0.26	0.22	-0.31	0.29	0.17	0.38
BIO5	Max Temperature of Warmest Period	0.98	0.07	0.98	0.01	0.97	-0.06	0.97	-0.09	-0.98	0.04

BIO6	Min Temperature of Coldest Period	0.93	0.12	0.94	0.06	0.07	0.48	0.05	0.50	-0.73	0.37
BIO7	Temperature Annual Range	0.59	-0.13	0.59	-0.16	0.94	-0.26	0.93	-0.29	-0.65	-0.28
BIO8	Mean Temperature of Wettest Quarter	0.97	0.05	0.97	-0.01	0.84	-0.18	0.84	-0.17	-0.93	0.02
BIO9	Mean Temperature of Driest Quarter	0.96	0.12	0.97	0.05	0.88	0.20	0.89	0.14	-0.96	0.21
BIO10	Mean Temperature of Warmest Quarter	0.97	0.08	0.98	0.02	0.89	0.01	0.89	0.00	-0.96	0.17
BIO11	Mean Temperature of Coldest Quarter	0.96	0.06	0.97	0.00	0.89	-0.11	0.89	-0.14	-0.97	0.04
BIO12	Annual Precipitation	0.38	0.62	0.26	0.63	-0.21	0.72	-0.21	0.67	0.05	0.97
BIO13	Precipitation of Wettest Period	0.50	0.26	0.42	0.23	-0.21	0.30	-0.19	0.25	0.17	0.77
BIO14	Precipitation of Driest Period	0.15	0.94	0.05	0.95	-0.13	0.95	-0.17	0.93	-0.03	0.90
BIO15	Precipitation Seasonality (Coefficient of Variation)	0.38	-0.75	0.38	-0.76	0.00	-0.87	0.01	-0.89	0.12	-0.66

Table A1-3. Continuation

BIO16	Precipitation of Wettest Quarter	0.49	0.26	0.40	0.23	-0.25	0.29	-0.22	0.25	0.20	0.77
BIO17	Precipitation of Driest Quarter	0.15	0.94	0.05	0.94	-0.13	0.94	-0.16	0.92	-0.03	0.91
BIO18	Precipitation of Warmest Quarter	0.43	0.11	0.33	0.11	-0.32	0.09	-0.28	0.10	0.35	0.57
BIO19	Precipitation of Coldest Quarter	0.23	0.90	0.14	0.91	-0.06	0.92	-0.11	0.90	-0.13	0.83

% of variance explained	**41.41**	**18.87**	**40.17**	**18.77**	**36.70**	**24.16**	**36.90**	**23.50**	**38.50**	**30.50**
Cumulative %	**41.41**	**60.29**	**40.17**	**58.94**	**36.70**	**60.86**	**36.90**	**60.40**	**38.50**	**69.00**

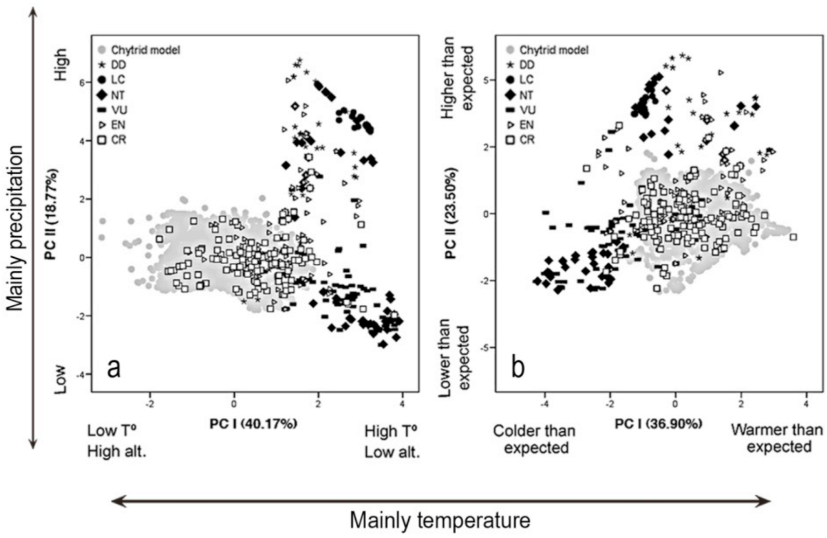
Table A1-4. Mann-Whitney post hoc multiple comparison analyses. These are based on the Bonferroni corrected approach, to determine if differences in range reduction between different extinction risk (IUCN) categories were statistically significant. IUCN categories are as follows: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC). Only Vulnerable and Least Concern categories differed (*P*-values in bold).

Extinction risk category	**Extinction risk category**	***P*-value**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
CR	EN	1.000	-2.75E+15	2.75E+15
	LC	1.000	-2.29E+15	5.75E+15
	NT	1.000	-2.48E+15	4.31E+15
	VU	0.488	-5.74E+15	1.06E+15
EN	CR	1.000	-2.75E+15	2.75E+15
	LC	1.000	-1.76E+15	5.22E+15
	NT	1.000	-1.84E+15	3.66E+15
	VU	0.157	-5.09E+15	4.06E+14
LC	CR	1.000	-5.75E+15	2.29E+15
	EN	1.000	-5.22E+15	1.76E+15
	NT	1.000	-4.84E+15	3.20E+15
	VU	**0.040**	-8.09E+15	-5.24E+13
	CR	1.000	-4.31E+15	2.48E+15

Table A1-4. Continuat

	EN	1.000	-3.66E+15	1.84E+15
NT	LC	1.000	-3.20E+15	4.84E+15
	VU	0.070	-6.65E+15	1.44E+14
VU	CR	0.488	-1.06E+15	5.74E+15
	EN	0.157	-4.06E+14	5.09E+15
	LC	**0.040**	5.24E+13	8.09E+15
	NT	0.070	-1.44E+14	6.65E+15

Figure A1. Axes I and II from principal components analysis (PCA) based on 19 environmental variables at 4000 random points within the predicted, thresholded chytridiomycosis environmental niche model in Ecuador (gray circles). All unique species amphibian records without *Pristimantis* ones (502) were also included in the PCA (black and white symbols). Species occurrence records classified based on IUCN Red List (Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD)). (**a**) PCA conducted using raw environmental variables and altitude, latitude and longitude and (**b**) PCA conducted using variables where the influence of altitude was removed.



Appendix 2. Evaluation of different climate data sources on analyses

Given potential data deficiencies associated with the WorldClim data set, especially associated with precipitation in montane areas (this is acknowledged by Hijmans et al. 2005), we evaluated the robustness of our climate analyses using an additional climate source. We used the Ecuadorian bioclimatic model recently created by Ministerio del Ambiente del Ecuador (MAE, 2011). This model used high quality dataset from all available climate stations from Instituto Nacional de Metereología e Hidrología del Ecuador (INAMHI). Using more (and higher quality) climate station data is probably the most important aspect for modeling climate. The MAE climate model was obtained through Cokriging interpolation method of the observations made at climate stations with a terrain numerical model and WorldClim variables as co-variables. The model uses monthly and annual precipitation and maximum and minimum temperature, and consists of climate grids (annual precipitation and annual temperature) with a spatial resolution of 1 km^2 for the 1970-2000 period. The comparison between MAE-INAMHI data and WordClim model reveals no significant differences in temperature, however, there are some discrepancies in annual precipitation (MAE, 2011). These differences are both in their spatial distribution and the average values, with the WordClim model generally underestimating the data recorded from INAMHI stations (MAE, 2011).

To evaluate if this new information would change the conclusions made in our paper we conducted a linear regression of the altitude raster on the MAE precipitation raster to obtain residuals and thus controls for the effect of elevation. We only used the precipitation raster given that our previous analysis using Worldclim database did not yield a clear geographic pattern associated with temperature (see main text of the manuscript) and the temperature data did not vary between the two sources. Then, the free-altitude precipitation raster was classified using the Jenks Natural Breaks method, which identifies break points that best group similar values and maximize the differences between classes (Jenks 1967). We obtained three precipitation classes which corresponded to areas with less, equal and more precipitation relative to that expected based on their altitude. We then calculated the geographic overlap between each climatic class, the chytridiomycosis model and the percentage of Critically Endangered species records that fell in each climatic class. Regression analyses were performed in ArcInfo Workstation 9.0 (ESRI 2005).

Our results show that areas with equal or less precipitation than expected are primarily located in western slopes of Andes as well as in some inter-montane valleys and in some parts of the eastern Cordilleras of southern Ecuador (e.g. Cutucú Cordillera). Wetter regions than expected for their altitude are located mainly in the eastern Andean slopes of Ecuador and some parts of the western slopes of northern Andes. Only in the areas with equal or less precipitation than expected do the majority (80%) of Critically Endangered records occur (i.e. 49.2% in areas with less precipitation and 30.8% in those close to the expected precipitation conditions for their altitude). Remarkably, just 20% of Critically Endangered records of all analyzed species occur in wetter areas than expected (Fig. A2-a). Further, 38.4% of the chytridiomycosis model overlapped with drier areas than expected for their altitude, 39.3% overlapped with areas that did not deviate from expected precipitation conditions. Only 22.3% of the model overlapped with areas wetter than expected (Fig. A2-b). In sum, regions that were drier or closer to the expected precipitation conditions for their altitude, contained most of the Critically Endangered species' occurrences. These same areas also appear to have better climatic conditions for chytridiomycosis. These results are qualitatively consistent with those from Worldclim and would not change the conclusions drawn from the Worldclim based analyses.

References

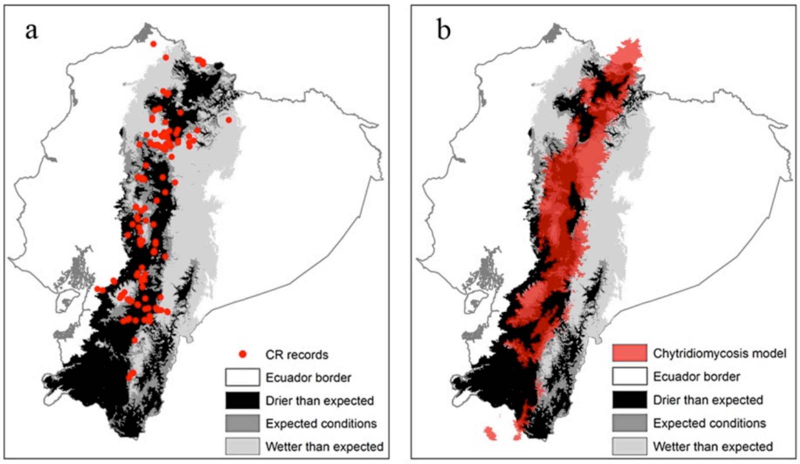
ESRI. 2005. ArcMap v. 9.1. — ESRI, Redland.

Hijmans, R. J. et al. 2005. Very high resolution interpolated climate surfaces for global land areas. — International Journal of Climatology 25: 1965–1978.

Jenks, G. F. 1967. The data model concept in statistical mapping. — International Yearbook of Cartography **7:** 186–190.

MAE, 2011. Modelo Bioclimático del Ecuador Continental. — Ministerio del Ambiente (MAE) del Ecuador.

Figure A2. Free-altitude precipitation rasters. Areas with less precipitation than expected are black colored, areas with equal precipitation than expected are gray darker colored, whereas wetter regions than expected for their altitude are light gray colored. (**a**) Records from Critically Endangered (CR) species are shown in red; (**b**) Chytrid model is shown in red.



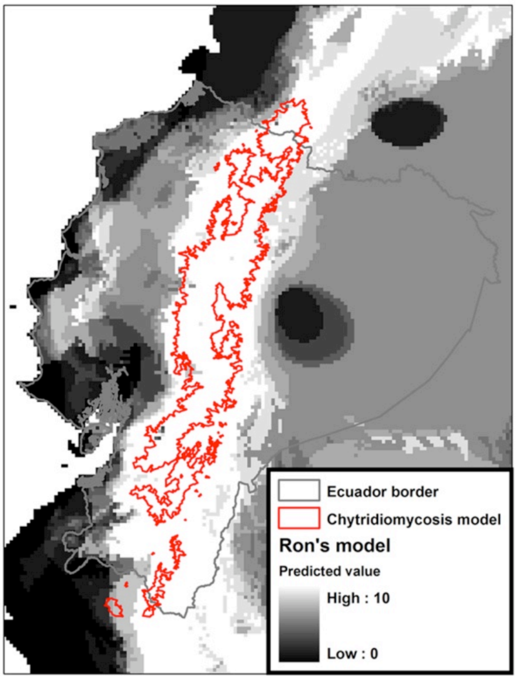
Appendix 3. Comparison of Ecuadorian and global models of chytridiomycosis distribution

To evaluate if our model adequately represented the pathogen's niche in Ecuador we compared the global predictive model of the potential distribution of amphibian infected with chytridiomycosis from Ron (2005) with our model. Ron (2005) used 44 *B. dendrobatidis*-positive localities in the New World to model the pathogen potential distribution that integrate the final output from ten models. These ten models were added and then divided by 10 generating a final model with values ranging from 0 to 1 (1 for those regions where all the models predicted niche presence). Ninety-five percent of our chytrid model overlapped with those areas where all models predicted niche presence in the global predictive model from Ron (2005, Fig. A3). Three percent of our model overlapped with those regions where 9 out of 10 models predicted niche presence, whereas only 2% of our model overlapped with those regions where 3-8 out of 10 models predicted presence in the global model. Based on these analyses we conclude that our model sufficiently captures the general geographical and environmental patterns of the distribution of the pathogen.

References

Ron, S. R. 2005. Predicting the Distribution of the Amphibian Pathogen Batrachochytrium dendrobatidis in the New World. — Biotropica 37: 209–221.

Figure A3. Overlap between our chytridiomycosis model (red) and the Chytrid global predictive model (gray-scale) from Ron (2005). Note that the Ron's model integrates the final output from ten models. These ten models were added generating a final model with values ranging from 0 to 10 (10 for those regions where all the models predicted niche presence).



Appendix 4. Analyses of combination of multiple factors threaten amphibians

In order to evaluate the effect of chytridiomycosis, climate change and habitat loss simultaneously on Ecuadorian amphibians, we conducted a principle component analysis (PCA) using Morisita's overlap index (Cm) on temperature and precipitation, Hurlbert's niche breadth index (B') along temperature and precipitation, marginality values and percentage of reduction in geographic range size due to habitat degradation as variables for 66 amphibian species for which MaxEnt models were created. This analysis was followed by Kruskal-Wallis tests and by Mann-Whitney post hoc multiple comparison analyses with Bonferroni correction (Sokal and Rohlf 1995) to determine if differences in PC I scores and PC II scores among different extinction risk categories were statistically significant. The first axis (58.6% variation explained) of the PCA was mainly defined by Cm on temperature, marginality and Cm on precipitation. Along this axis, B' along precipitation and B' along temperature were also important but have negative loadings (Table A4-1). The second PCA axis (19.7% of the variation explained) was primarily based on reduction in geographic range size due to habitat degradation (Table A4-1). Generally speaking, Critically Endangered species tended to have higher overlap values for the Cm index on temperature and precipitation (i.e. more overlap with the chytrid model), higher marginality values and lower values for B' along precipitation and temperature (i.e. more specialized niches; Fig. A4). There were overall differences in PC I scores among all risk extinction categories (Kruskal-Wallis $\chi2 = 12.97$, $P < 0.05$), but post hoc multiple comparison analysis indicated that only Critically Endangered species significantly differed from Endangered, Near Threatened and Least Concern species ($P < 0.05$, Table A4-2). There were no overall differences in PC II among all categories. All these results are entirely consistent with our previous results and exemplify an integrative analysis combining the three amphibian threats analyzed in our paper.

References

Sokal, R. R. and Rohlf, F. J. 1995. Biometry, the principles and practice of statistics in biological research. — Third edition. Freeman.

Table A4-1. Loadings of 6 variables from a Principal component analysis (PCA) that measure the major threats to amphibians (see methods in the main text). PCA was applied to 66 amphibian species for which MaxEnt models were created.

Variables	Code	PC I	PC II
Morisita overlap index on Temperature	*Cm* on *T*	0.92	0.22
Morisita overlap index on Precipitation	*Cm* on *P*	0.85	0.35
Marginality	*M*	0.90	0.26
Niche breath on Temperature	*B-T*	-0.69	0.37
Niche breath on Precipitation	*B-P*	-0.76	0.31
Reduction in range size due to habitat degradation	%HL	-0.29	0.84
% of variance explained		58.56	19.68
Cumulative %		58.56	78.25

Tabla A4-2. Mann-Whitney post hoc multiple comparison analyses. These are based on the Bonferroni corrected approach, to determine if differences in PC I scores and PC II scores between different extinction risk (IUCN) categories were statistically significant. IUCN categories are as follows: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC). Only Critically Endangered species significantly differed from Endangered, Near Threatened and Least Concern species (*P*-values in bold).

Extinction risk category	**Extinction risk category**	***P*-value**
CR	EN	**0.026**
	LC	**0.023**
	NT	**0.010**
	VU	0.052
EN	CR	**0.026**
	LC	0.058
	NT	0.149
	VU	0.680
LC	CR	**0.023**
	EN	0.058
	NT	0.286
	VU	0.062

Table A4-2. Continuation

NT	CR	**0.010**
	EN	0.149
	LC	0.286
	VU	0.133
VU	CR	0.052
	EN	0.680
	LC	0.062
	NT	0.133

Figure A4. Axes I and II from principal components analysis (PCA) based on 6 variables that measure the major threats to amphibians at 66 species for which MaxEnt models were created (see methods in the main text). Species were classified based on IUCN Red List (Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD)). For eigenvectors and eigenvalues see Table A-1.