Supplementary material

Temporal range dynamics of Lataste´s viper (*Vipera latastei* Boscá, 1878) in Doñana (Spain): insights into anthropogenic-driven factors

Rafael Carmona-González[1], Francisco Carro[1], Juan Pablo González de la Vega[2], Fernando Martínez-Freiría[3,4]

1. Estación Biológica de Doñana (EBD-CSIC). Avda. Américo Vespucio, 45 41092, Seville, Spain; 2. Avda. Andalucía, 70. 4ºD. 21007, Huelva, Spain; 3. CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Universidade do Porto, Vairão, Portugal; 4. BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Vairão, Portugal.

Correspondence: Rafael Carmona-González: rafael.carmona@ebd.csic.es; Fernando Martínez-Freiría: fmartinez-freiria@cibio.up.pt

TABLES

Table S1 - Bioclimatic variables derived in this study, depicting code, meaning (and units) and ranges of variation for the historical and contemporary periods.

CODE	Meaning (and units)	Historical	Contemporary
BIO 01	Annual Mean Temperature (ºC)	29.079-29.192	29.118-29.226
BIO 02	Mean Diurnal Range (Mean of monthly (max temp-min temp)	1.126-0.56	1.142-0.561
BIO 03	Isothermality (BIO2/BIO7) x100 (coefficient of variation)	31.701-40.047	30.429-39.418
BIO 04	Temperature Seasonality (Standard Deviation x 100)	43.514-59.024	46.709-63.663
BIO 05	Max Temperature of Warmest Month (ºC)	30.036-30.697	30.131-30.805
BIO 06	Min Temperature of Coldest Month (ºC)	27.866-28.269	27.886-28.287
BIO 07	Temperature Annual Range (BIO5-BIO6) (ºC)	1.767-2.814	1.844-2.902
BIO 08	Mean Temperature of Wettest Quarter (ºC)	28.515-28.705	28.803-28.967
BIO 09	Mean Temperature of Driest Quarter (ºC)	29.628-29.896	29.71-30
BIO 10	Mean Temperature of Warmest Quarter (ºC)	29.67-29.918	29.726-30
BIO 11	Mean Temperature of Coldest Quarter (ºC)	28.415-28.603	28.42-28.608
BIO 12	Annual precipitation (mm)	513.321-647.229	534.315-688.163
BIO 13	Precipitation of Wettest Month (mm)	94.80-119.27	84.749-104.784
BIO 14	Precipitation of Driest Month (mm)	3.751-1.274	0.881-0.498
BIO 15	Precipitation Seasonality (Coefficient of Variation)	72.966-77.987	66.263-70.08
BIO 16	Precipitation of Wettest Quarter (mm)	263.25-327.586	241.967-299.384
BIO 17	Precipitation of Driest Quarter (mm)	12.21-20.875	9.2-16.371
BIO 18	Precipitation of Warmest Quarter (mm)	23.58-35.559	9.845-37.987
BIO 19	Precipitation of Coldest Quarter (mm)	220.366-270.874	179.329-242.685

Table S2 - NDVI variables derived in this study, depicting names and ranges of variation for the historical and contemporary periods.

NDVI variable	Historical	Contemporary
Spring mean	-0.499 - 0.568	-0.503 - 0.637
Spring Standard Deviation	0.02 - 0.304	0.028 - 0.279
Summer Mean	-0.431 - 0.652	-0.429 - 0.726
Summer Standard Deviation	0.023 - 0.199	0.012 - 0.226
Autumn Mean	-0.528 - 0.594	-0.518 - 0.592
Autumn Standard Deviation	0.03 - 0.238	0.026 - 0.271

Table S3 - Performance evaluation of the historical model based on features and regularization parameters.

fc	rm	tune.args	auc.train	cbi.train	auc.diff.avg	auc.diff.sd	auc.val.avg	auc.val.sd	cbi.val.avg	cbi.val.sd	or.10p.avg	or.10p.sd	or.mtp.avg	or.mtp.sd	AICc	delta.AICc	w.AIC	ncoef	
1	L	1	fc.L_rm.1	0.86269662	0.907	0.06922389	0.05324601	0.8679828	0.06892624	0.76975	0.08638817	0.103125	0.14732864	0.046875	0.09375	675.213531	0	0.14671836	5
2	Q	1	fc.Q_rm.1	0.8648181	0.952	0.06834808	0.05254017	0.86947628	0.06780467	0.754	0.13454615	0.103125	0.14732864	0.046875	0.09375	679.322556	4.10902504	0.01880273	7
3	P	1	fc.P_rm.1	0.86715738	0.957	0.06552568	0.05037848	0.87169005	0.06514743	0.76725	0.083934	0.0875	0.11814539	0.046875	0.09375	681.843902	6.63037117	0.00532988	8
4	LQ	1	fc.LQ_rm.1	0.86524562	0.95	0.0672052	0.05401505	0.86847186	0.06741982	0.75825	0.10722989	0.103125	0.14732864	0.046875	0.09375	688.27959	13.066059	0.00021342	10
5	LQP	1	fc.LQP_rm.1	0.86672985	0.962	0.06687233	0.05391244	0.87034401	0.06705807	0.7745	0.0624313	0.103125	0.14732864	0.046875	0.09375	681.599083	6.38555244	0.00602392	8
6	H	1	fc.H_rm.1	0.89691458	0.871	0.04991911	0.0558067	0.87252093	0.05435936	0.78625	0.09012722	0.153125	0.17688715	0.0625	0.125	750.76226	75.5487287	5.77E-18	26
7	LQH	1	fc.LQH_rm.1	0.89780995	0.937	0.05076862	0.05390725	0.87867548	0.0542138	0.769	0.07615773	0.128125	0.15491093	0.046875	0.09375	705.274494	30.0609627	4.35E-08	20
8	L	2	fc.L_rm.2	0.86276115	0.904	0.0692626	0.05273025	0.86837526	0.06870252	0.7575	0.08349651	0.103125	0.14732864	0.046875	0.09375	675.378138	0.16460715	0.13512648	5
9	Q	2	fc.Q_rm.2	0.86460031	0.956	0.06799423	0.05276733	0.86927937	0.06752195	0.7365	0.14995444	0.103125	0.14732864	0.046875	0.09375	677.01669	1.80315869	0.0595571	6
10	P	2	fc.P_rm.2	0.8674155	0.93	0.06396116	0.04826523	0.87218673	0.06298321	0.75075	0.10459565	0.103125	0.14732864	0.046875	0.09375	675.376756	0.16322459	0.13521992	5
11	LQ	2	fc.LQ_rm.2	0.86456804	0.95	0.06696555	0.0539948	0.86837229	0.06719032	0.77475	0.11798128	0.103125	0.14732864	0.046875	0.09375	685.711164	10.4976333	0.00077082	9
12	LQP	2	fc.LQP_rm.2	0.86660079	0.964	0.06553387	0.05327741	0.8701804	0.0662455	0.7845	0.07265214	0.103125	0.14732864	0.046875	0.09375	679.974763	4.76123171	0.01357051	7
13	H	2	fc.H_rm.2	0.88216907	0.795	0.05797458	0.05665819	0.87351162	0.06164049	0.842	0.03397058	0.13958333	0.16292679	0.0625	0.125	690.299559	15.0860279	7.77E-05	14
14	LQH	2	fc.LQH_rm.2	0.88182222	0.88	0.05536261	0.05479255	0.87406693	0.05930456	0.80775	0.03063087	0.11875	0.17721809	0.046875	0.09375	698.780853	23.5673217	1.12E-06	16
15	L	3	fc.L_rm.3	0.86303541	0.929	0.06898258	0.05241064	0.86857677	0.06828847	0.777	0.09764903	0.103125	0.14732864	0.046875	0.09375	675.640192	0.4266605	0.11853219	5
16	Q	3	fc.Q_rm.3	0.86447931	0.947	0.06730342	0.0526202	0.86911755	0.06677362	0.76975	0.07893193	0.103125	0.14732864	0.046875	0.09375	677.491435	2.27790385	0.04697253	6
17	P	3	fc.P_rm.3	0.86818182	0.954	0.061129	0.0451206	0.87214232	0.05975079	0.73425	0.12610677	0.103125	0.14732864	0.046875	0.09375	675.379484	0.16595286	0.13503559	4
18	LQ	3	fc.LQ_rm.3	0.86458417	0.939	0.06653415	0.05346806	0.86851312	0.06661933	0.7875	0.06996428	0.103125	0.14732864	0.046875	0.09375	686.215735	11.0022037	0.00059894	9
19	LQP	3	fc.LQP_rm.3	0.86689925	0.961	0.0646127	0.0523614	0.87004904	0.06558703	0.79	0.06833252	0.103125	0.14732864	0.046875	0.09375	681.452194	6.23866312	0.006483	7
20	H	3	fc.H_rm.3	0.87683714	0.787	0.06100654	0.05392222	0.87055958	0.06309318	0.81575	0.07926485	0.13958333	0.16292679	0.0625	0.125	683.643847	8.4303157	0.00216703	10
21	LQH	3	fc.LQH_rm.3	0.87127128	0.928	0.0612031	0.05443129	0.86899605	0.0640046	0.78825	0.05518076	0.103125	0.14732864	0.046875	0.09375	703.345598	28.132067	1.14E-07	15
22	L	4	fc.L_rm.4	0.86300315	0.904	0.06844892	0.05236949	0.86845617	0.06774545	0.808	0.07514874	0.103125	0.14732864	0.046875	0.09375	675.99328	0.77974849	0.09934917	5
23	Q	4	fc.Q_rm.4	0.86440671	0.949	0.06670998	0.05260332	0.8688694	0.06623014	0.76675	0.07795886	0.103125	0.14732864	0.046875	0.09375	678.122604	2.90907306	0.03425999	6
24	P	4	fc.P_rm.4	0.86822215	0.957	0.05788474	0.04140838	0.87041099	0.05615887	0.7495	0.09198007	0.12585227	0.13237011	0.046875	0.09375	678.318166	3.10463486	0.03106859	4
25	LQ	4	fc.LQ_rm.4	0.86453577	0.944	0.06614175	0.05328222	0.8684602	0.06619492	0.774	0.07880355	0.103125	0.14732864	0.046875	0.09375	686.860047	11.6465158	0.00043399	9
26	LQP	4	fc.LQP_rm.4	0.86691538	0.958	0.06382764	0.05163433	0.87016498	0.0646899	0.7925	0.07635225	0.103125	0.14732864	0.046875	0.09375	683.356618	8.14308668	0.0025017	7
27	H	4	fc.H_rm.4	0.87384448	0.838	0.06167214	0.05216837	0.86912347	0.06304042	0.8465	0.0767789	0.15520833	0.19321162	0.0625	0.125	685.762866	10.5493351	0.00075115	9
28	LQH	4	fc.LQH_rm.4	0.86453577	0.944	0.06515105	0.0533288	0.86829428	0.06624063	0.79025	0.05615084	0.103125	0.14732864	0.046875	0.09375	686.860047	11.6465158	0.00043399	9

Table S4 - Performance evaluation of the contemporary model based on features and regularization parameters.

fc	rm	tune.args	auc.train	cbi.train	auc.diff.avg	auc.diff.sd	auc.val.avg	auc.val.sd	cbi.val.avg	cbi.val.sd	or.10p.avg	or.10p.sd	or.mtp.avg	or.mtp.sd	AICc	delta.AICc	w.AIC	ncoef	
1	L	1	fc.L_rm.1	0.901274073	0.905	0.034554189	0.022951794	0.885496292	0.032168087	0.81825	0.094982016	0.170833333	0.173405434	0.025	0.05	636.6070354	5.419417881	0.014558862	8
2	Q	1	fc.Q_rm.1	0.904326802	0.901	0.031614058	0.024961538	0.889724798	0.030506851	0.79925	0.085418089	0.145833333	0.175	0.075	0.15	631.6837235	0.496105969	0.170691158	7
3	P	1	fc.P_rm.1	0.896707594	0.927	0.031996577	0.027585614	0.883128652	0.032725845	0.778	0.082595399	0.1625	0.158917053	0.025	0.05	632.3092606	1.121643139	0.124846782	5
4	LQ	1	fc.LQ_rm.1	0.906454461	0.937	0.030396965	0.026198871	0.889640374	0.030748136	0.80675	0.088477398	0.1625	0.158917053	0.075	0.15	641.7741769	10.58655943	0.001099251	11
5	LQP	1	fc.LQP_rm.1	0.90317467	0.926	0.029714702	0.027551268	0.885849144	0.030903027	0.79775	0.12241834	0.1625	0.158917053	0.075	0.15	641.3033479	10.11573036	0.001391029	10
6	H	1	fc.H_rm.1	0.919237238	0.906	0.040501859	0.042932022	0.882008641	0.034271311	0.581	0.300232132	0.158333333	0.125830574	0.075	0.15	666.4036246	35.21600708	4.93E-09	20
7	LQH	1	fc.LQH_rm.1	0.917202086	0.935	0.034450223	0.039456703	0.886490481	0.030762865	0.7625	0.132477671	0.133333333	0.124721913	0.075	0.15	675.5301002	44.34248271	5.14E-11	21
8	L	2	fc.L_rm.2	0.898095198	0.931	0.034656508	0.024186402	0.88415316	0.032607612	0.787	0.143017481	0.170833333	0.173405434	0.025	0.05	636.3961142	5.20849672	0.016178132	7
9	Q	2	fc.Q_rm.2	0.902089816	0.967	0.031228378	0.02304862	0.887921591	0.030256179	0.7965	0.107171203	0.120833333	0.127202813	0.075	0.15	631.1876175	0	0.21874547	6
10	P	2	fc.P_rm.2	0.895681608	0.946	0.029803636	0.031267957	0.882466749	0.034602383	0.805	0.087662231	0.141666667	0.177169097	0.025	0.05	634.8942625	3.706645003	0.03428083	5
11	LQ	2	fc.LQ_rm.2	0.902897149	0.952	0.031587576	0.024889176	0.887816231	0.031608624	0.77675	0.106543809	0.145833333	0.175	0.075	0.15	635.5005176	4.31290013	0.025316561	8
12	LQP	2	fc.LQP_rm.2	0.898910941	0.902	0.031411162	0.028775557	0.884348001	0.034211815	0.80575	0.06575903	0.120833333	0.127202813	0.05	0.1	639.6841365	8.496518957	0.003125672	8
13	H	2	fc.H_rm.2	0.905335968	0.872	0.030481921	0.039551224	0.880788425	0.0335644	0.67025	0.081549065	0.154166667	0.099419612	0.05	0.1	650.2926958	19.1050783	1.55E-05	14
14	LQH	2	fc.LQH_rm.2	0.908842822	0.936	0.028437656	0.028313841	0.888298474	0.02722175	0.8115	0.079466974	0.154166667	0.099419612	0.075	0.15	643.7784802	12.5908627	0.000403523	13
15	L	3	fc.L_rm.3	0.896253469	0.939	0.03370575	0.024903956	0.884318871	0.033257218	0.81275	0.111876047	0.170833333	0.173405434	0.025	0.05	632.5616422	1.374024719	0.110045779	5
16	Q	3	fc.Q_rm.3	0.901038601	0.971	0.030587481	0.02254008	0.88694921	0.029734621	0.78275	0.075110474	0.145833333	0.131497782	0.05	0.1	632.8798102	1.692192711	0.093860765	6
17	P	3	fc.P_rm.3	0.893823059	0.946	0.028604543	0.033187275	0.880486498	0.034796572	0.766	0.19686205	0.141666667	0.177169097	0.05	0.1	638.5187222	7.331104685	0.005597704	5
18	LQ	3	fc.LQ_rm.3	0.901820705	0.952	0.030809882	0.024863074	0.886760876	0.03102871	0.77475	0.073938601	0.170833333	0.173405434	0.05	0.1	637.2318137	6.044196235	0.010652671	8
19	LQP	3	fc.LQP_rm.3	0.894773358	0.959	0.028689147	0.02841611	0.885141139	0.03253143	0.83025	0.106952871	0.095833333	0.082073815	0.025	0.05	641.0421274	9.854509867	0.00158511	7
20	H	3	fc.H_rm.3	0.897001934	0.834	0.034764046	0.037307548	0.879899454	0.039626107	0.744	0.086409876	0.120833333	0.127202813	0.025	0.05	646.4812207	15.29360318	0.000104466	11
21	LQH	3	fc.LQH_rm.3	0.901686149	0.93	0.028340652	0.024457505	0.884564708	0.027862013	0.81425	0.075931438	0.1625	0.109184689	0.05	0.1	636.5259813	5.338363834	0.015161008	9
22	L	4	fc.L_rm.4	0.895942309	0.928	0.032374185	0.025430568	0.884786866	0.033120639	0.7965	0.094546285	0.145833333	0.131497782	0.025	0.05	633.1923591	2.004741561	0.080281406	5
23	Q	4	fc.Q_rm.4	0.898456816	0.944	0.030658061	0.023126077	0.88581312	0.030308204	0.7995	0.085827346	0.145833333	0.131497782	0.05	0.1	635.1735513	3.98593377	0.029812922	6
24	P	4	fc.P_rm.4	0.891586074	0.95	0.028202935	0.032769741	0.880128764	0.034202205	0.7865	0.123810339	0.116666667	0.129099445	0.05	0.1	636.8645365	5.676918962	0.012800053	3
25	LQ	4	fc.LQ_rm.4	0.899213691	0.939	0.030357966	0.025507557	0.885555104	0.031524232	0.796	0.087726849	0.145833333	0.131497782	0.05	0.1	639.5829949	8.395377403	0.003287805	8
26	LQP	4	fc.LQP_rm.4	0.893999664	0.948	0.027619452	0.028133904	0.885089455	0.031693551	0.82775	0.132243147	0.120833333	0.127202813	0.025	0.05	635.66988	4.482262544	0.023260986	4
27	H	4	fc.H_rm.4	0.894243546	0.864	0.032506372	0.034950634	0.880632842	0.038860335	0.7205	0.068476273	0.120833333	0.127202813	0.025	0.05	643.8178093	12.63019183	0.000395665	9
28	LQH	4	fc.LQH_rm.4	0.898961399	0.915	0.028454598	0.024248859	0.885189638	0.029546927	0.79525	0.074069224	0.1625	0.109184689	0.05	0.1	640.130175	8.942557465	0.002500849	9

Table S5.- Number of training and test simples, and average and standard deviation of training and test AUC, AUC standard deviation, and percentage of contribution and permutation of each variable for the contemporary and projection models.

	Historical	Contemporary
N Training - Test	40-9	38-9
Training AUC (±SD)	0.865±0.024	0.9±0.021
Test AUC (±SD)	0.842±0.07	0.879±0.057
AUC Standard Deviation	0.056	0.042
% contribution		
Bio 01	0±0	0.004±0.018
Bio 08	8.262±8.729	0.755±1.033
Bio 09	73.079±13.838	91.69±5.488
Bio 14	0.153±0.282	1.377±2.114
Bio 15	4.815±11.48	0.061±0.208
Autumn sd	3.421±4.608	0.174±0.737
Spring mean	0.663±1.161	1.214±2.177
Spring sd	8.378±5.285	4.328±4.521
Summer sd	1.23±2.262	0.398±0.559
% permutation (±SD)		
Bio 01	0±0	0.049±0.217
Bio 08	24.348±24.072	2.266±3.465
Bio 09	48.555±23.289	79.6502±19.45
Bio 14	0.136±0.390	6.594±12.373
Bio 15	3.92±10.704	0.402±1.242
Autumn sd	4.641±8.066	0.163±0.539
Spring mean	0.805±1.304	3.367±4.298
Spring sd	15.229±13.562	7.04±12.832
Summer sd	2.364±4.032	0.4696±0.884

FIGURES

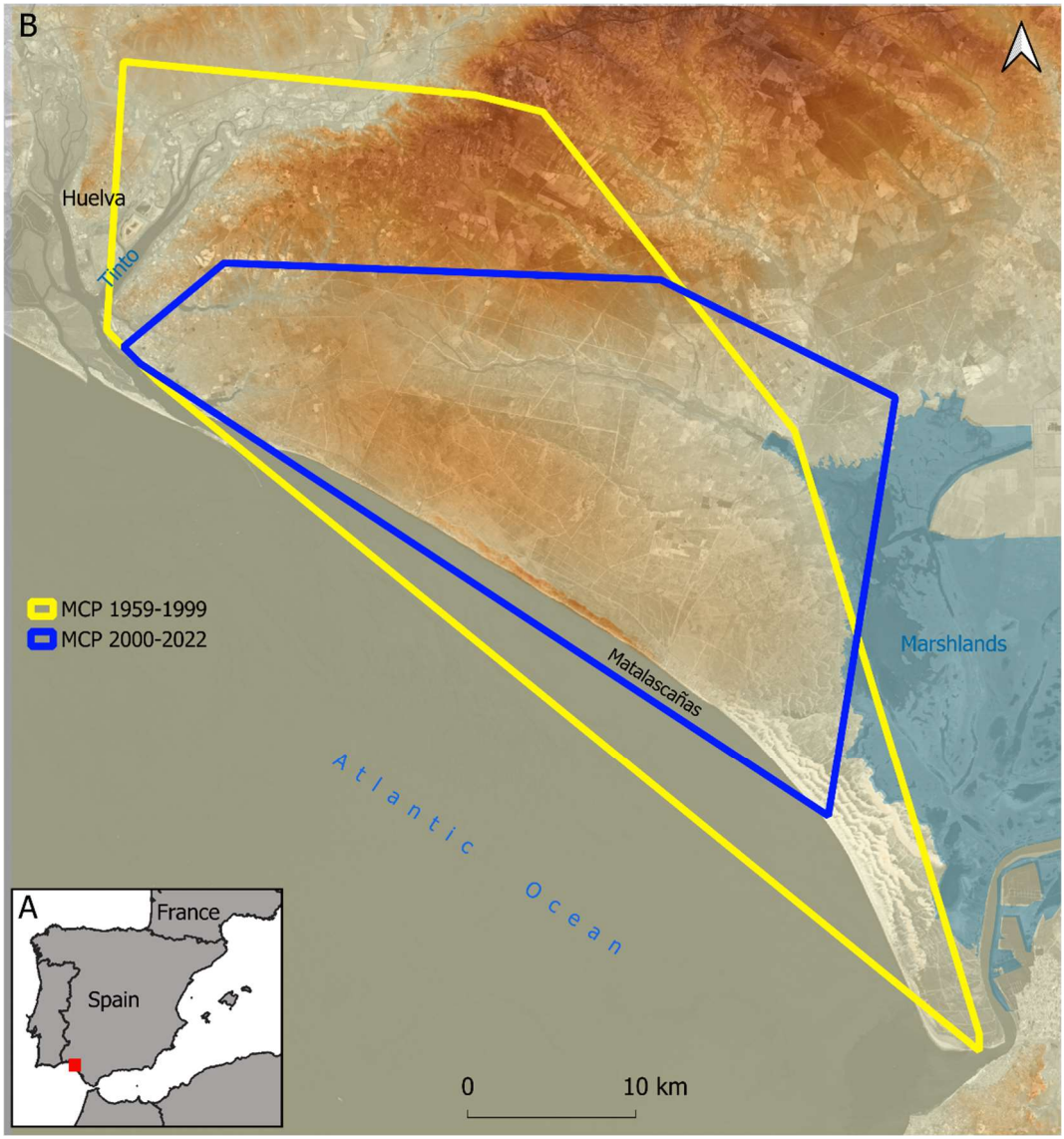


Figure S1- Minimum Convex Polygon (MCP) for the period 1959-1999 (yellow) and MCP for the period 2000-2022.

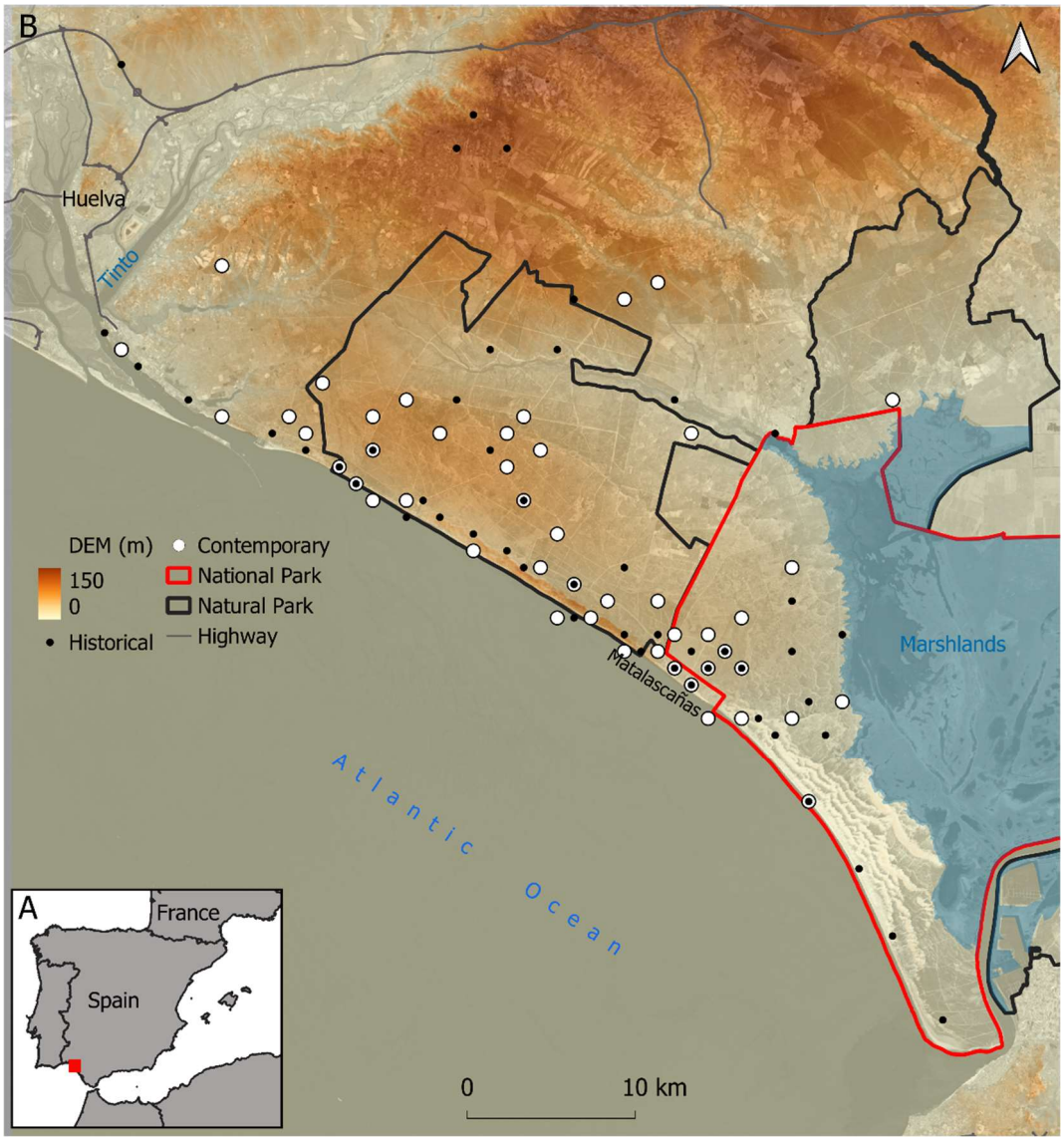


Figure S2-Occurrence data used to run ecological models in historical (white and black dots) and contemporary periods (black dots).

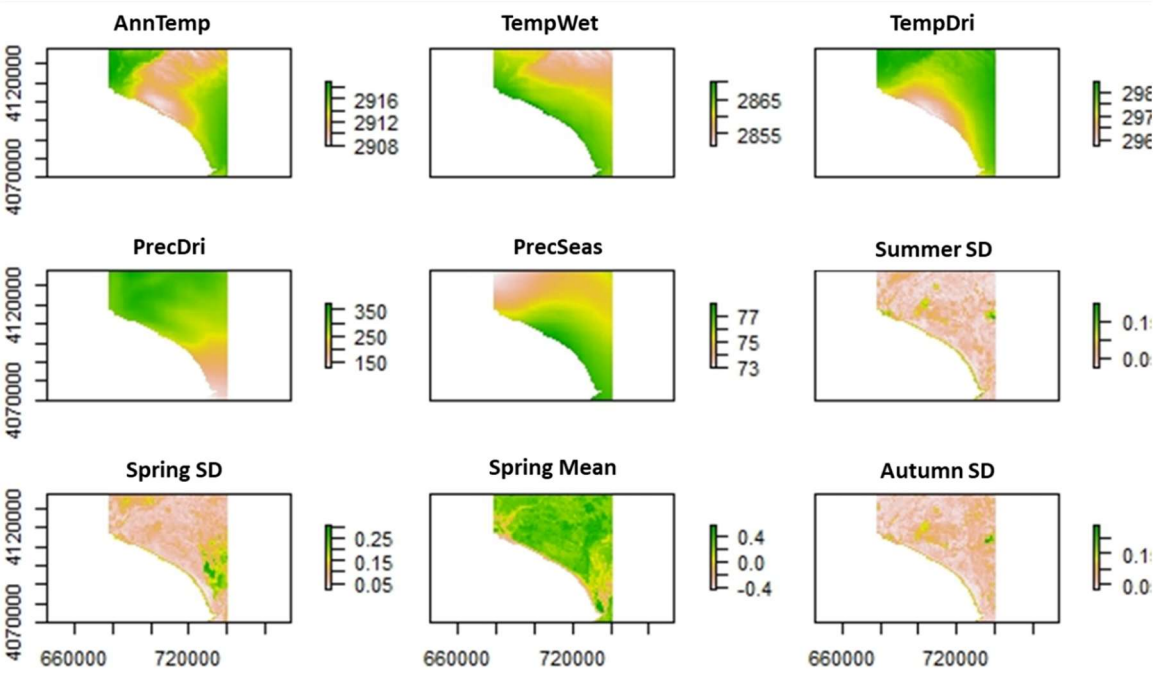


Figure S3- Spatial representation of the variables used in the historical models.

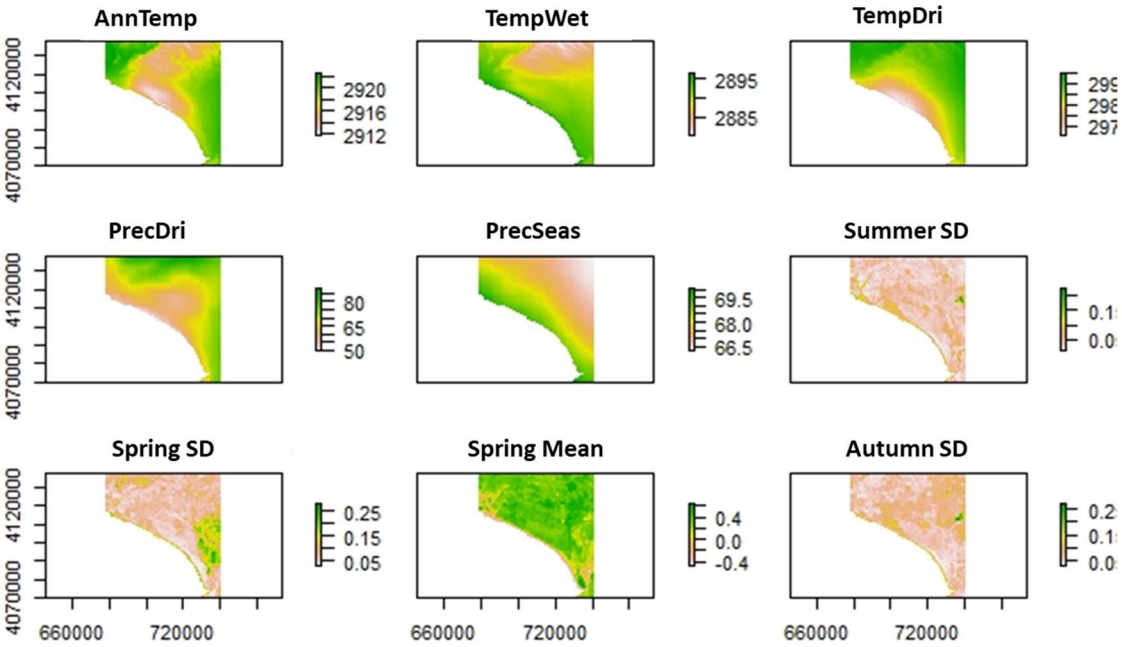


Figure S4- Spatial representation of the variables used in the contemporary models.

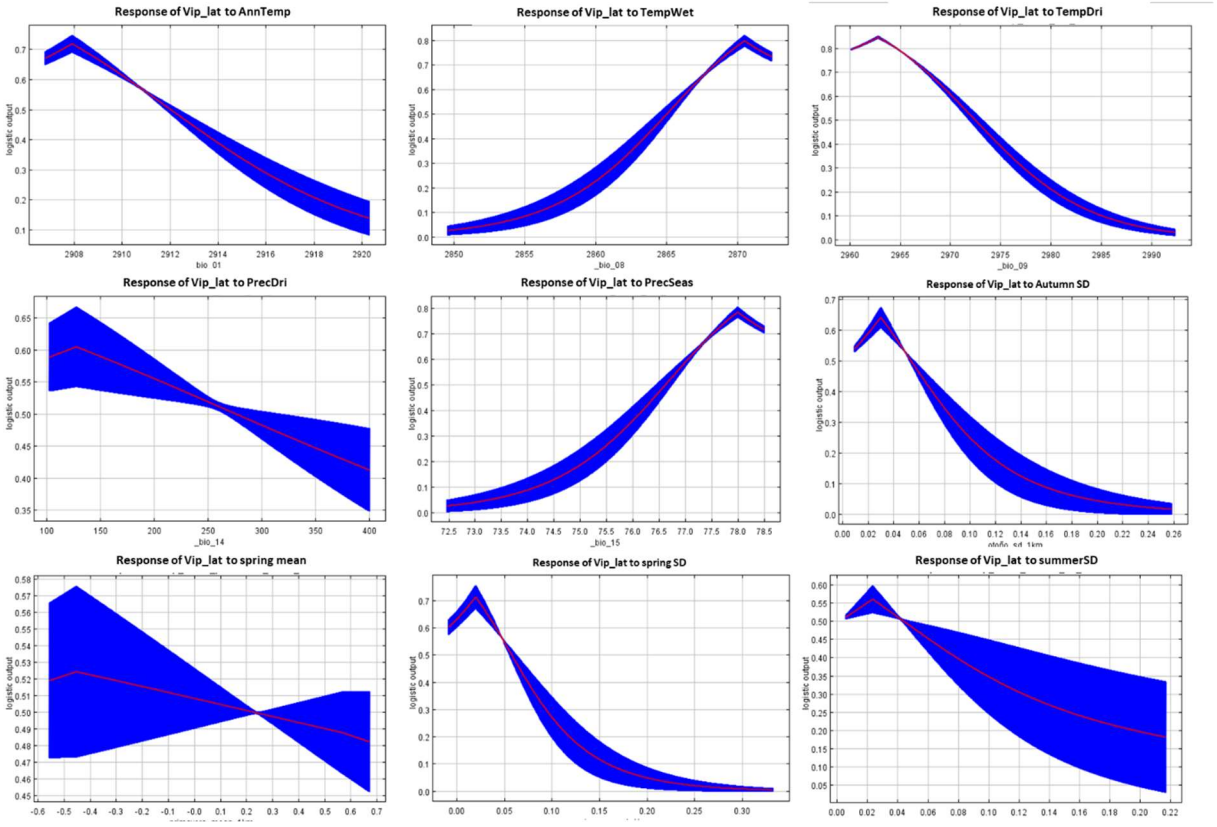


Figure S5- Response curves for the variables considered in the historical model.

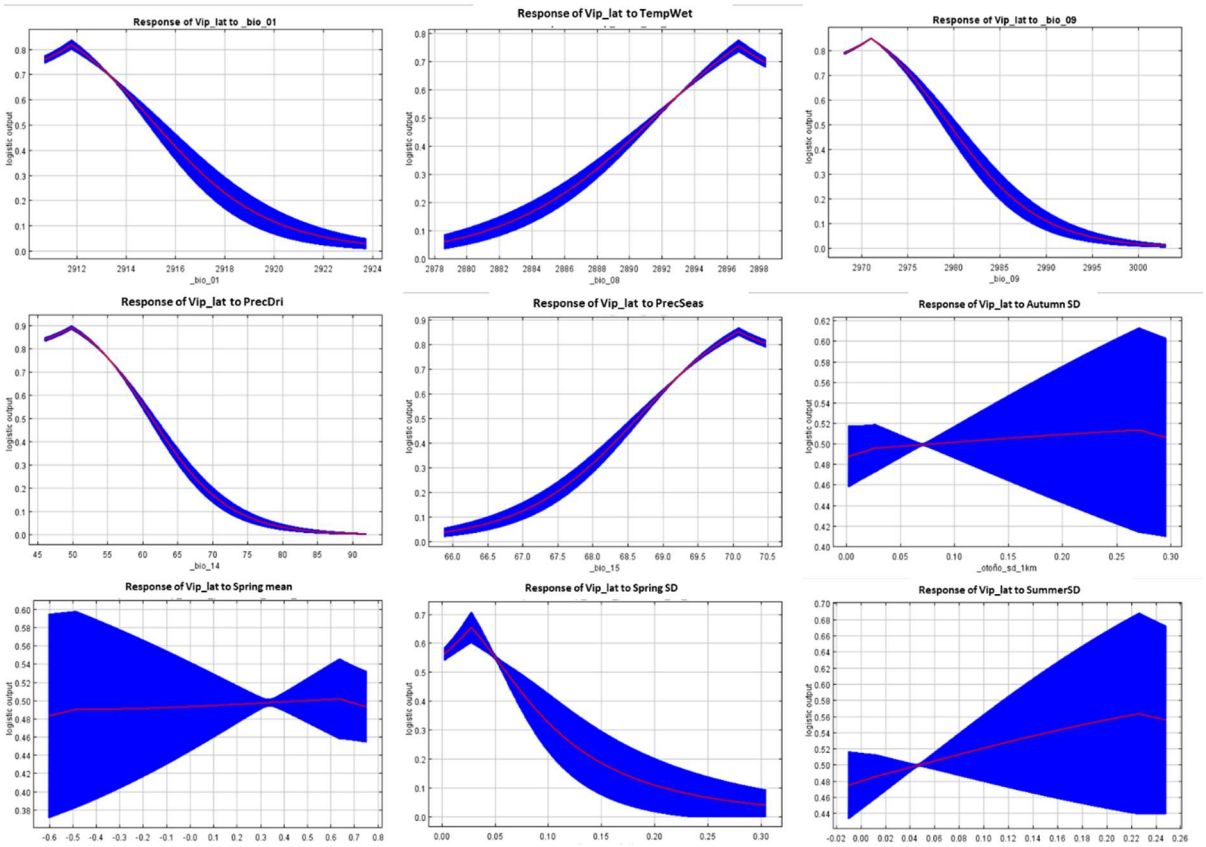


Figure S6- Response curves for the variables considered in the contemporary model.

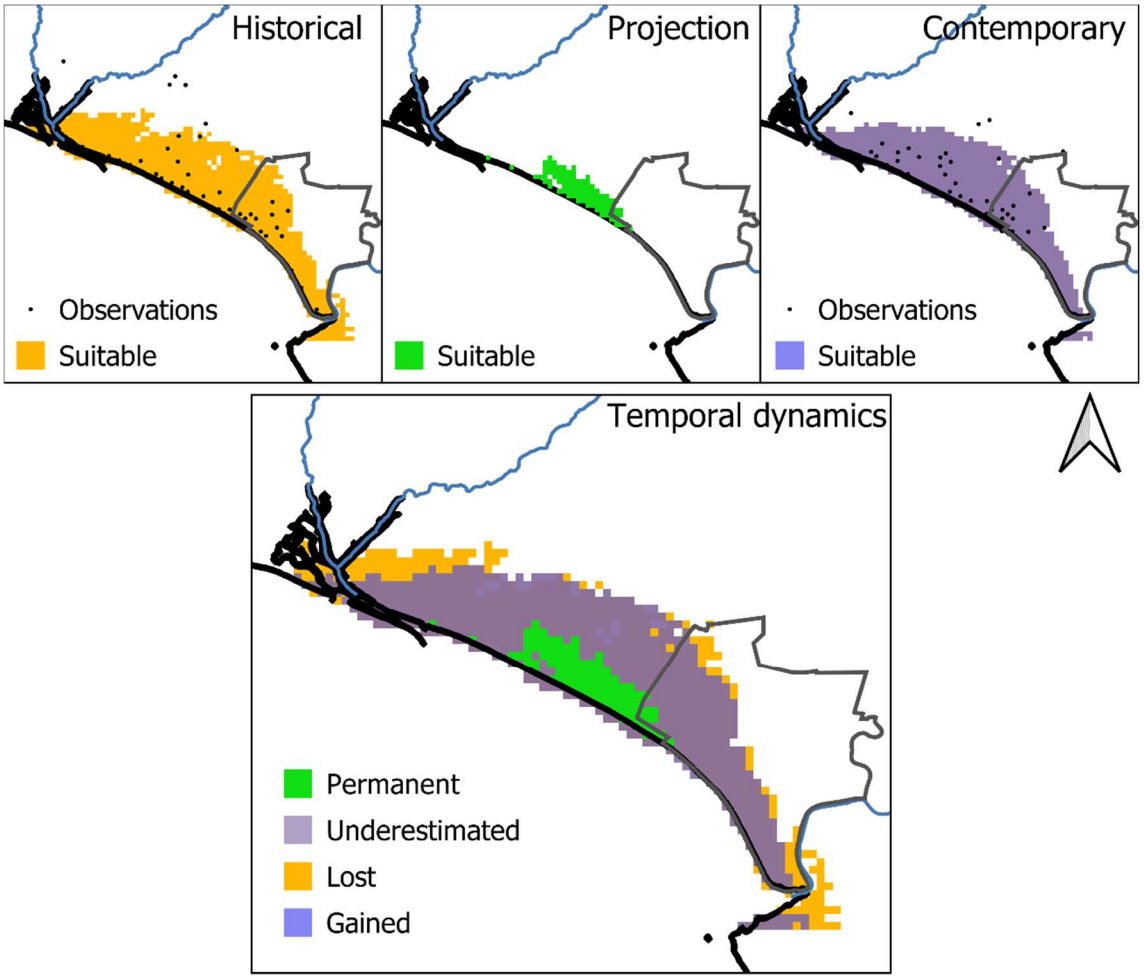


Figure S7- Historical, contemporary and projection of suitable habitats and temporal dynamics of habitat suitability for Lataste's viper in Doñana, considering the 10th percentile logistic threshold. Lost habitats refer to pixels identified in the Historical only; permanent suitable habitats to pixels identified in Historical, Projection and Contemporary; underestimated suitable habitats refer to pixels identified in the Contemporary and Historical; and gained suitable habitats refer to pixels identified in the Contemporary only.