Extinction risk through climate change in Megafauna

Natalia Villavicencio, Derek Corcoran and Pablo Marquet

1 Methods

1.1 Metrics of ectinction

In order to estimate if the predicted range of a species was low enough for a species to become extinct we estimated the Minimum Viable Area for each species. In order to do that we started by calculating the individual Home Range of a Species as shown in equation (1) modified from (Lindstedt et al., 1986) to calculate it in Km^2.

$$\begin{aligned} HR_{Herb} &= 0.0271 \times M^{1.02} \\ HR_{Omni} &= 0.034 \times M^{0.92} \\ HR_{Carn} &= 1.37 \times M^{1.37} \end{aligned} \tag{1}$$

This equation diferienciates between Herbivores, Omnivores and Carnivores, where at the same size Carnivores need much larger range. After that we since we know the area neede by one individual we assume that the Minimum Viable Area (MVA hereafter) is calculated by multipling the Home Range according to equation (1),by the Minimum Viable Population (MVP hereafter), as is show in equation (2), the result of this equation is the Km^2 needed for a species to persist. For MVP we used two estimates from (Traill et al., 2007), where it was estimated that the MVP for most vertebrates was 4,169 individuals, but in order to get a more strict estimate we also used the higher estimation of the 95% confidence interval of 5,129 to make more conservative estimates.

$$MVA = MVP * HR_{Feed} \tag{2}$$

Since the Estimated MVA ranged from 3,947, to 16,426,903 Km^2 we decided to standardize the MVAs as Number of Viable Areas (NVA here after) to make easier to compare between species, the calculation of NVA is shown in equation (2),

$$NVA = \frac{A}{MVA} \tag{3}$$

1.2 Species occurences

[[**Naty**]] We rounded the species ocurrences to the nearest decade

1.3 Species Distribution Modeling

We downladed average high and low monthly temperature and average monthly precipitation represented as a difference from present conditions using PaleoView Software (Fordham et al., 2017) for the period from 21 kyr BP to the present for South America, using worlclim's version 1.4 as current conditions (Hijmans et al., 2005) instead of the newer 2.0 version (Fick and Hijmans, 2017) since it has 1975 as reference to calculate differences in climate, the same as Paleoview. Then we applied a modified version of the detla method to this layers to consider the changes in sea level (Schmatz et al., 2015), using prior works to estimate sealevels (Fleming et al., 1998, Milne et al. (2005)), and using the gebco bathymetry layers in order to estimate the coastline for each time-slice (Weatherall et al., 2015). After downscaling the layers a 2.5 minute resolution (approximately 5 Km^2) we used the biovars of the dismo package (Hijmans et al., 2017) to generate bioclimatic layers. The code for the downscaling method can be found at (Corcoran, 2020)

The we used the bioclimatic variables to build the species distribution models following (Phillips et al., 2006; Elith et al., 2011), using the regularization method to avoid overfitting (Allouche et al.,2006; Hastie et al., 2009; Merow et al., 2013). This method allows machine learning algorithm techniques to decide which biolclimatic variables are important to model the distribution of the different species analyzed. The variable selected for each of the species we used in this study can be found in the Supplementary Material section.

2 Results

In figure 1, we can see the number of viable areas (NVA hereafter) estimated for each species as a solid line across time, and the lower NVA as a semitransparent area, each time a species NVA drops bellow one (red dashed line),a species is estimated to be extinct. If we look at the estimation, only 2 of the 44 species are predicted to be extinct. The species that should become extinct are Panthera onca mesembrina and Smilodon populator, when we look at the lower estimate interval that number icreases to 3, where the species predicted to become extinct are Panthera onca, Panthera onca mesembrina and Smilodon populator

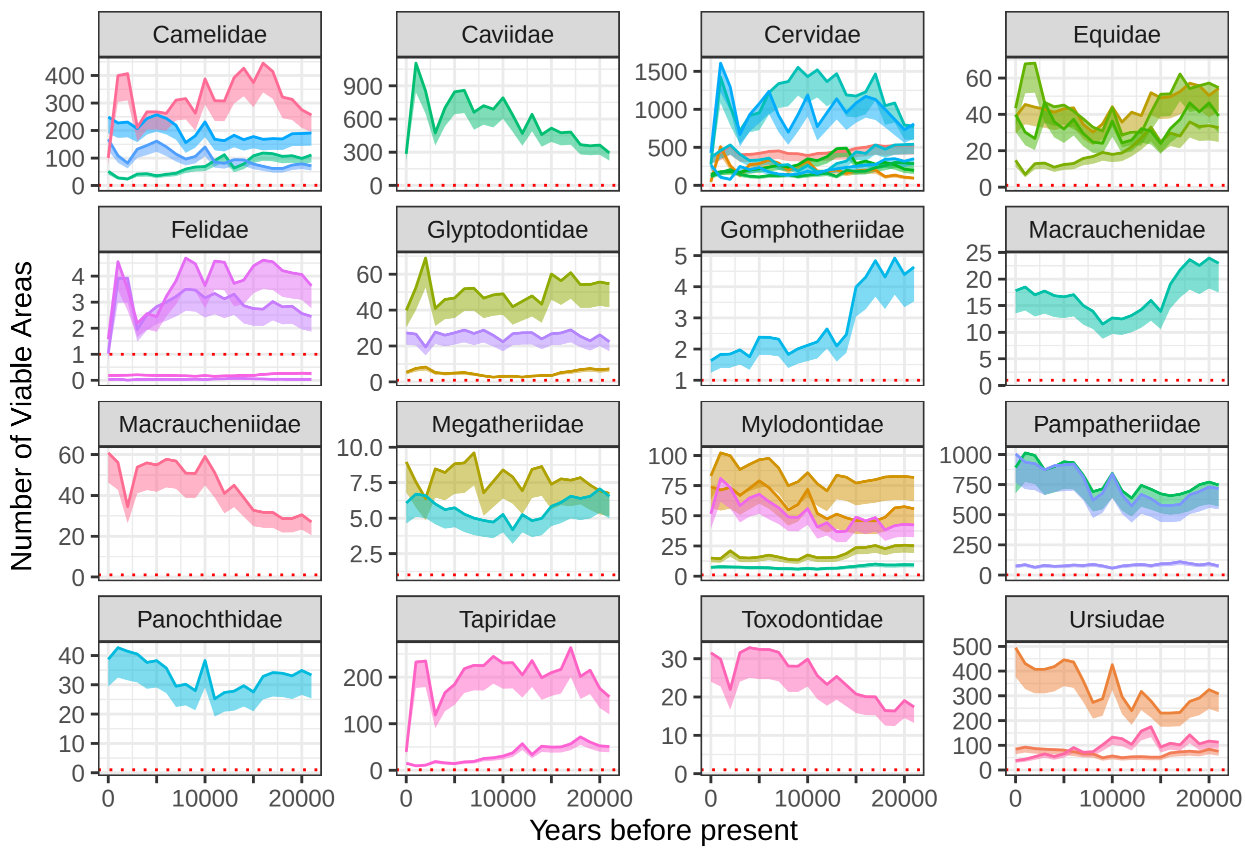


Figure 1: graph showing the estimation of Number of viable areas for each species and the area showing the lower Estimate of number of viable areas by feeding habits, if a species goes bellow the red dotted line, they are predicted to be extinct

3 Discusion

4 Suplementary materials

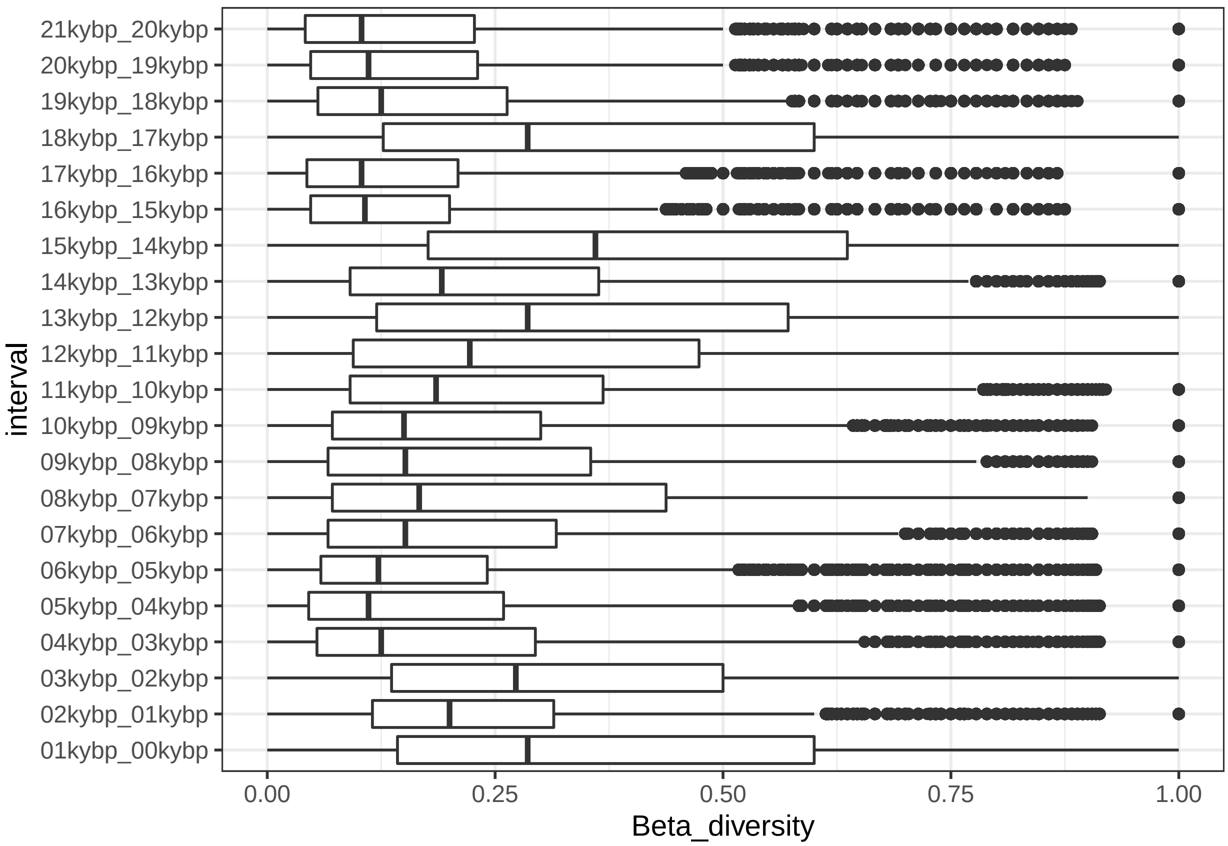
4.1 Table with all the modeled species

Table 1: Al the model
Range, and the estima
interval estimation of

Order	Family	Species	State	Feeding
Artiodactyla	Cervidae	Antifer ultra	Extinct	Herbivore
Carnivora	Ursiudae	Arctotherium tarijense	Extinct	Omnivore
Carnivora	Ursiudae	Arctotherium wingei	Extinct	Omnivore
Artiodactyla	Cervidae	Blastocerus dichotomus	Extant	Herbivore
Pilosa	Mylodontidae	Catonyx chiliense	Extinct	Herbivore
Pilosa	Mylodontidae	Catonyx cuvieri	Extinct	Herbivore
Cingulata	Glyptodontidae	Doedicurus clavicaudatus	Extinct	Herbivore
Perissodactyla	Equidae	Equus neogeus	Extinct	Herbivore
Pilosa	Megatheriidae	Eremotherium laurillardi	Extinct	Herbivore
Pilosa	Mylodontidae	Glossotherium robustum	Extinct	Herbivore
Cingulata	Glyptodontidae	Glyptodon clavipes	Extinct	Herbivore
Perissodactyla	Equidae	Hippidion devillei	Extinct	Herbivore
Perissodactyla	Equidae	Hippidion principale	Extinct	Herbivore
Perissodactyla	Equidae	Hippidion saldiasi	Extinct	Herbivore
Artiodactyla	Cervidae	Hippocamelus antisensis	Extant	Herbivore
Artiodactyla	Cervidae	Hippocamelus bisulcus	Extant	Herbivore
Cingulata	Pampatheriidae	Holmesina paulacouti	Extinct	Herbivore
Rodentia	Caviidae	Hydrochoerus hydrochaeris	Extant	Herbivore
Artiodactyla	Camelidae	Lama guanicoe	Extant	Herbivore
Pilosa	Mylodontidae	Lestodon armatus	Extinct	Herbivore
Litopterna	Macrauchenidae	Macrauchenia patachonica	Extinct	Herbivore
Artiodactyla	Cervidae	Mazama americana	Extant	Herbivore
Pilosa	Megatheriidae	Megatherium americanum	Extinct	Herbivore
Artiodactyla	Cervidae	Morenelaphus brachyceros	Extinct	Herbivore
Cingulata	Panochthidae	Neosclerocalyptus paskoensis	Extinct	Herbivore
Proboscidea	Gomphotheriidae	Notiomastodon platensis	Extinct	Herbivore
Artiodactyla	Cervidae	Odocoileus virginianus	Extant	Herbivore
Artiodactyla	Cervidae	Ozotoceros bezoarticus	Extant	Herbivore
Artiodactyla	Camelidae	Palaeolama major	Extinct	Herbivore
Artiodactyla	Camelidae	Palaeolama weddelli	Extinct	Herbivore
Cingulata	Pampatheriidae	Pampatherium humboldti	Extinct	Herbivore
Cingulata	Pampatheriidae	Pampatherium typum	Extinct	Herbivore
Cingulata	Glyptodontidae	Panochthus tuberculatus	Extinct	Herbivore
Carnivora	Felidae	Panthera onca	Extant	Carnivore
Carnivora	Felidae	Panthera onca mesembrina	Extinct	Carnivore
Carnivora	Felidae	Puma concolor	Extant	Carnivore
Pilosa	Mylodontidae	Scelidotherium leptocephalum	Extinct	Herbivore
Carnivora	Felidae	Smilodon populator	Extinct	Carnivore
Perissodactyla	Tapiridae	Tapirus bairdi	Extant	Herbivore
Perissodactyla	Tapiridae	Tapirus pinchaque	Extant	Herbivore

Table 1: Al the model
Range, and the estima
interval estimation of

Order	Family	Species	State	Feeding
Perissodactyla	Tapiridae	Tapirus terrestris	Extant	Herbivore
Notoungulata	Toxodontidae	Toxodon platensis	Extinct	Herbivore
Carnivora	Ursiudae	Tremarctos ornatus	Extant	Herbivore
Artiodactyla	Camelidae	Vicugna vicugna	Extant	Herbivore
Litopterna	Macraucheniidae	Xenorhinotherium bahiense	Extinct	Herbivore



References

Derek Corcoran. derek-corcoran-barrios/DownscalinPaleoMod: Downscale PaleoView, September 2020. URL https://doi.org/10.5281/zenodo.4016075.

Stephen E Fick and Robert J Hijmans. Worldclim 2: new 1-km spatial resolution climate surfaces for global land areas. *International journal of climatology*, 37(12):4302–4315, 2017.

Kevin Fleming, Paul Johnston, Dan Zwartz, Yusuke Yokoyama, Kurt Lambeck, and John Chappell. Refining the eustatic sea-level curve since the last glacial maximum using far-and intermediate-field sites. *Earth and Planetary Science Letters*, 163(1-4):327–342, 1998.

Damien A Fordham, Frédérik Saltré, Sean Haythorne, Tom ML Wigley, Bette L Otto-Bliesner, Ka Ching

Chan, and Barry W Brook. Paleoview: a tool for generating continuous climate projections spanning the last 21 000 years at regional and global scales. *Ecography*, 40(11):1348–1358, 2017.

Robert J Hijmans, Susan E Cameron, Juan L Parra, Peter G Jones, and Andy Jarvis. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, 25(15):1965–1978, 2005.

Robert J. Hijmans, Steven Phillips, John Leathwick, and Jane Elith. *dismo: Species Distribution Modeling*, 2017. URL https://CRAN.R-project.org/package=dismo. R package version 1.1-4.

Stan L Lindstedt, Brian J Miller, and Steven W Buskirk. Home range, time, and body size in mammals. *Ecology*, 67(2):413–418, 1986.

Glenn A Milne, Antony J Long, and Sophie E Bassett. Modelling holocene relative sea-level observations from the caribbean and south america. *Quaternary Science Reviews*, 24(10-11):1183–1202, 2005.

DR Schmatz, J Luterbacher, NE Zimmermann, and PB Pearman. Gridded climate data from 5 gcms of the last glacial maximum downscaled to 30 arc s for europe. *Climate of the past Discussions*, 11(3):2585–2613, 2015.

Lochran W Traill, Corey JA Bradshaw, and Barry W Brook. Minimum viable population size: a meta-analysis of 30 years of published estimates. *Biological conservation*, 139(1-2):159–166, 2007.

Pauline Weatherall, Karen M Marks, Martin Jakobsson, Thierry Schmitt, Shin Tani, Jan Erik Arndt, Marzia Rovere, Dale Chayes, Vicki Ferrini, and Rochelle Wigley. A new digital bathymetric model of the world's oceans. *Earth and Space Science*, 2(8):331–345, 2015.