

**Climatic Niche differentiation between the Invasive Hornet
Vespa velutina nigrithorax and two Native Hornets in Europe,
Vespa crabro and *Vespa orientalis***

Simone Lioy, Luca Carisio, Aulo Manino, Marco Porporato

Department of Agriculture, Forest and Food Sciences, University of Turin,
Largo Paolo Braccini 2, 10095 Grugliasco, Italy

Supplementary information

Table S1. Number of records of the three *Vespa* species used for the different sections of the analyses.

Spatial scale	<i>V. velutina</i>	<i>V. crabro</i>	<i>V. orientalis</i>
Globally	24,104	28,330	363
Study area (western palearctic and saharo-arabian zoogeographic regions)	23,076	26,020	312
Study area (after applying a thinning process of 10 km to account for sampling bias)	2,213	5,015	162
Area of co-presence of <i>V. v. nigrithorax</i> and <i>V. crabro</i>	9,270	11,113	-
Area of co-presence of <i>V. v. nigrithorax</i> and <i>V. crabro</i> (after applying a thinning process of 1 km to account for sampling bias)	5,113	7,684	-

Table S2. Mean and Standard Deviation of the climatic variables observed for the three species in the study area (*Vespa velutina nigrithorax*, *V. crabro* and *V. orientalis*) and in the area of co-occurrence (*V. v. nigrithorax* and *V. crabro*).

Variables	Study Area						Area of Co-Occurrence			
	VVN		VC		VO		VVN		VC	
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Bio 01 - Annual Mean Temperature (°C)	11.4	1.5	8.9	2.4	17.5	3.1	11.8	1.4	11.2	1.3
Bio 02 - Mean Diurnal Range (°C)	8.9	1.2	8.0	1.1	9.8	2.5	8.9	1.2	8.9	0.9
Bio 03 - Isothermality (%)	0.4	0.0	0.3	0.0	0.4	0.1	0.4	0.0	0.4	0.0
Bio 04 - Temperature Seasonality (°C)	53.4	5.8	62.0	12.0	59.8	12.1	53.4	5.7	57.1	6.4
Bio 05 - Max Temperature of Warmest Month (°C)	24.4	2.0	22.6	2.4	31.6	3.3	24.8	2.1	24.8	2.0
Bio 06 - Min Temperature of Coldest Month (°C)	0.7	1.9	-2.6	3.7	5.3	4.1	1.1	1.6	0.2	1.6
Bio 07 - Temperature Annual Range (°C)	23.6	2.6	25.2	3.9	26.3	5.2	23.6	2.6	24.6	2.4
Bio 08 - Mean Temperature of Wettest Quarter (°C)	9.5	4.2	12.5	4.7	12.0	4.0	9.8	3.7	12.1	4.6
Bio 09 - Mean Temperature of Driest Quarter (°C)	13.3	6.4	5.3	6.6	23.7	5.1	14.0	6.3	9.8	5.9
Bio 10 - Mean Temperature of Warmest Quarter (°C)	18.2	1.6	16.8	1.9	25.1	2.6	18.6	1.5	18.4	1.5
Bio 11 - Mean Temperature of Coldest Quarter (°C)	4.5	1.9	1.0	3.5	10.0	4.0	5.0	1.7	3.8	1.6
Bio 12 - Annual Precipitation (mm)	810.1	145.6	751.7	173.2	599.4	298.0	806.5	143.8	757.4	136.0
Bio 13 - Precipitation of Wettest Month (mm)	90.5	23.4	85.4	22.9	121.3	60.4	91.1	24.6	81.4	23.7
Bio 14 - Precipitation of Driest Month (mm)	45.6	11.0	42.3	13.1	5.6	10.4	43.7	11.1	45.4	10.3
Bio 15 - Precipitation Seasonality (mm)	18.3	9.3	21.5	9.4	79.7	22.7	19.0	9.9	15.4	10.2
Bio 16 - Precipitation of Wettest Quarter (mm)	248.8	64.1	240.1	64.2	317.7	158.3	251.0	65.9	223.0	64.8
Bio 17 - Precipitation of Driest Quarter (mm)	158.9	32.6	139.9	40.0	22.9	35.8	155.4	32.2	151.3	28.1
Bio 18 - Precipitation of Warmest Quarter (mm)	175.5	36.0	206.7	61.1	32.1	59.0	171.2	33.6	175.4	36.5
Bio 19 - Precipitation of Coldest Quarter (mm)	220.4	66.5	177.8	63.2	281.9	153.3	219.4	65.1	194.3	63.1
Elevation (m a.s.l.)	224.1	249.1	217.1	265.3	313.8	419.6	163.8	172.9	181.3	166.9
Aspect (degrees)	201.6	106.4	185.5	107.2	191.5	96.7	179.5	101.6	183.9	105.7
Slope (degrees)	0.4	0.6	0.4	0.6	1.6	1.3	1.7	2.3	1.4	2.2

VVN: *V. v. nigrithorax*; VC: *V. crabro*; VO: *V. orientalis*.

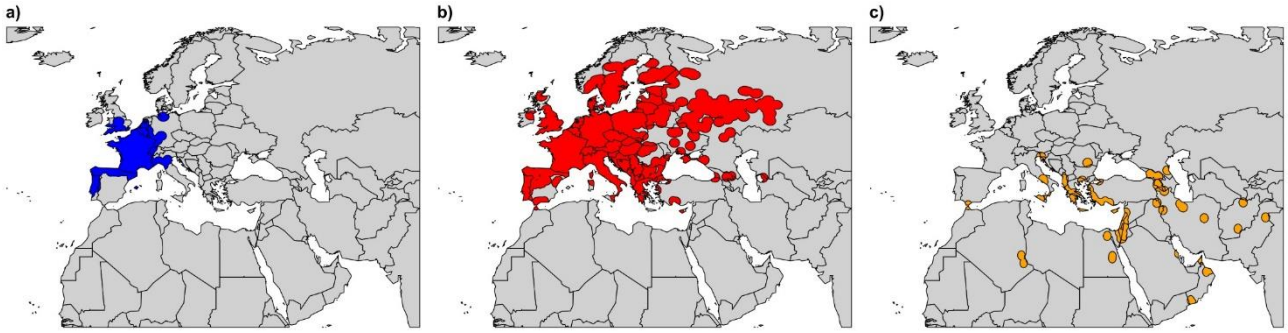


Figure S1. Buffer areas of 100 km around the records of *V. v. nigrithorax* (a), *V. crabro* (b) and *V. orientalis* (c) in the western palearctic and saharo-arabian zoogeographic regions. Buffer areas were used for defining the background environment for the PCA-env niche analysis at the study area level.

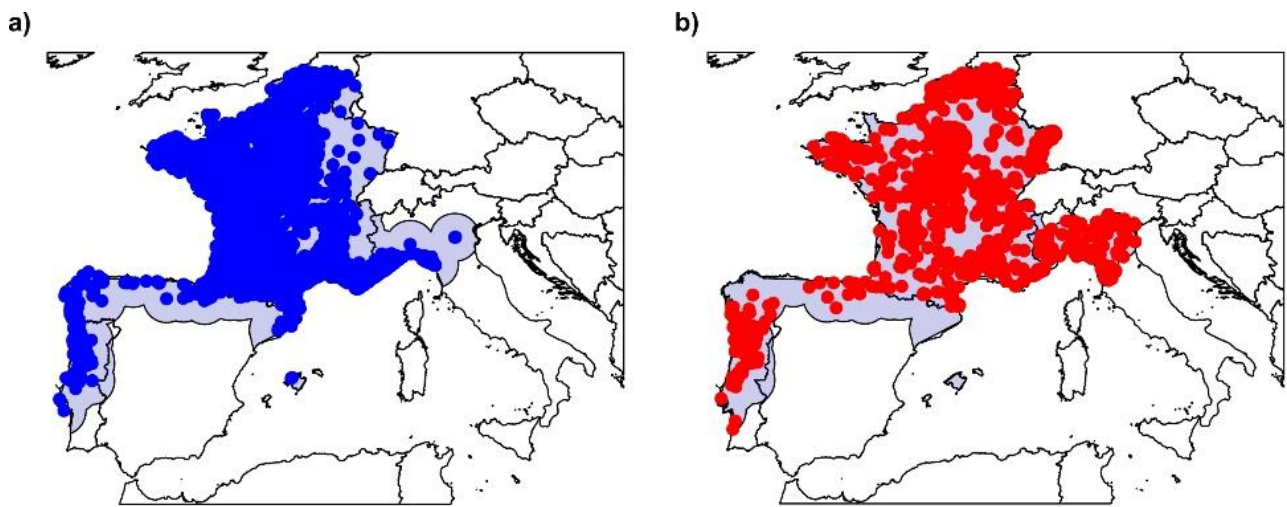


Figure S2. Records of *V. v. nigrithorax* (a) and *V. crabro* (b) in the area of co-occurrence of the two species, which has been defined as the 100 km buffer area that encompasses all *V. v. nigrithorax* records within the main colonised countries of Europe, namely, France, Spain, Portugal, Italy, and Belgium. The temporal range of the data is 1990-2021.

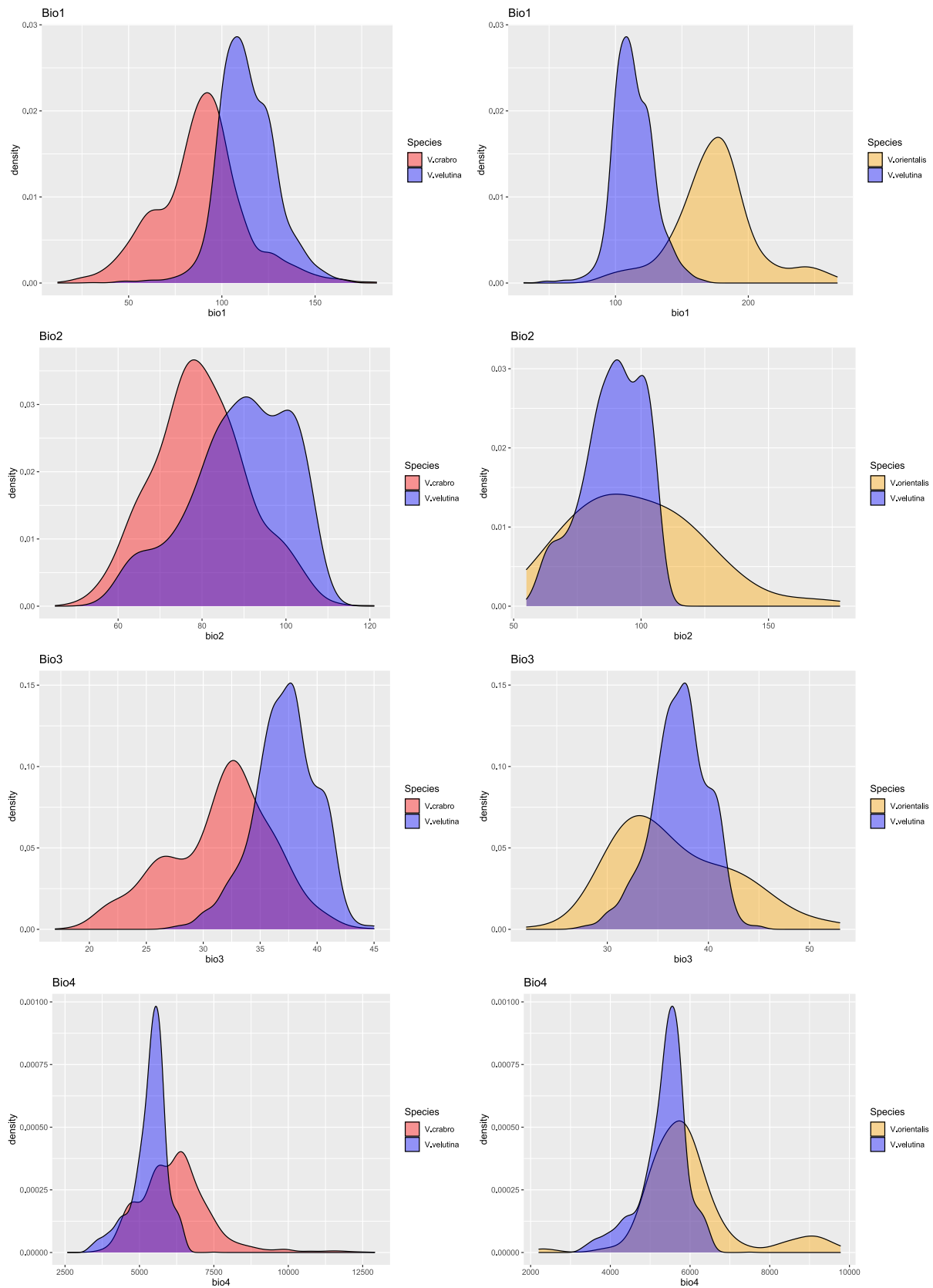


Figure S3. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for Bio1, Bio2, Bio3 and Bio4. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

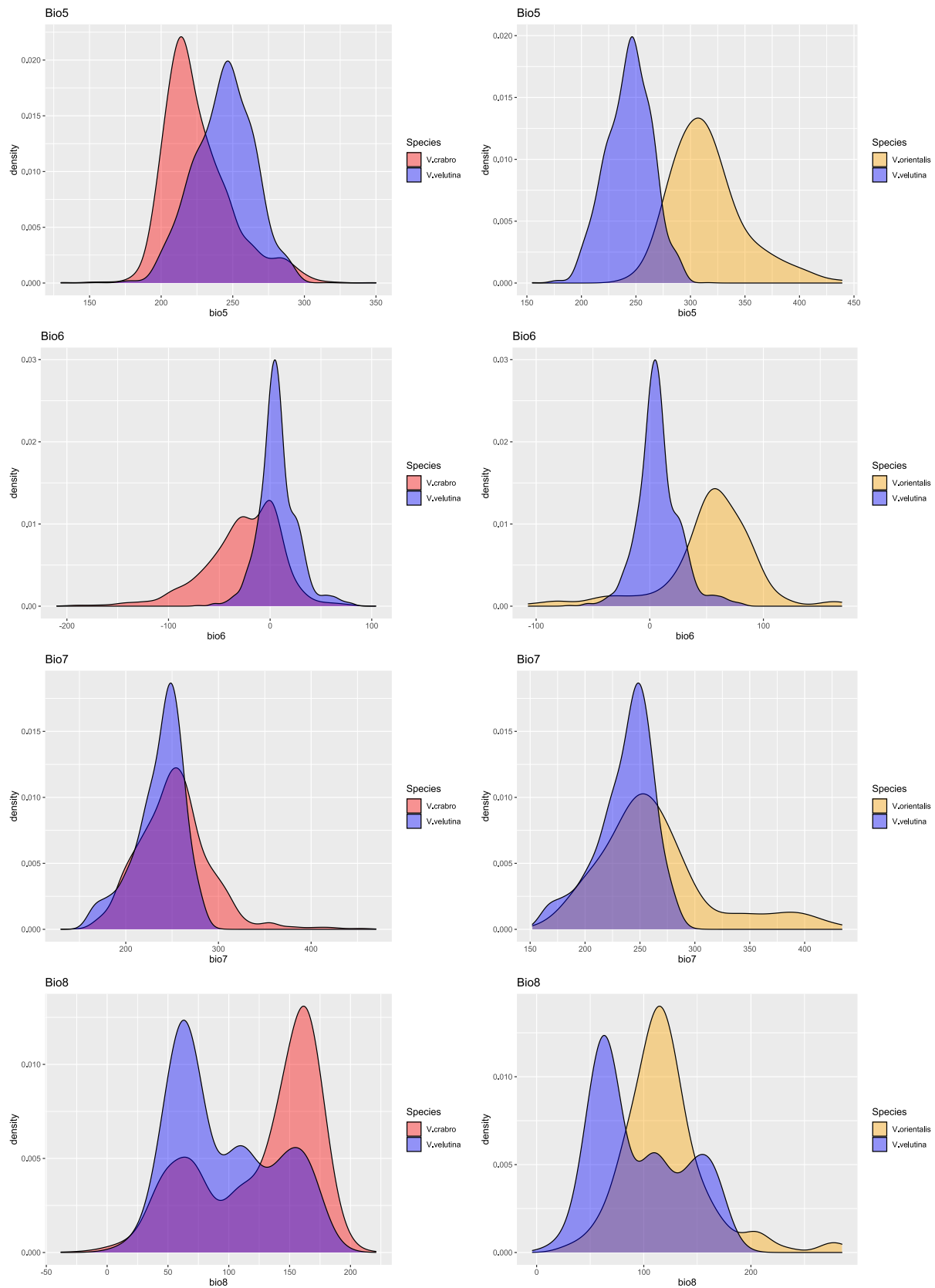


Figure S4. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for Bio5, Bio6, Bio7 and Bio8. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

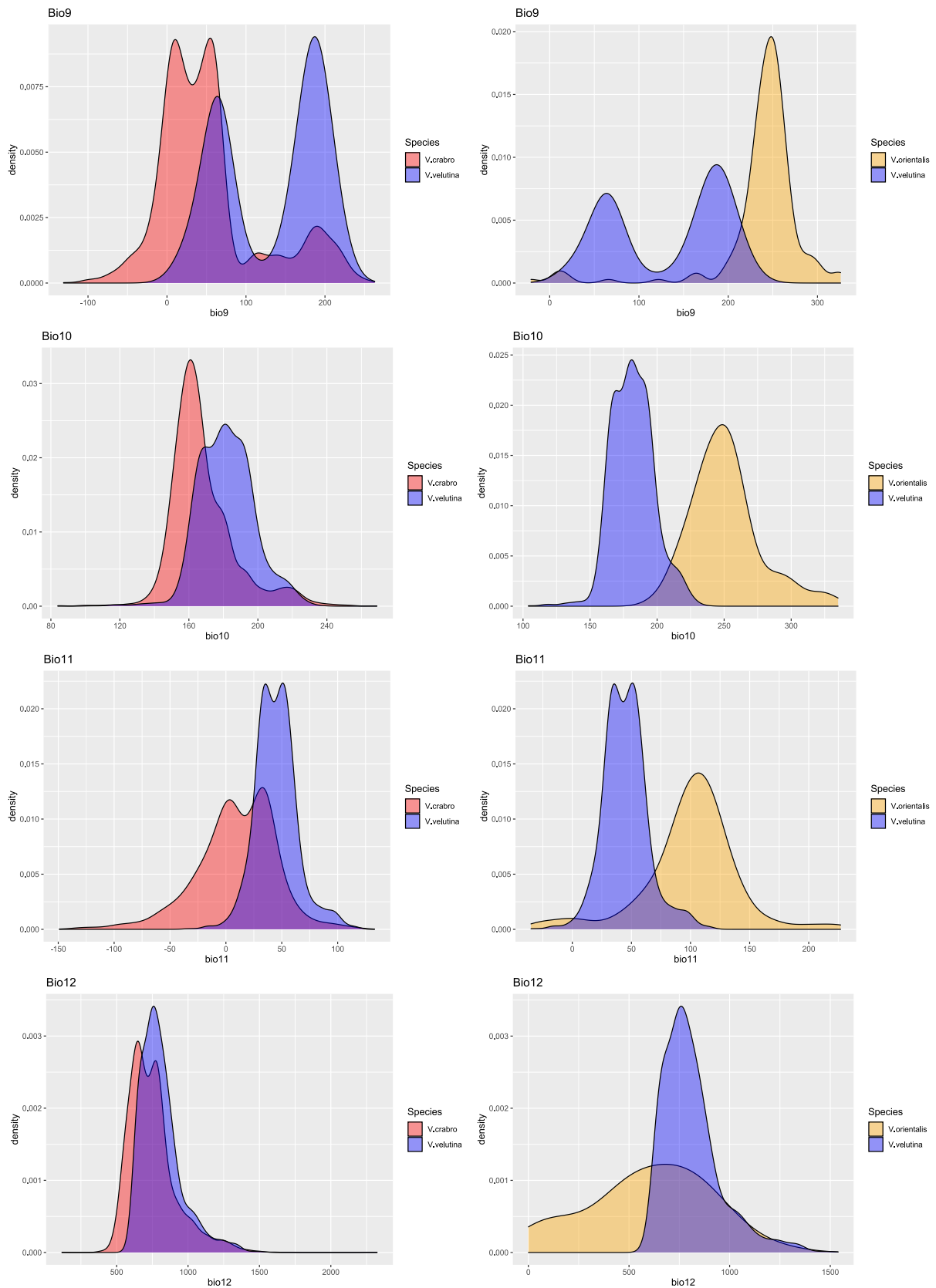


Figure S5. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for Bio9, Bio10, Bio11 and Bio12. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

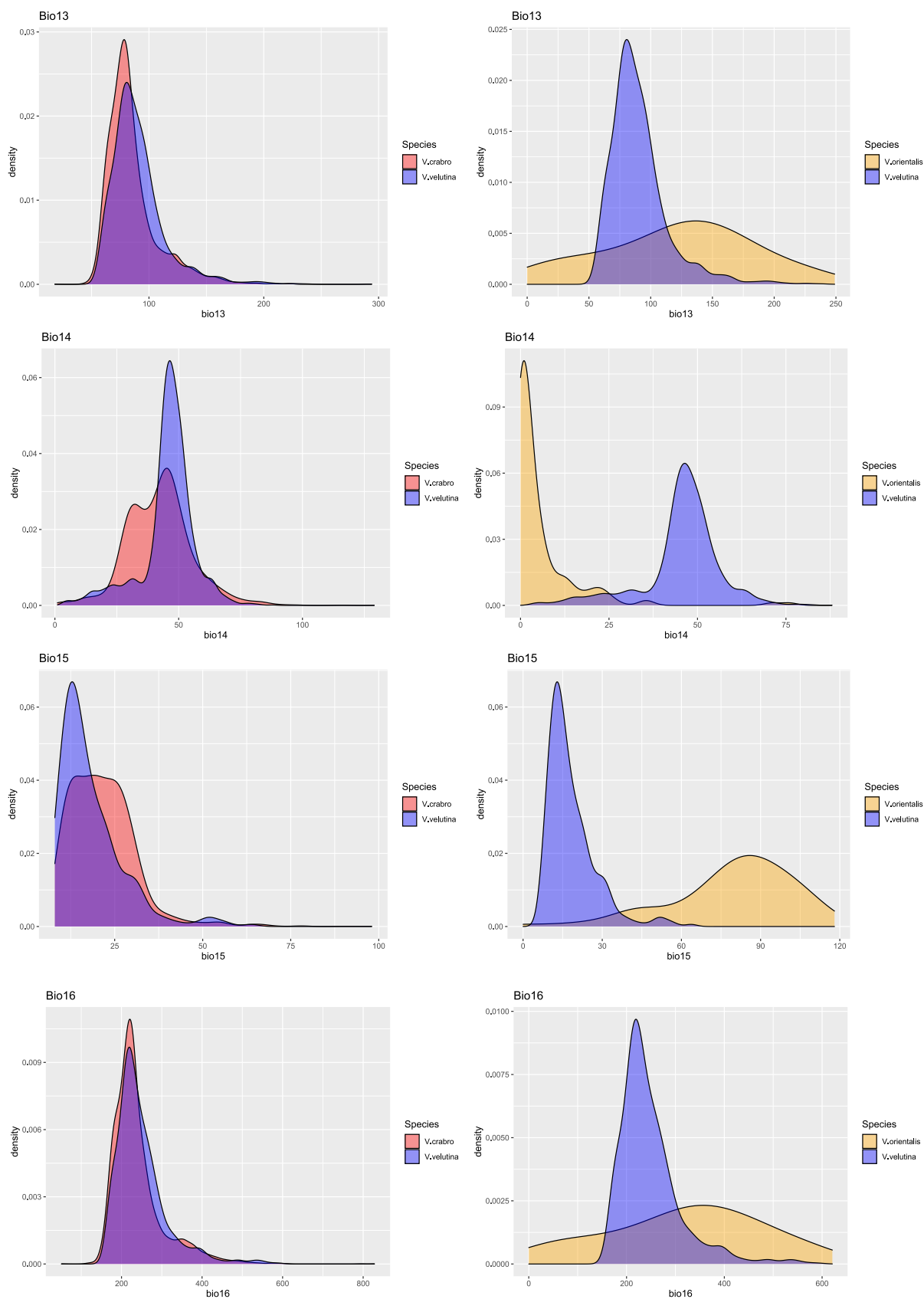


Figure S6. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for Bio13, Bio14, Bio15 and Bio16. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

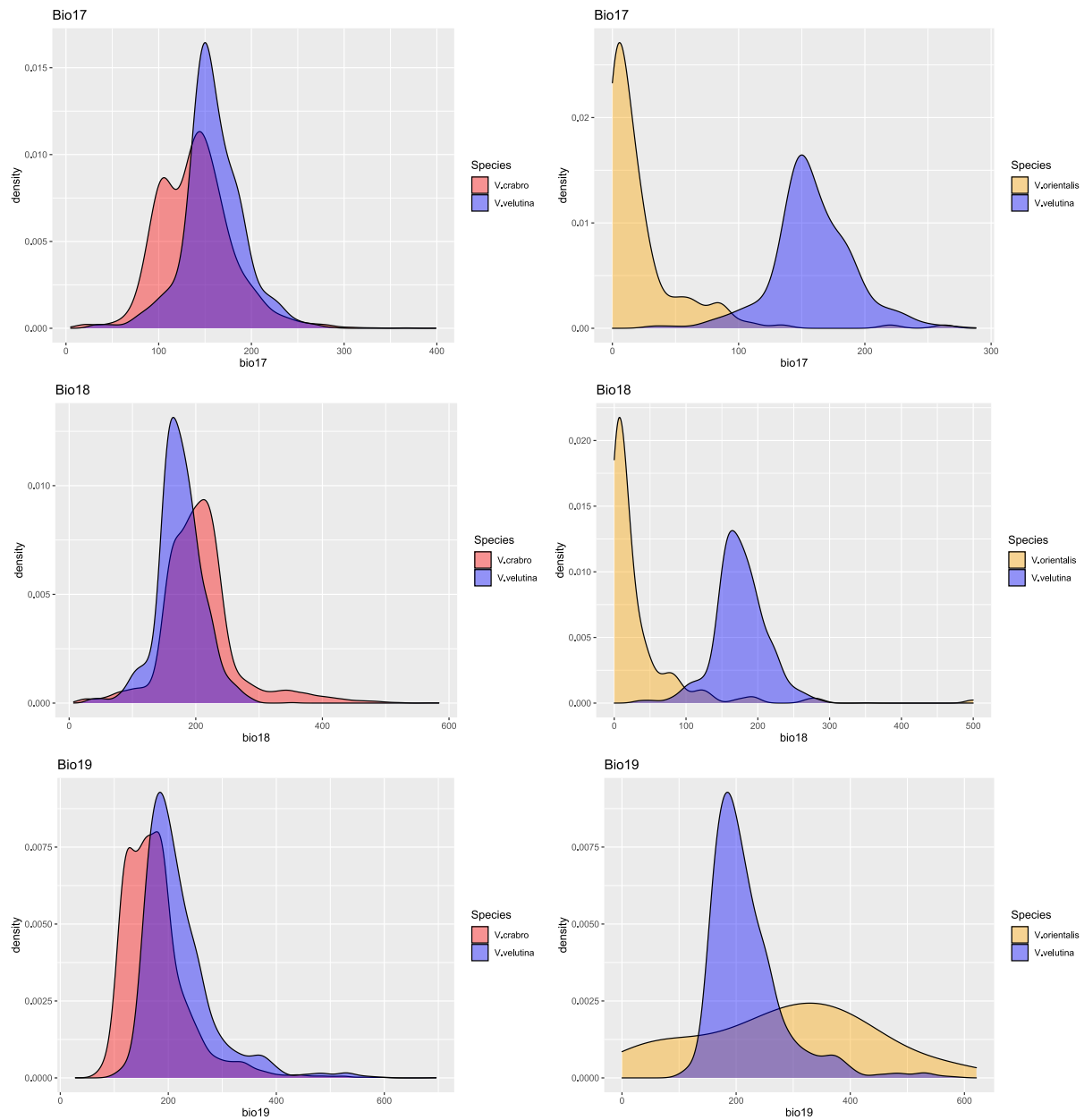


Figure S7. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for Bio17, Bio18 and Bio19. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

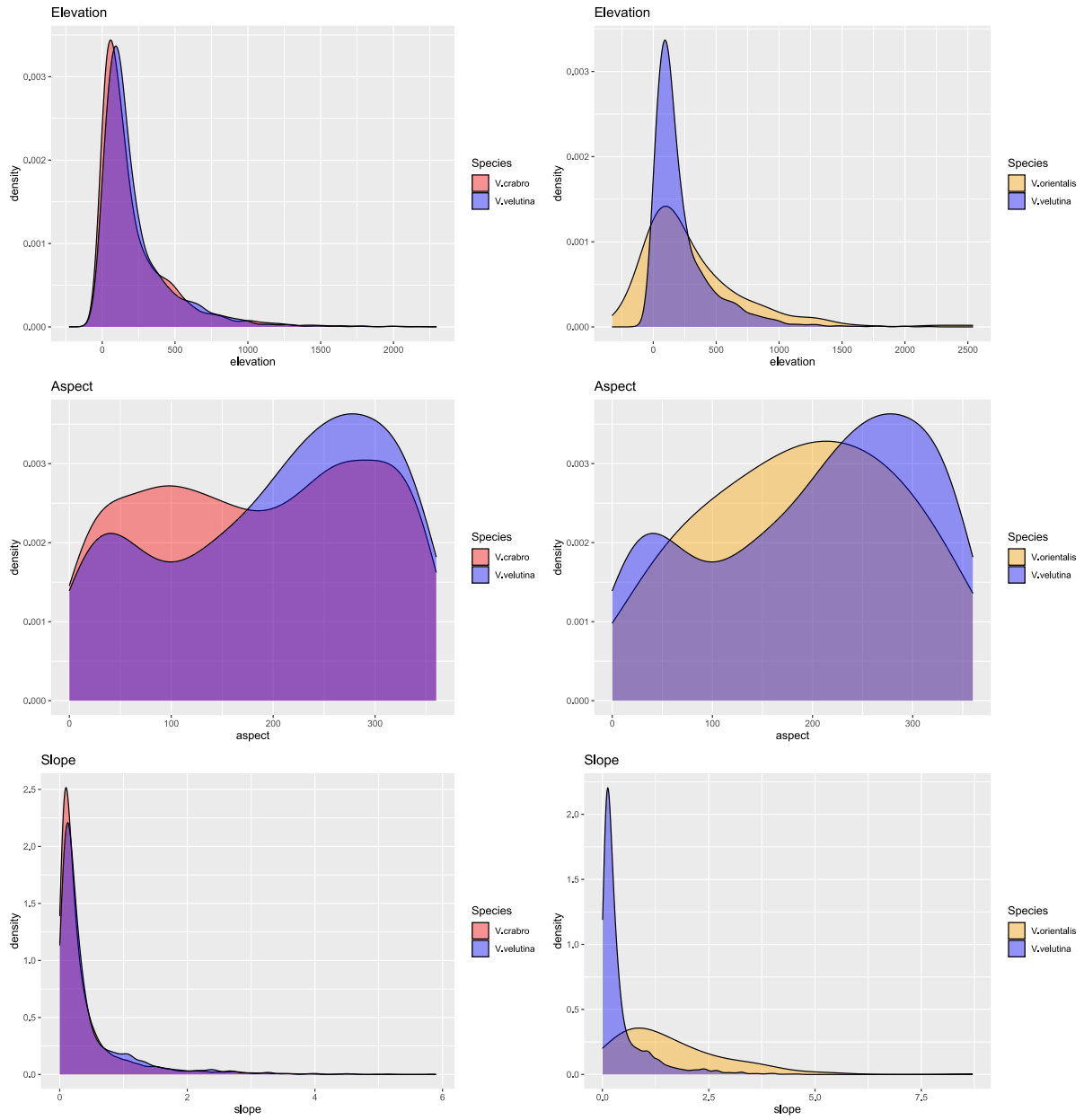


Figure S8. Density plots of *V. v. nigrithorax* (blue), *V. crabro* (red) and *V. orientalis* (yellow) at the study area level for the variables elevation, aspect and slope.

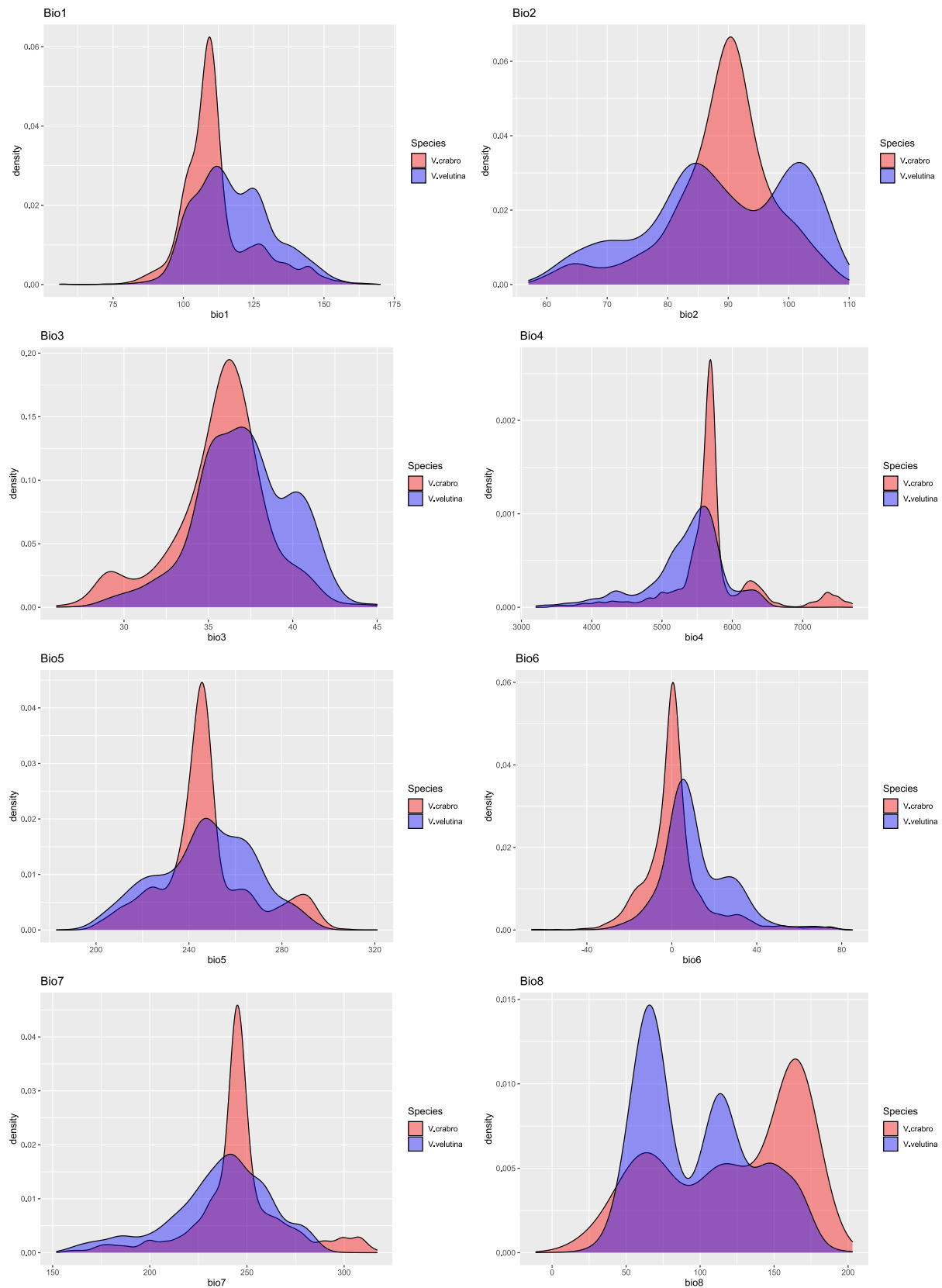


Figure S9. Density plots of *V. v. nigrithorax* (blue) and *V. crabro* (red) in the areas of co-occurrence of the two species for Bio1-Bio8. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

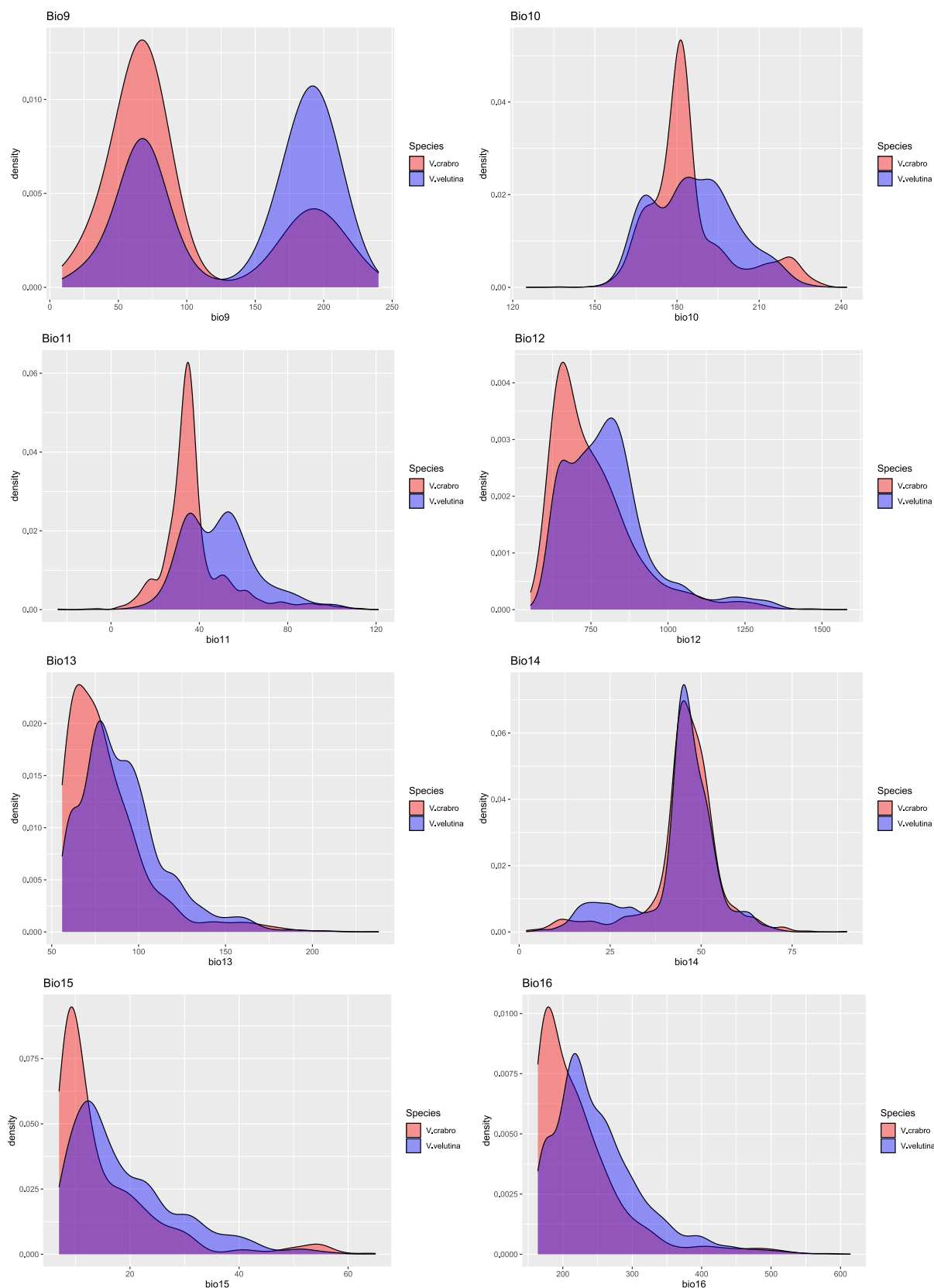


Figure S10. Density plots of *V. v. nigrithorax* (blue) and *V. crabro* (red) in the areas of co-occurrence of the two species for Bio9-Bio16. Variable detailed explanation can be found at www.worldclim.org/data/bioclim.html.

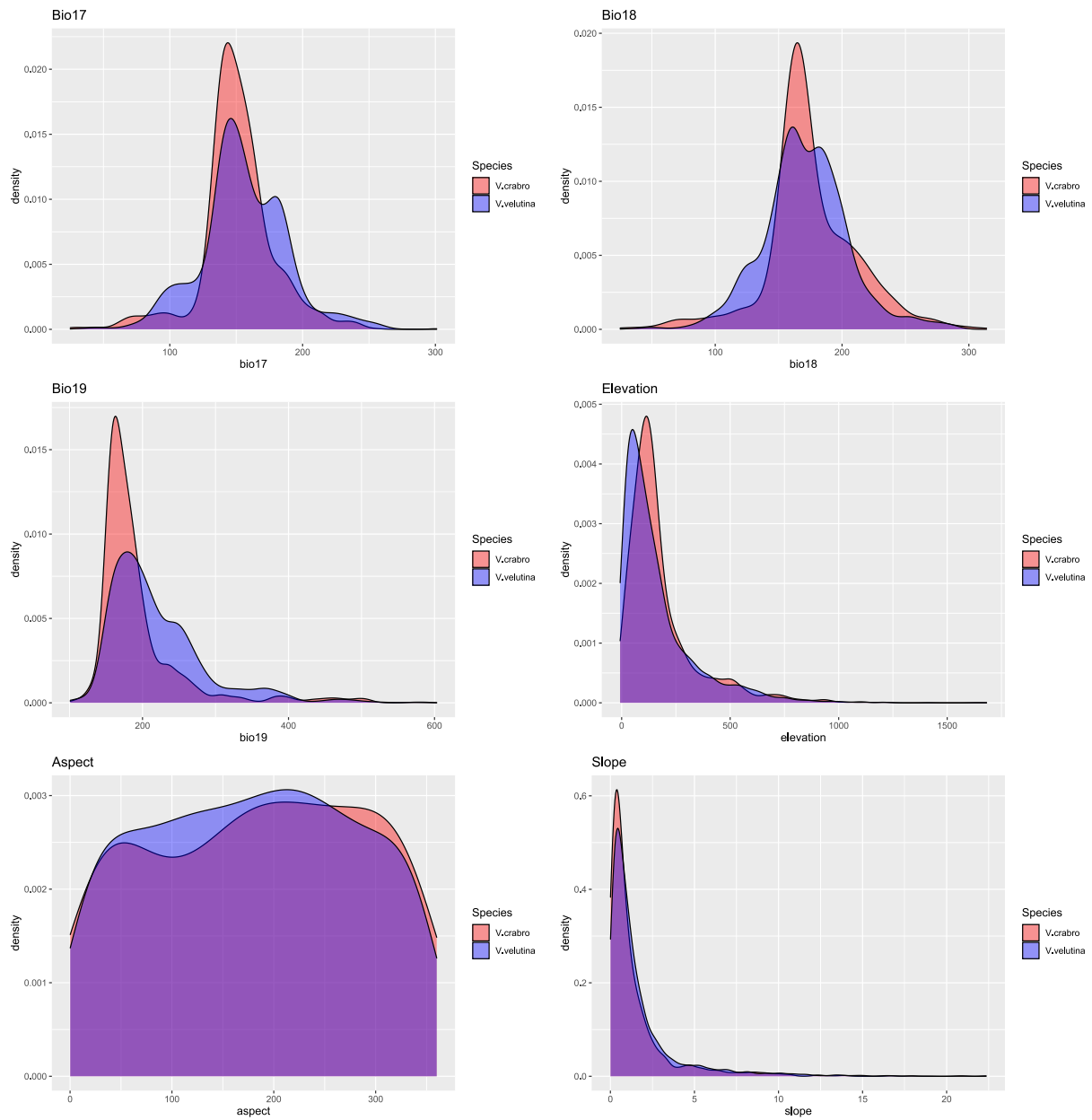


Figure S11. Density plots of *V. v. nigrithorax* (blue) and *V. crabro* (red) in the areas of co-occurrence of the two species for the variables Bio17-Bio19, elevation, aspect and slope. Variable detailed explanation of bioclimatic variable can be found at www.worldclim.org/data/bioclim.html.