Short-term predicted extinction of Andean populations of the lizard *Stenocercus guentheri* (Iguanidae: Tropidurinae)

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ABSTRACT

We studied the thermal physiology of the Andean lizard *Stenocercus guentheri* in order to evaluate the possible effects of global warming on this species. We determined the preferred body temperature (T_{pref}), critical thermals (CT_{min}, CT_{max}), and hours of restriction and activity. T_{pref} was 32.14 ± 1.83 °C; CT_{min} was 8.31 °C in adults and 9.14 °C in juveniles, whereas CT_{max} was 43.28 °C in adults and 41.68 °C in juveniles. To assess extinction risk, we used the model created by Sinervo et al. (2010) and predicted that 16.7% of the population will have a high risk of extinction by 2020, with an increase to 26.7% by 2050. These results suggest that this species, despite being able to maintain its T_{pref} through behavioral thermoregulation and habitat selection, could be physiologically sensitive to climate warming; thus, the potential for local adaptation may be limited under a warmer climate. Further studies focusing on the ability of *S. guentheri* to evolve higher T_{pref} and thermal tolerances are needed to understand the ability of this species to respond to climate change.

Key words: Andes, critical thermal, evolutionary history, extinction, global warming, preferred body temperature, *Stenocercus guentheri*.

1. INTRODUCTION

Global warming is one of the greatest threats to global biodiversity (Malcom et al., 2006; Thomas et al., 2004; Vörösmarty et al., 2010). The global mean surface temperature increased by 0.85 °C (0.65 to 1.06 °C) over the period 1880–2012. The decade 2003–2012 has been the warmest over the instrumental record. Climate projections indicate that global mean surface air temperature increase during this century could be from 0.9 to 2.3 °C under the best scenario, and 3.2 to 5.4 °C under a worse one (IPCC, 2014).

Both yearly minimum and maximum temperatures have increased in South America, with the daily temperature amplitude (i.e., difference between the lower and higher temperatures) dropping in some regions (Barry and Seimon, 2000). In Venezuela, Colombia, Ecuador and Peru, the mean annual temperature has increased by 0.8 °C in the last century (Herzog et al., 2011), which has caused retreat of the tropical Andean glaciers at an increasing rate since the late 1970s (Rabatel et al., 2013). Projections of climate change in the tropical Andes indicate a trend of continuous warming throughout this century, with a higher temperature increase at higher altitudes (Herzog et al., 2011; Vuille et al., 2008). Further changes in hydrological cycles are also predicted, with increasing rainfall during the wet season and decreasing rainfall during the dry season (Vuille et al., 2008).

Climate change has an impact on different aspects of species natural histories, such as phenology, morphology, physiology, and behavior (Deutsch et al., 2008; Sinervo et al., 2010). The vulnerability of species to climate change depends on their sensitivity to environmental changes, the degree of exposure to changes, their resilience, and their adaptive potential (Williams et al., 2008). In addition, the impact of climate change on species varies geographically (Thomas et al., 2004). For example warming increases at higher latitudes (IPCC, 2007). Thermal tolerance of many organisms is proportional to the magnitude of annual variation in temperature (Ghalambor et al., 2006), a feature of climate that also increases with latitude. Those species with narrower thermal tolerances, such as tropical species, would be the most affected by climate change (Williams et al., 2007). Organisms with the highest extinction risk are those with narrow thermal tolerance, limited acclimation ability, and reduced dispersal (Deutsch et al., 2008).

Most of reptiles' physiological processes are temperature dependent and frequently optimal only within a narrow range of body temperatures, known as optimal temperature range (Huey and Stevenson, 1979). Essentially, temperature affects all aspects of behavior and life history of reptiles, including locomotion, reproductive biology, sensory information, foraging ability, courtship, and feeding and growth rates (Angilletta et al., 2002; Boretto and Ibargüengoytía, 2009; Espinoza et al., 2004; Ibargüengoytía et al., 2010; Sears, 2005; Zug et al., 2001). In addition, temperature is a determining factor for species distribution ranges (Andrews, 1998).

The thermo-physiological profile of a reptile species is essential to predict whether global warming will cause harm or benefit. To visualize the effect of temperature increase on the fitness of a species, it is necessary to know the body temperature in nature (T_b) in relation to the optimal temperature of performance (T_o; Kubich, 2013), which generally coincides with the preferred temperature (T_{pref}) obtained in the laboratory (Martin and Huey, 2008). Likewise, knowledge of critical thermal minimum and maximum temperatures is necessary because it helps us calculate the limits of thermal tolerance, rates and efficiencies of performance, and the relationship of latitude with the ranges of thermal tolerance (Grigg and Buckley, 2013; Huey et al., 2009; Huey et al., 2012). Another important factor in reptiles like lizards is behavioral thermoregulation. The effectiveness of lizards to thermoregulate depends on environmental sources of gain and loss of heat (Zug et al., 2001). To evaluate this factor, it is necessary to know the hours of restriction, which are the daily number of hours a lizard must spend in a refuge due to excessive heat. Restriction hours limit the amount of time available for foraging, dispersal and reproduction (Kubisch, 2013; Sinervo et al., 2010). Global warming may increase the hours of restriction experienced by a population, reducing population growth rates and increasing extinction risk (Sinervo et al., 2010).

Studies of thermal physiology of tropical species of lizards are scarce (Jordán and Pérez, 2012; Sepúlveda et al., 2008; Van Berkum et al., 1986), and, to our knowledge, there are no published studies on lizards' species from the tropical Andes, which are being severely affected by climate warming (Rabatel et al., 2013). The purpose of this study is to determine the preferred body temperature, critical thermal temperatures, and hours of restriction and activity in the Andean lizard *Stenocercus guentheri*, and use these data to predict possible population-level effects of global warming. This species is an active thermoregulator that inhabits the northern Andes of Ecuador at an altitude range of 2135-3890 m (Torres-Carvajal and Mafla-Endara, 2013).

2. MATERIALS AND METHODS

2.1. Study area and field work data collection

This study was carried out in one of the last patches of Dry Andean Matorral and Dry Montane Forest in the Northern Andes. The study site lies on Jerusalem Recreational Park and Protected Forest (00° 00' 19'' - 00° 00' 51'' N, and 78° 21' 06'' - 78° 24' 08'' W), a 1109 ha protected area with an elevation range between 2450-3000 m. (Navarrete, 2010).

Five one-day sampling trips were conducted from 24 March to 21 April 2014, in which 39 specimens (13 males, 14 females, and 12 juveniles) were caught between 9:00-12:00 by noosing. Each individual's body temperature (T_b) was measured immediately after capture using a thermocouple (Omega 4-Channel Handheld Data Logger Thermometer). Additionally, the environmental temperature was recorded at the capture sites by measuring substrate temperature and air temperature 1 cm above the ground. Body mass was recorded for each lizard using a precision digital scale (My Weigh I300), and reproductive status (Juvenile / Adult) and sex were determined by observation of phenotypic traits (Torres-Carvajal, 2007).

2.2. Thermal preference

T_{pref} was obtained in the laboratory one day after capture. Lizards (n=39) were put directly into thermal gradients (substrate temperature range: 23–63 °C; air temperature range: 23.5–40 °C) that consisted of plywood board tracks that were each 1m long, 12cm wide and 20cm high. The thermal gradient was created along each channel by placing a 100 watt light bulb as a heat source at one end. Body temperature was recorded in four lizards in real time using a thermocouple (Omega 4-Channel Handheld Data Logger Thermometer) that was placed anterior to the cloacal region and secured with medical cloth tape. Lizards were placed in individual channels for an hour and a half. Body temperature of each lizard was recorded every 30 seconds after an acclimation period of 15 minutes. Mean T_{pref} was calculated by averaging the recorded body temperatures of each lizard and this value was then averaged among all lizards to get the mean population T_{pref} (Angilleta y Werner, 1998).

We compared the data between groups (males, females, and juveniles) using One-Way-ANOVA. Assumptions of normality and variance-homogeneity were tested with the one-sample Kolmogorov-Smirnov and Levene tests, respectively. We also performed a *t*-test to compare T_{pref} and T_b of this species, and to compare between T_{pref} and T_b of *S. guentheri* with T_b of clade Tropidurinae (Sinervo et al., 2010).

2.3. Critical thermal temperatures

The tolerance to low temperatures was measured using the critical thermal minima measurement (CT_{min}) 2 days after capture (lizards were maintained at room temperature; *n*=35). CT_{min} was determined by placing each lizard in a transparent and dry glass chamber that was immersed in ice water; the temperature dropped in a range of 22.8-1 °C, at an approximated rate of 0.8 °C per minute (Table S1). Body temperature was recorded every 30 seconds until the individual was unable to right itself after being placed on its back.

The tolerance to high temperatures was measured using the critical thermal maxima (CT_{max}) 3 days after capture (lizards were maintained at room temperature; *n*=35). CT_{max} was determined using the same procedure as for the CT_{min}, but with a chamber immersed in water heated by a stove (temperature range: 20.4-54.8 °C; approximated rate of heating: 1.8 °C per minute; Table S1).

Mean critical thermal temperatures were calculated averaging temperature values of all lizards in each group (males, females, and juveniles). We compared the data between groups using One-Way-ANCOVA, with body mass as covariate. Assumptions of normality and variance-homogeneity were tested with the one-sample Kolmogorov-Smirnov and Levene tests, respectively.

2.4. Model of extinction prediction

The model introduced by Sinervo et al. (2010) was used to predict where extinctions of *S. guentheri* populations are likely to occur. This model integrates georeferenced points of distribution, T_{pref}, global daily maximum temperature surfaces, and a predictive equation for hours of restriction (*H*r), based on operative environmental temperature (T_{e}) and daily maximum air temperature (T_{max}). The model estimates the breakpoint and the year in which the value of *H*r is too high to allow for a population to be viable according to the physiological model of local extinction (*sensu* Sinervo et al., 2010).

A total of 217 georeferenced localities (WGS84) of occurrence of *Stenocercus guentheri* were obtained from the collection database of Museo de Zoología QCAZ, Pontificia Universidad Católica del Ecuador. Of these, 30 were included in the extinction model (Table S2), because they were separated from each other by at least 1 km, a requirement to avoid pseudoreplication (Peterson et al., 2004).

The program R: A language and environment for statistical computing (R Core Team, 2014) was used to extract T_{max} values from global climate layers from the WorldClim web site (www.worldclim.org) for the years 1975, and WORLDCLIM predictions for T_{max} in the years 2010, 2020, 2050 and 2080 IPPC 4th Assessment, CCSM a2a scenario (10-arc minute resolution); this way, we constructed the map of predicted extinction sites by date of expected extinction using ArcGIS.

To consider if localities of occurrence of *S. guentheri* have different climatic properties, we conducted a Principal Component Analysis (PCA), using 19 temperature and precipitation-based bioclimatic variables (BioClim) generated from climatic data provided by Ministerio del Ambiente de Ecuador (MAE, 2013).

2.5. Operative Environmental Temperature (T_{e})

The operative environmental temperature represents the internal T_{b} of a lizard that is in equilibrium with the environment (Dzialoeski, 2005). The determination of T_{e} is needed to assess the availability of thermal microenvironments in the range of optimal physiological temperatures (Williams et al., 2008). In order to make an estimation of T_e in the field, physical models of lizards were placed at five capture sites that representative of the different microhabitats used by *Stenocercus guentheri*.

Models were constructed using 2 cm wide PVC pipes, 10 cm long, with the ends sealed with liquid silicone. The models were connected in pairs to V2-Pro HOBO data loggers, with one model on each of two probes. For each data logger, one model was placed in a shaded refuge site, whereas the other was placed in a sun-exposed site similar to where active lizards were observed. Data loggers were launched for five months between 23 March and 23 August 2014.

T_e is used to calculate Hr, defined as the number of hours in which lizards must shelters to avoid overheating. According to the Sinervo et al. (2010) model, Hr is calculated as the number of hours per day in which the average T_e across all models is higher than the T_{pref}. Additionally, we calculated the hours of activity, Ha – hours that lizards are active outside their shelters performing various behaviors (Ibargüengoytía, 2005) – as the number of daily hours in which T_e is between the minimum temperature of activity and T_{pref} of the species. In accordance with Sinervo et al. (2010), we assumed that the minimum temperature of activity for thermoregulatory species is 25 °C.

To calculate the relationship between Hr and T_{max}, data of T_{max} from a weather station located 4-km-away (Guayllabamba) were provided by the Instituto Nacional de Meteorología e Hidrología (INAMHI) for the same days in which the lizard models were placed.

A linear regression of the Hr versus the difference between T_{max} and T_{pref} was performed to obtain the equation: Hr = slope * ($T_{max} - T_{pref}$) + intercept. This equation was used to model of extinction based on T_{max} values from global climate layers for the years 1975, 2010, 2020, 2050 and 2080.

3. RESULTS

3.1. Preferred temperatures and critical thermals

There were no differences in T_{pref} among males, females and juveniles (ANOVA, F=1.262, P=0.295). Since no differences were found, the average T_{pref} for all individuals was pooled in other analyses. The established T_{pref} of *S. guentheri* was 32.14 ± 1.83 °C (n=39). Additionally, we established that T_{b} is 31.93 ± 2.32 °C (n=22). We found no differences between T_{pref} and T_{b} of *S. guentheri* (*t*-test, t=0.378, P=0.707). Highly significant differences were found between T_{pref} of *S. guentheri* and T_{b} of clade Tropidurinae (*t*-test, t=-3.520, P=0.001), and between T_{b} of *S. guentheri* and T_{b} of clade Tropidurinae (*t*-test, t=-3.037, P=0.003).

Conversely, highly significant differences in $\mathrm{CT}_{\mathrm{min}}$ were found among males, females and juveniles (ANCOVA, F=4.73, P=0.008), as well as between adults and juveniles (ANCOVA, F=5.814, P=0.007), but no differences were found between sexes (ANCOVA, F=2.203, P=0.137). Hence we established that $\mathrm{CT}_{\mathrm{min}}$ is 8.31 °C in adults and 9.14 °C in juveniles (Table 1).

Highly significant differences in $\mathrm{CT}_{\mathrm{max}}$ were found among males, females and juveniles (ANCOVA, F=7.317, P=0.001), as well as between adults and juveniles (ANCOVA, F=10.805, P<0.001), but no differences were found between sexes (ANCOVA, F=2.169, P=0.138). Hence we established that $\mathrm{CT}_{\mathrm{max}}$ in adults is 43.28 °C and in juveniles is 41.68 °C (Table 1).

3.2. *H*r, *H*a and extinction prediction

Fluctuations of *H*r and *H*a in *Stenocercus guentheri* are shown in Figure 1. Monthly, *H*r varies from 1.31 to 5.57, while *H*a varies from 2.43 to 3.93, during the five months evaluated. A significant and positive correlation between *H*r and the difference between T_{max} and T_{pref} was found (Pearson correlation, R= 0.738, n=143, P<0.001). The linear equation describing this relationship was: $Hr = 1.02222 * (T_{\mathrm{max}} - T_{\mathrm{pref}}) + 10.113$.

Using georeferenced points of distribution, the T_{pref} obtained in the laboratory, global monthly T_{max} surfaces and the equation mentioned above, we estimated the year in which the hours of restriction are too many for a population to be viable according to the physiological model of local extinction. We found that by 2020, 16.67% of the populations have a high risk of extinction, and this increases to 26.67% by 2050 (Figure 2). Populations with high risk of extinction by 2020 occur in localities with similar climatic properties (Figure 3).

4. DISCUSSION

The extinction model (Figure 3) shows localities of high extinction risk. By 2020, 16.67% of the populations could be extinct, with this percentage increasing to 26.67 % by 2050. These findings are disturbing because some of the populations predicted to go extinct five years from now seem to have a high population density (MBA, personal observation).

Because some populations of *Stenocercus guentheri* already live in warm environments and have relatively low T_{b}, T_{pref} and $\mathrm{CT}_{\mathrm{max}}$, an increase in T_{a} may force them to reduce their activity time (Dunham, 1993) leading to local extinctions. Nonetheless, our analysis shows localities that are less vulnerable to warming, even by 2080 (Figure 3). These localities occur in environments with lower temperatures (mean air temperature (T_{a})

range: 8.6–15.3 °C and mean T_{max} range: 17.5–28.5 °C) than those that show greater risk of extinction (mean T_a range: 14.1–17.3 °C; mean T_{max} range: 27.5–28.6 °C), and share similar climatic properties (Figure 3). Present-day T_a is important to determine whether climate warming is detrimental to ectotherms (Bakken, 1992). If T_a in the coolest localities is below the optimal performance temperature of a lizard (T_o), and if shade is readily accessible, lizards confronting climate warming can find thermal refugia and therefore remain active (Kearney et al., 2009), which could be the scenario for the less sensitive areas in our study. In fact, populations that live in the coolest environments, such as at high altitudes, may even benefit if T_a increases (Buckley, 2008; Kearney and Porter, 2004; Kearney et al., 2009).

Thermoregulator lizards have mechanisms (behavioral or physiological) to efficiently achieve T_b close to their T_{pref} (Huey, 1982). We found that in *Stenocercus guentheri* the T_{pref} measured in the laboratory (32.14 ± 1.83 °C) closely matches the active body temperature recorded in the field (31.93 ± 2.32 °C). Despite the T_{pref} and T_b values of this species differ from the mean body temperature reported for the clade Tropidurinae (33.7 ± 0.35 °C; Sinervo et al., 2010), it is known that lizard thermal physiologies exhibit conservatism across the phylogeny (Huey et al., 2009), thus the phylogenetically constraints could limit the potential for local adaptation that could soothe the impact of climate change (Angilletta, 2009), as has been predicted for tropical species (Huey et al., 2009; Tewksbury et al., 2008). This insight could explain why *S. guentheri* is so sensitive to extinction due to rapid warming; because, even though these lizards are able to maintain their T_{pref} through behavioral thermoregulation and habitat selection, the T_b and the thermal tolerances are historically constrained, rather than dependent on ecological filtering, dispersal, or local adaptation (Grigg and Buckley, 2013).

We also found that adults had larger thermal tolerance breadth (CT_{min} and CT_{max}) (8.31 – 43.28 °C) than juveniles (9.14 – 41.68 °C). These findings contribute to explaining the high risk of extinction in some populations due to warming. Because a narrow thermal tolerance breadth confers sensitivity to climate warming (Grigg and Buckley, 2013), juveniles are more at-risk than adults, which may decrease rates of recruitment into adulthood, causing population declines. These ontogenetic differences in critical thermal tolerances suggest that the physiological systems underlying thermal tolerance change with age, possibly meaning a differential used of microhabitats by juveniles and adults. In addition, species that exhibit ontogenetic changes in body size are expected to exhibit ontogenetic changes in body temperatures because of their basic biophysical properties (Stevenson, 1985).

Although our analyses indicate that some populations of *Stenocercus guentheri* are at high extinction risk due to climate warming, these results should be interpreted with caution. The areas occupied by this species are complex, with several microhabitats that lizards could occupy as refuges or activity sites. Thermoregulation is a complex process that must integrate detection of temporal and spatial variation in the thermal environment with behavioral and physiological responses (Seebacher and Shine, 2004; Valdecantos et al., 2013). Thus, to better understand the efficiency in thermoregulation achieved by this species, it is imperative to collect additional information. For instance, it is necessary to measure microclimate variation due to habitat structure when relying on thermal models to predict extinctions (Clusella-Trullas and Chown, 2011). Future work must be done in other localities to assess the validity of our physiological results. Furthermore, short-term extinctions predicted by our model can be easily scrutinized by visiting the corresponding localities five years from now. In this way the model could be tested, allowing rectifications that could improve its reliability.

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FIGURES

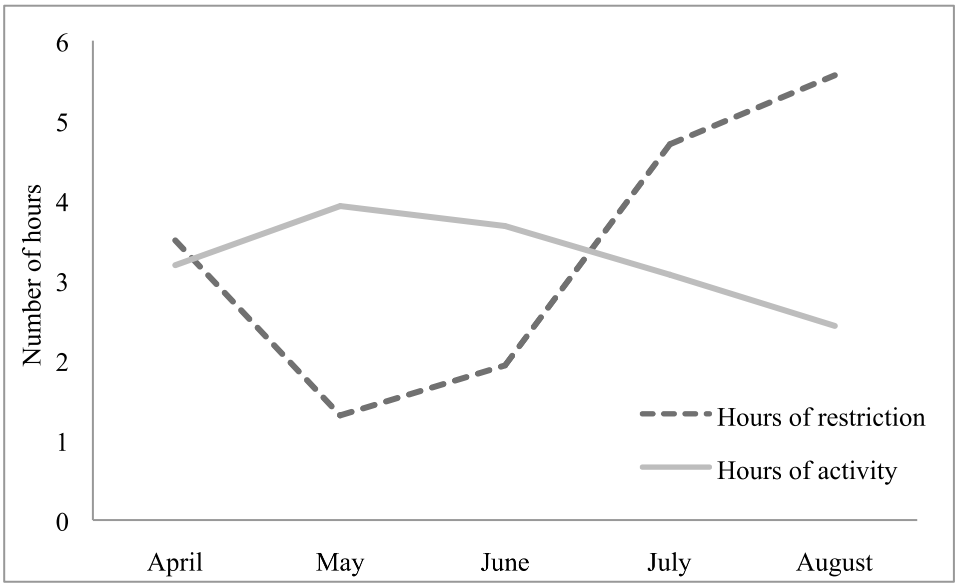

Figure 1. Fluctuation of the hours of restriction and activity plotted by month (2014). The solid line shows the number of hours of activity, *H*a, when T_{e} is between 25 °C and 32.14 ° C (T_{pref}). The dotted line shows the number of hours of restriction, *H*r, when T_{e} exceeds T_{pref}.

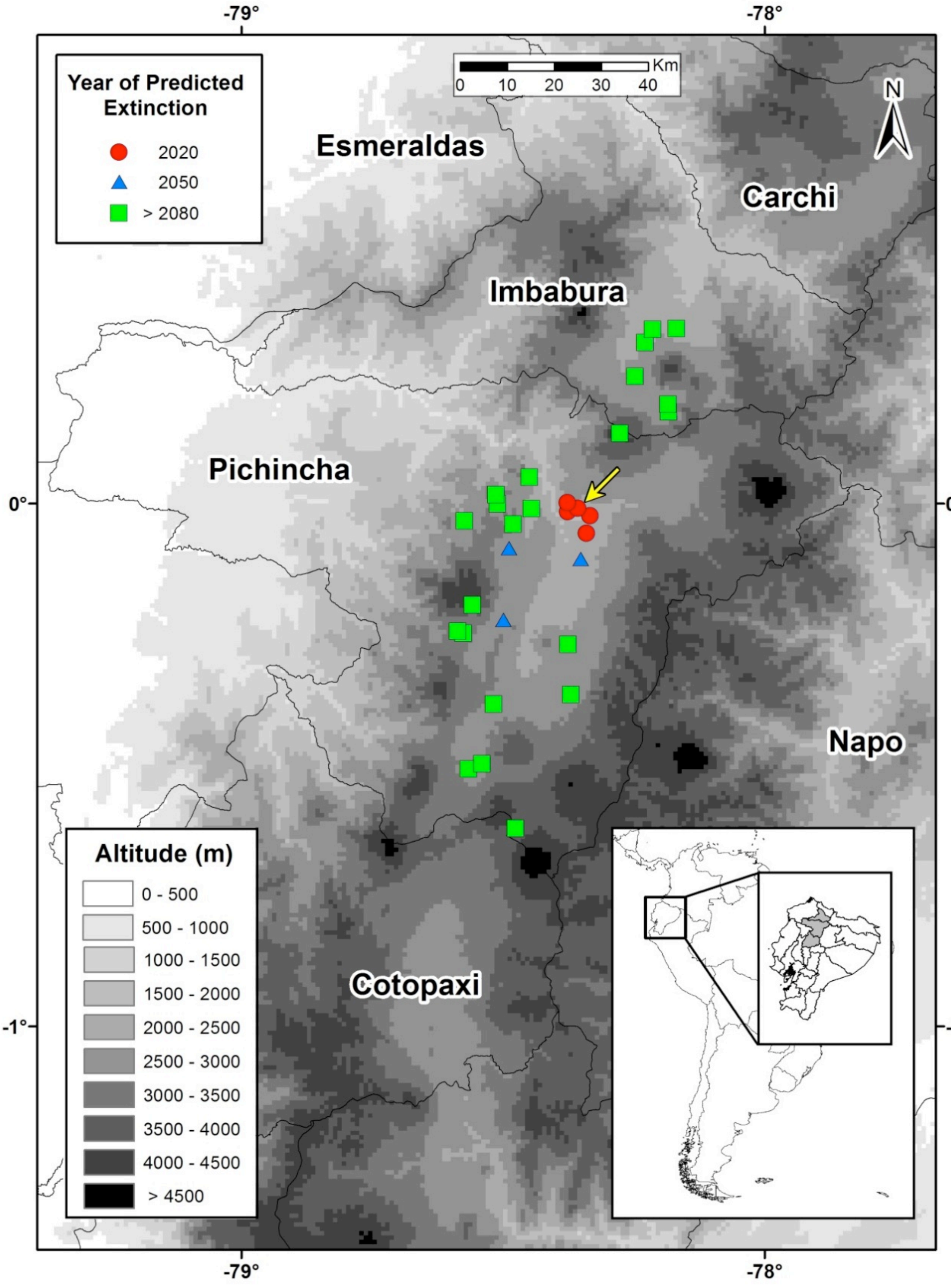

Figure 2. Map of predicted extinction for 30 sampled populations of *Stenocercus guentheri* from northern Ecuador. The yellow arrow shows the study area.

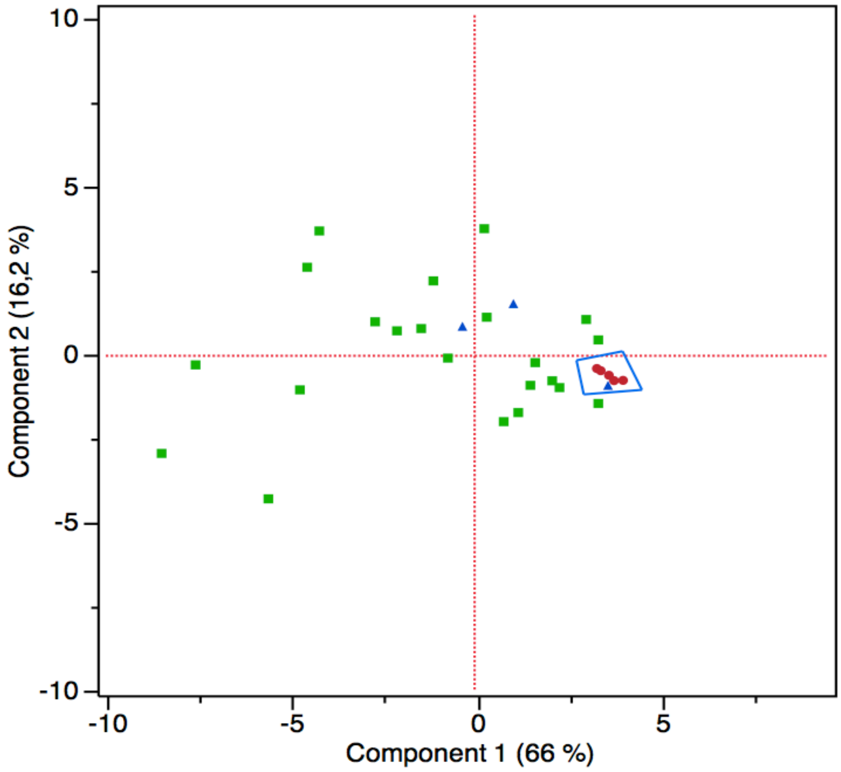

Figure 3. Projections of localities of occurrence of *Stenocercus guentheri*. Red circles show localities with predicted extinction by 2020, blue triangles show localities with predicted extinction by 2050, green squares show the least vulnerable localities. Blue polygon shows the cluster of localities with most vulnerable populations.

TABLES

Table 1. Critical thermal minima (CT_{min}) and maxima (CT_{max}) for juveniles (*n*=12) and adults (*n*=23) of *Stenocercus guentheri*. Mean, Standard Error (SE), and Lower and Upper bounds of a 95% confidence interval are given.

	Mean	**SE**	**95% Confidence Interval**	
			Lower Bound	Upper Bound
CT_{min}				
Juveniles (*n*=12)	9.137	0.646	7.821	10.452
Adults (*n*=23)	8.307	0.423	7.446	9.168
CT_{max}				
Juvenile (*n*=12)	41.676	0.851	39.947	43.406
Adult (*n*=23)	43.283	0.520	42.227	44.339

SUPPLEMENTARY MATERIAL

Table S1. Rate of temperature change (°C/min) for CT_{min} and CT_{max} experimentation of all individuals *n*=35. Start time (H_o), stop time (H_f), initial temperature in the glass chamber (T_o) in °C, final temperature in the glass chamber (T_f) in °C. Reproductive status and sex are shown in parenthesis (M=male, F=female, J=juvenile).

	CT_{min}					CT_{max}				
	H_o	H_f	T_o	T_f	Rate	H_o	H_f	T_o	T_f	Rate
***n* 1 (M)**	14h20	14h41	20,1	3,3	0.8	14h36	14h56	20.4	54	1.7
***n* 2 (F)**	9h51	10h14	19.6	3.4	0.7	17h03	17h21	20.8	54.1	1.9
***n* 3 (M)**	10h43	11h12	19.5	2.4	0.6	16h21	16h40	21.4	53.5	1.7
***n* 4 (M)**	10h09	10h47	20.8	2.2	0.5	8h54	9h17	21	54.8	1.5
***n* 5 (F)**	13h45	14h05	19.5	3	0.8	9h43	10h05	21.2	54.6	1.5
***n* 6 (F)**	14h28	14h51	20.6	3.5	0.7	10h25	10h42	22.6	50.9	1.7
***n* 7 (F)**	16h01	16h21	18.3	2.3	0.8	11h01	11h16	21.4	49.1	1.8
***n* 8 (F)**	16h41	17h12	19.7	1.2	0.6	14h26	14h44	20.7	53.2	1.8
***n* 9 (F)**	17h42	18h01	19.5	3.4	0.8	15h04	15h20	22.2	49.1	1.7
***n* 10 (F)**	18h27	18h47	20.4	1.4	0.9	15h42	15h56	22.2	46.1	1.7
***n* 11 (F)**	19h09	19h29	19.2	1.6	0.9	16h16	16h35	23.2	54.3	1.6
***n* 12 (M)**	9h27	9h58	21.3	1	0.7	9h24	9h43	22	54.3	1.7
***n* 13 (J)**	10h16	10h35	19.3	3.2	0.8	10h00	10h17	22	52.3	1.8
***n* 14 (J)**	10h46	11h05	19.6	5.1	0.8	10h37	10h52	22.5	48.2	1.7
***n* 15 (F)**	14h10	14h28	20.3	5.3	0.8	14h23	14h41	21.4	53	1.8
***n* 16 (J)**	11h14	11h34	19.7	3.2	0.8	15h00	15h10	23.8	44.3	2.1
***n* 17 (F)**	15h56	16h15	19.3	4.4	0.8	15h31	15h46	23.1	50.5	1.8
***n* 18 (J)**	16h37	16h43	20.3	7	2.2	16h05	16h19	23.4	44	1.5
***n* 19 (J)**	17h05	17h26	20.5	4.2	0.8	16h47	17h00	22.7	47.7	1.9
***n* 20 (M)**	9h22	10h00	22.8	1.6	0.6	9h26	9h42	21.9	54.1	1.9
***n* 21 (J)**	10h27	10h47	20.7	3.8	0.8	10h03	10h19	22.5	50.8	1.8
***n* 22 (J)**	11h06	11h27	20.4	4.2	0.8	10h33	10h49	23.5	53.2	1.9
***n* 23 (F)**	14h01	14h30	21.5	2.9	0.6	11h04	11h20	22.2	51.4	1.8
***n* 24 (J)**	15h03	15h19	19.2	4.8	0.9	9h17	9h32	23	51.7	1.9
***n* 25 (J)**	15h31	15h53	19.7	3.3	0.7	9h49	10h04	24.4	52.2	1.9
***n* 26 (J)**	16h11	16h32	20.2	4.3	0.8	10h29	10h44	23.8	53	1.9
***n* 27 (F)**	16h48	17h14	20.9	3.8	0.7	10h57	11h13	23.1	52.4	1.8
***n* 28 (M)**	9h21	9h53	21.9	2.9	0.6	8h39	8h56	21.8	54	1.9
***n* 29 (M)**	10h16	10h44	21.3	3	0.7	9h12	9h28	23.1	47.1	1.5
***n* 30 (M)**	11h02	11h25	20.5	2	0.8	9h46	10h01	22.6	51.3	1.9
***n* 31 (M)**	14h58	15h18	21.8	3.3	0.9	10h23	10h39	23.1	52	1.8
***n* 32 (F)**	15h32	15h56	20.4	2.5	0.7	10h59	11h15	23	52.2	1.8
***n* 33 (M)**	16h11	16h31	20.5	3.2	0.9	11h41	11h56	23.4	47.1	1.6
***n* 34 (J)**	16h45	17h03	20.6	3.9	0.9	12h14	12h28	23.5	50.6	1.9
***n* 35 (J)**	17h12	17h27	20.4	4.8	1	12h42	12h57	21.7	50.5	1.9

Table S2. Name, province, latitude and longitude of 30 localities of occurrence of *Stenocercus guentheri* used in this study. Data were obtained from Museo de Zoología QCAZ, Pontificia Universidad Católica del Ecuador.

Locality	*Province*	*Latitude*	*Longitude*
Limpiopungo lake	Cotopaxi	-0.6208	-78.4762
Machachi (around the Factory “Tesalia”)	Pichincha	-0.5074	-78.5659
Machachi	Pichincha	-0.4973	-78.5403
Uyumbicho	Pichincha	-0.3831	-78.5183
Pintag	Pichincha	-0.3650	-78.3701
Ilalo (ranch Chuspiyacu)	Pichincha	-0.2690	-78.3759
Lloa	Pichincha	-0.2479	-78.5757
Lloa (20 m from the main entrance)	Pichincha	-0.2441	-78.5866
Quito (Itchimbía)	Pichincha	-0.2226	-78.4990
Quito (brook Cóndor Huachana)	Pichincha	-0.1936	-78.5583
Tababela	Pichincha	-0.1057	-78.3510
Pusuquí	Pichincha	-0.0857	-78.4884
Guayllabamba	Pichincha	-0.0564	-78.3406
Casitagua (near Pomasqui)	Pichincha	-0.0390	-78.4810
Alambi hill	Pichincha	-0.0330	-78.5740
Road Pisque river – Parque Recreacional y Bosque Protector Jerusalem	Pichincha	-0.0234	-78.3337
Parque Recreacional y Bosque Protector Jerusalem (1)	Pichincha	-0.0153	-78.3767
San Antonio de Pichincha	Pichincha	-0.0091	-78.4458
Parque Recreacional y Bosque Protector Jerusalem (detour to Malchinguí).	Pichincha	-0.0087	-78.3573
Calacalí (stadium)	Pichincha	-0.0001	-78.5106
Parque Recreacional y Bosque Protector Jerusalem (2)	Pichincha	0.0020	-78.3770
Calacalí (Simón Bolívar Street)	Pichincha	0.0171	-78.5135
Quito (20.9 km N)	Pichincha	0.0510	-78.4500
Tabacundo (Mojanda lake)	Imbabura	0.1349	-78.2771
Itambí river	Imbabura	0.1757	-78.1839
Otavalo (San Pablo, COUSIN hostel)	Imbabura	0.1904	-78.1847
Otavalo (Jatunyacu river)	Imbabura	0.2435	-78.2482
Ibarra (Panamericana 7.5 km N)	Imbabura	0.3080	-78.2290
Atuntaqui	Imbabura	0.3331	-78.2140
San Antonio de Ibarra	Imbabura	0.3351	-78.1688