

Potential biodiversity map of lizard species in Southern Patagonia: Environmental characterization, desertification influence and analyses of protection areas

Yamina Micaela Rosas^{1,*}, Pablo Luis Peri², Guillermo Martínez Pastur¹

Abstract. The distribution of biodiversity at the landscape level is shaped by biotic, abiotic and anthropogenic factors. Biodiversity maps provide the basis for defining management and conservation strategies that can minimize human impacts. The objective was to elaborate a map of potential biodiversity of lizards based on habitat suitability maps of individual species in Santa Cruz (Argentina). Also, we analysed desertification influence and the representativeness of the current network of protected areas on the lizard biodiversity. For this, we used a database of eight lizard species and we explored 41 potential explanatory variables to develop habitat suitability maps, which were combined to obtain one single map of the potential biodiversity. We analysed the outputs in a GIS project using the marginality and the specialization indexes and the normalized difference vegetation index of each species. Also, we characterized the potential biodiversity using the following variables: desertification, ecological areas and current network of protected areas. We detected differences in the occupied niches for the different species throughout the landscape. The map of potential biodiversity uncovered hotspots of biodiversity in the north-east study area, where the prevalence of unique climatic conditions showed a dry steppe and a high degree of desertification due to the human impacts (e.g. livestock). These results can be readily used as a support system for conservation and management strategies at different scale levels in areas with higher human impacts or to develop new protection areas.

Keywords: climatic and topographic variables, conservation, ENFA, habitat suitability, human impacts, reptiles.

1 - Laboratorio de Recursos Agroforestales, Centro Austral de Investigaciones Científicas (CONICET), Houssay 200, Ushuaia (9410) Tierra del Fuego, Argentina

2 - Departamento Forestal, Agricultura y Manejo del Agua (INTA EEA Santa Cruz), Universidad Nacional de la Patagonia Austral (UNPA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), cc 332, Río Gallegos (9400) Santa Cruz, Argentina

* Corresponding author;

e-mail: micaela.rosas@cadic-conicet.gob.ar

Table S1. Explanatory variables used in modelling of habitat suitability of lizard species.

Category	Description	Code	Unit	Data source
Climate	annual mean temperature	AMT	°C	WorldClim ⁽¹⁾
	mean diurnal range	MDR	°C	WorldClim ⁽¹⁾
	isothermality	ISO	%	WorldClim ⁽¹⁾
	temperature seasonality	TS	°C	WorldClim ⁽¹⁾
	max temperature of warmest	MAXW	°C	WorldClim ⁽¹⁾
	min temperature of coldest	MINCM	°C	WorldClim ⁽¹⁾
	temperature annual range	TAR	°C	WorldClim ⁽¹⁾
	mean temperature of wettest	MTWEQ	°C	WorldClim ⁽¹⁾
	mean temperature of driest	MTDQ	°C	WorldClim ⁽¹⁾
	mean temperature of warmest	MTWA	°C	WorldClim ⁽¹⁾
	mean temperature of coldest	MTCQ	°C	WorldClim ⁽¹⁾
	annual precipitation	AP	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation of wettest month	PWEM	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation of driest month	PDM	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation seasonality	PS	%	WorldClim ⁽¹⁾
	precipitation of wettest quarter	PWEQ	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation of driest quarter	PDQ	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation of warmest quarter	PWAQ	mm.years ⁻¹	WorldClim ⁽¹⁾
	precipitation of coldest quarter	PCQ	mm.years ⁻¹	WorldClim ⁽¹⁾
	global potential evapo-	EVTP	mm.years ⁻¹	CSI ⁽²⁾
global aridity index	GAI		CSI ⁽²⁾	
Topograph	elevation	ELE	m.a.s.l.	DEM ⁽³⁾
	slope	SLO	degree	DEM ⁽³⁾
	aspect	ASP	cosine	DEM ⁽³⁾
	aspect	ASP	sine	DEM ⁽³⁾
	distance to locality	DL	km	SIT Santa Cruz ⁽⁴⁾
	distance to lakes	DLK	km	SIT Santa Cruz ⁽⁴⁾
	distance to rivers	DR	km	SIT Santa Cruz ⁽⁴⁾
	distance to routs	DW	km	SIT Santa Cruz ⁽⁴⁾
Landscape	forest edge density	ED	m.ha ⁻¹	Forest map ⁽⁴⁾ / Fragstats ⁽⁵⁾
	total core area	TCA	ha	Forest map ⁽⁴⁾ / Fragstats ⁽⁵⁾
	large parch index	LPI	%	Forest map ⁽⁴⁾ / Fragstats ⁽⁵⁾
	normalized difference vegetation	NDVI		MODIS ⁽⁶⁾
	net primary productivity	NPP	gr C.m ² .year ⁻¹	MODIS ⁽⁷⁾
	desertification	DES	degree	CENPAT ⁽⁸⁾
	soil carbon	SC	kg.m ⁻²	Soil Carbon map ⁽⁹⁾
	total forest	TF	occurrence	Forest map ⁽⁴⁾
	total mixed forests	TMF	occurrence	Forest map ⁽⁴⁾
	total <i>Nothofagus pumilio</i>	TNP	occurrence	Forest map ⁽⁴⁾
	total <i>Nothofagus antarctica</i>	TNA	occurrence	Forest map ⁽⁴⁾
total <i>Nothofagus betuloide</i>	TNB	occurrence	Forest map ⁽⁴⁾	

(1) Hijmans et al. (2005), (2) Consortium for Spatial Information (CSI) (Zomer et al., 2008), (3) Farr et al. (2007), (4) SIT - Santa Cruz (<http://www.sitsantacruz.gob.ar>), (5) McGarigal et al. (2012), (6) ORNL DAAC (2008), (7) Zhao and Running (2010), (8) Del Valle et al. (1998), (9) Peri et al. (2018).

Table S2. Correlation indices among the variables included in the modelling of the habitat suitability maps of lizard species.

Variable	MINCM	AP	PCQ	EVAPO	ELE	NDVI
AMT	-0.25	0.43	0.48	0.96	0.32	0.58
MINCM		-0.60	-0.56	-0.49	-0.85	-0.55
AP			0.99	0.56	0.69	0.51
PCQ				0.60	0.70	0.52
EVAPO					0.53	0.67
ELE						0.45

AMT = annual mean temperature (°C), MINCM = min temperature of coldest month (°C), AP = annual precipitation (mm.year⁻¹), PCQ = precipitation of coldest quarter (mm.year⁻¹), EVTP = global potential evapo-transpiration (mm.year⁻¹), ELE = elevation (m.a.s.l.), NDVI = normalized difference vegetation index.

Table S3. Model outputs for each habitats suitability of lizards, eigenvalues and percentage of explained information for the first four axes.

Species	E1	E2	E3	E4	Total
<i>Diplolaemus bibronii</i>	179.69(0.90)	16.24(0.08)	2.78(0.01)	1.63(0.01)	(1.00)
<i>Liolaemus bibronii</i>	172.97(0.84)	27.61(0.31)	2.98(0.01)	2.47(0.01)	(1.00)
<i>L. fitzingerii</i>	242.40(0.80)	35.10(0.12)	22.46(0.07)	2.94(0.01)	(1.00)
<i>Homonota darwinii darwinii</i>	127.31(0.60)	60.15(0.29)	19.80(0.09)	4.03(0.02)	(1.00)
<i>L. kingii</i>	190.53(0.85)	18.90(0.08)	9.78(0.04)	2.74(0.01)	(1.00)
<i>L. lianeomaculatus</i>	476.33(0.94)	19.57(0.04)	6.52(0.01)	1.56(0.00)	(1.00)
<i>L. sarmientoi</i>	592.20(0.87)	56.53(0.08)	22.67(0.03)	5.28(0.01)	(1.00)
<i>L. escarchadosi</i>	451.27(0.81)	78.92(0.14)	23.97(0.04)	2.65(0.01)	(1.00)

Value (Expl. Spec.)

Table S4. Statistics for the adjustment of the map models.

Species	B	P(B=0)	Bcont(20)	AVI	CVI
<i>Diplolaemus bibronii</i>	0.19(0.54)	0.55(0.33)	0.20(0.50)	0.54(0.35)	0.35(0.33)
<i>Liolaemus bibronii</i>	0.20(0.69)	0.36(0.25)	0.03(0.59)	0.52(0.39)	0.39(0.35)
<i>L. fitzingerii</i>	0.18(0.54)	0.51(0.25)	-0.02(0.53)	0.53(0.35)	0.43(0.35)
<i>Homonota darwini darwini</i>	0.26(0.61)	0.43(0.28)	-0.01(0.40)	0.58(0.40)	0.49(0.40)
<i>L. kingii</i>	0.10(0.61)	0.49(0.30)	0.03(0.49)	0.46(0.37)	0.31(0.36)
<i>L. lianeomaculatus</i>	0.20(0.60)	0.46(0.28)	0.02(0.55)	0.63(0.43)	0.41(0.41)
<i>L. sarmientoi</i>	0.37(0.62)	0.33(0.20)	-0.04(0.61)	0.63(0.42)	0.49(0.40)
<i>L. escarchadosi</i>	0.31(0.34)	0.60(0.23)	0.11(0.42)	0.68(0.24)	0.52(0.24)

B = Boyce index, P(B=0) = proportion of validation points, Bcont(20) = continuous Boyce index, AVI = absolute validation index, CVI = contrast validation index. Mean (S.D.).

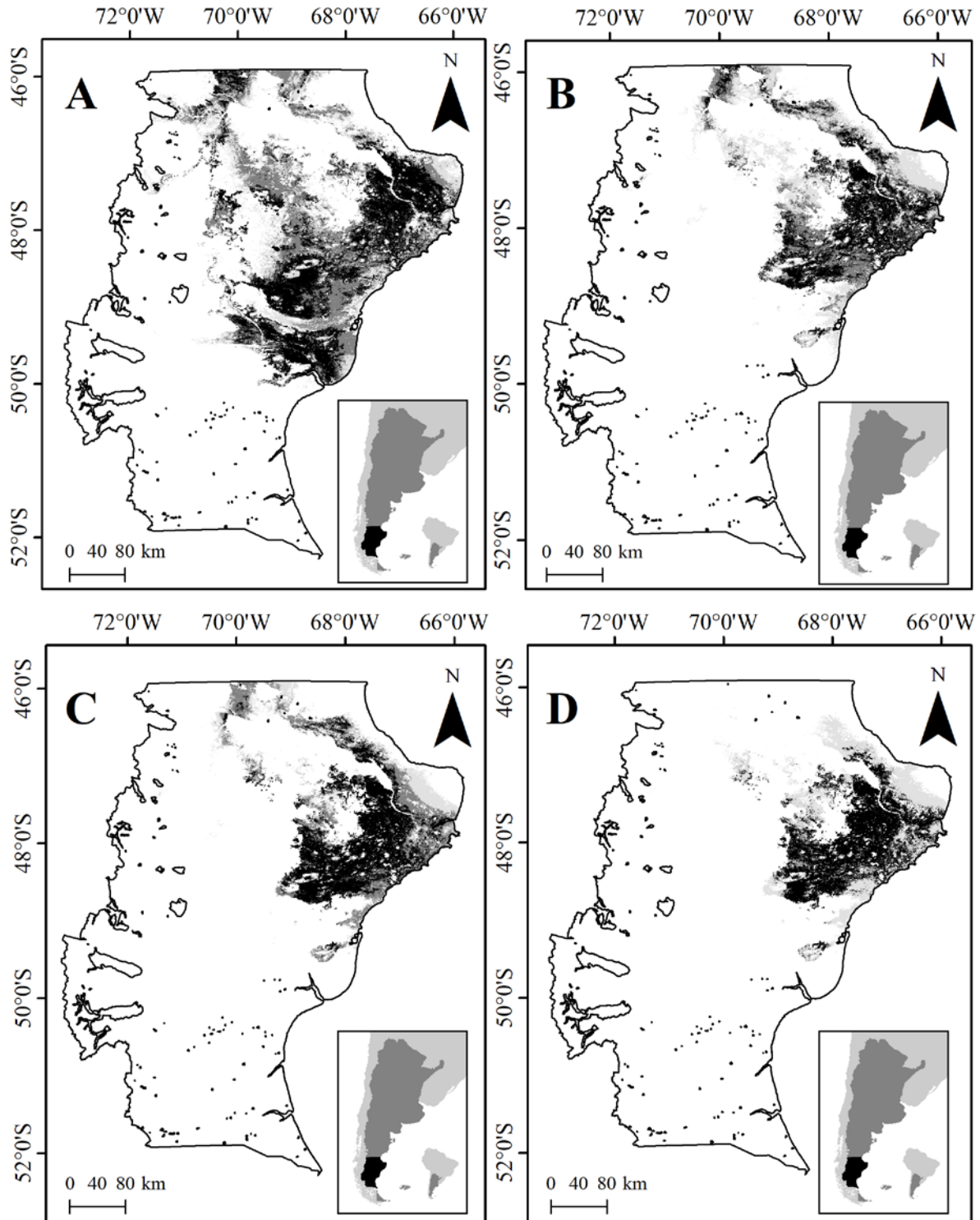


Figure S1. Maps of potential habitat suitability of lizard species in Santa Cruz province, where light grey showed lower potential, dark grey showed medium potential and black showed higher potential areas. White showed unsuitable areas (values <50%). A = *Diplolaemus bibronii*; B = *Liolaemus bibronii*; C = *L. fitzingerii*; D = *Homonota darwinii darwinii*; E = *L. kingii*; F = *L. lioneomaculatus*; G = *L. sarmientoi*; H = *L. escarchadosi*.

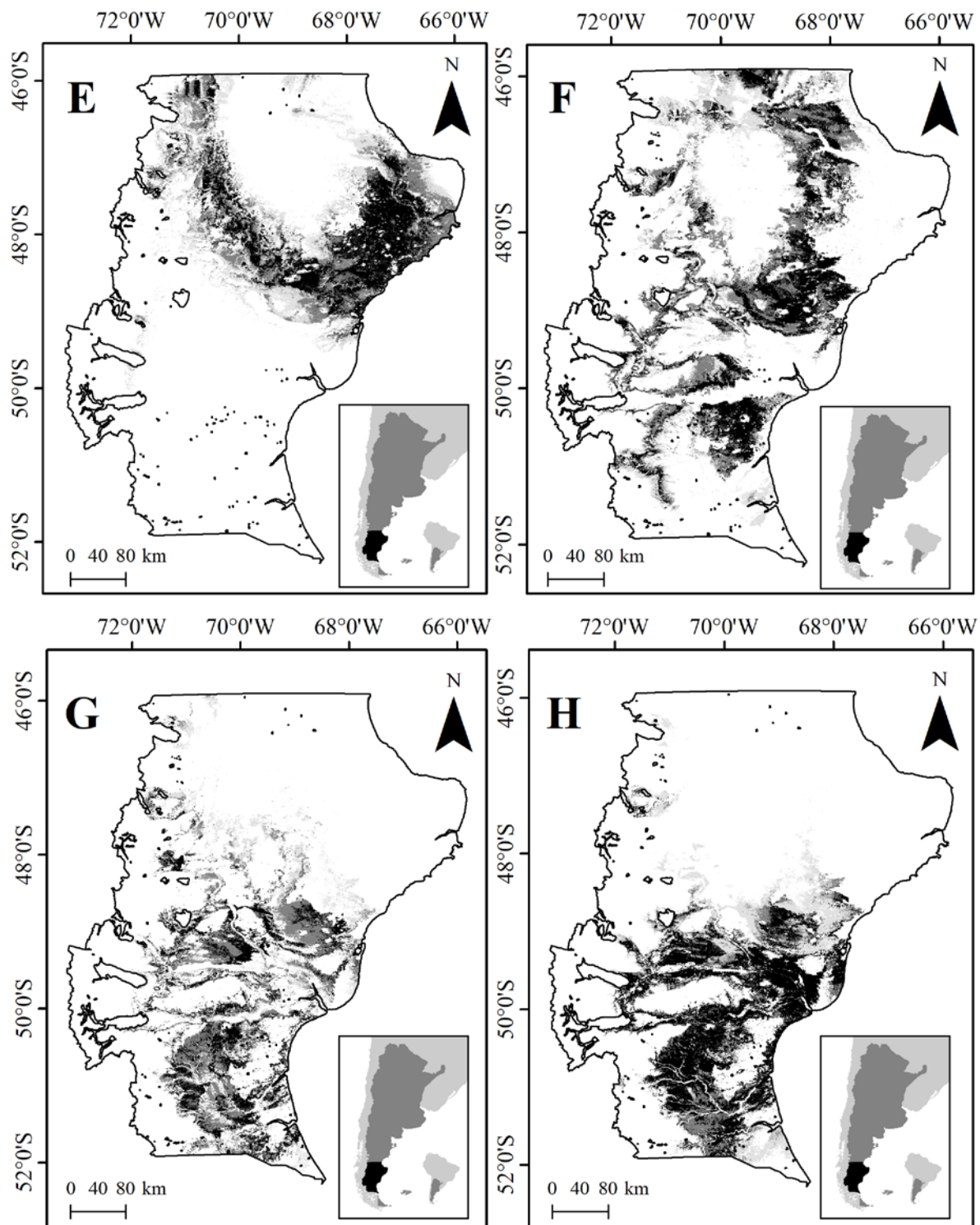


Figure S1. (cont.).