MORPHOLOGICAL CHANGES DURING AN INVASION EVENT: THE CALIFORNIA KINGSNAKE (*LAMPROPELTIS CALIFORNIAE*) IN GRAN CANARIA ISLAND

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Introduction

Invasion events provide unique opportunities to explore how invasive species adapt to new environments. Size is one of the most important and obvious traits of an organism[1], so understanding its changes could provide interesting insights to unravel invasive species evolution and mechanisms of adaptation in their invasive range. The invasive California kingsnake (*Lampropeltis californiae*) in Gran Canaria constitutes an excellent case to explore phenotypical adaptation to new environments. This snake, native to North America[2], was introduced in Gran Canaria in 1998 as a result of pet trade. The species naturalization was confirmed in 2007[3], when control programs started, and since then it has steadily enlarged its range in the island. All snakes collected in the island since 2009 up to date have been morphologically characterized and included in a unique database that compiles all records.

We base our research on a database with all snake captures information to explore body size evolution of the invasive population of *L. californiae* in the island of Gran Canaria over a period of 10 years (2009-2019), as well as differences in SVL (snout–vent length) between sexes, morphs (normal *vs.* albino), patterns (stripped, banded *vs.* aberrant), and invasive populations within the island.

Material and methods

We first trimmed the database including all snakes presence data on Gran Canaria (Fig. 1) to select only adult individuals, *i.e.* larger than 60 cm (SVL)[4]. We log_{10}-transformed SVL to fulfill the assumption of normality. Secondly, we analyzed our data by performing:

- ANOVA tests to compare SVL between sexes, morphs, patterns, and invasive populations (Fig. 1).
- A GLM using sexes, morphs, patterns and invasive populations as explicative factors to determinate which one contributed the most to SVL differences.
- A Mann-Kendall trend test to assess potential temporal trends in snake SVL in Gran Canaria.

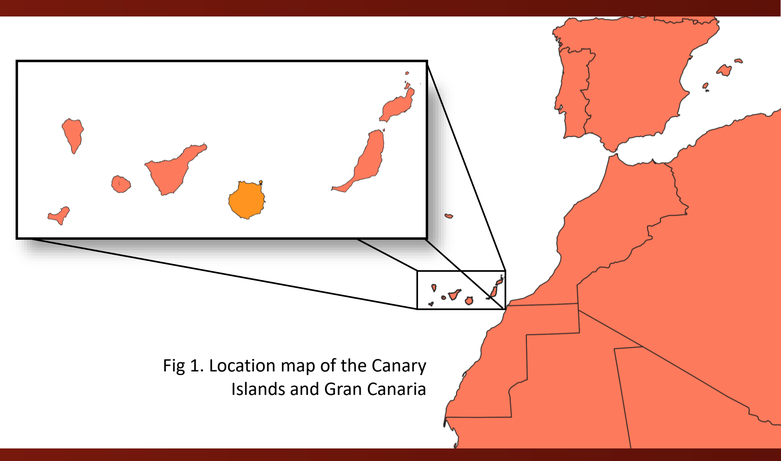


Fig 1. Location map of the Canary Islands and Gran Canaria

Results

Females are significantly larger than males

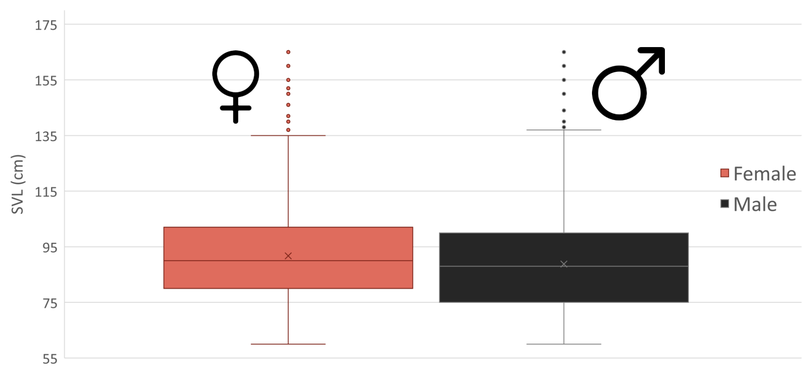
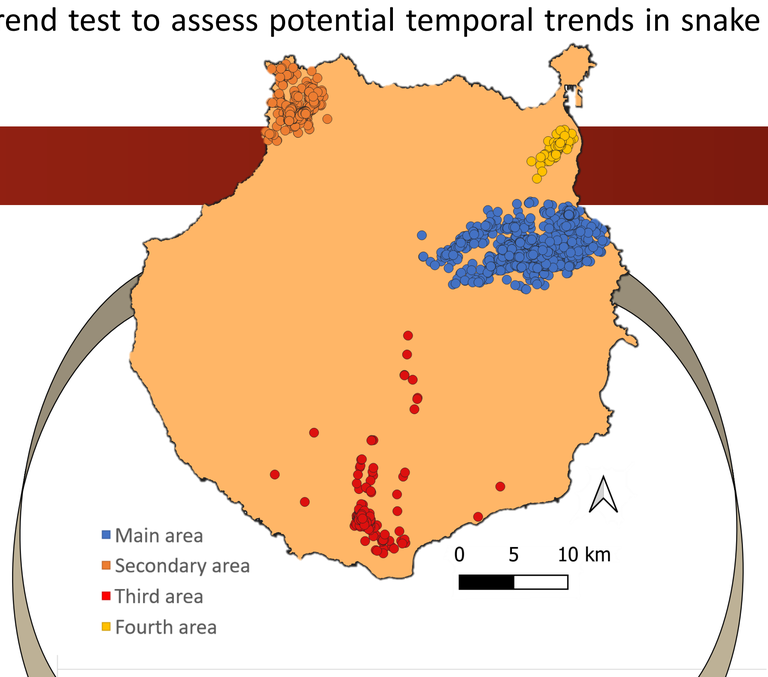


Fig 2. Mean and SD of SVL in females and males ($F_{1,5096}$=37.42; P = 1.02e^{-09}). Graphs are shown with raw values while statistics were done with log_{10}-transformed data.



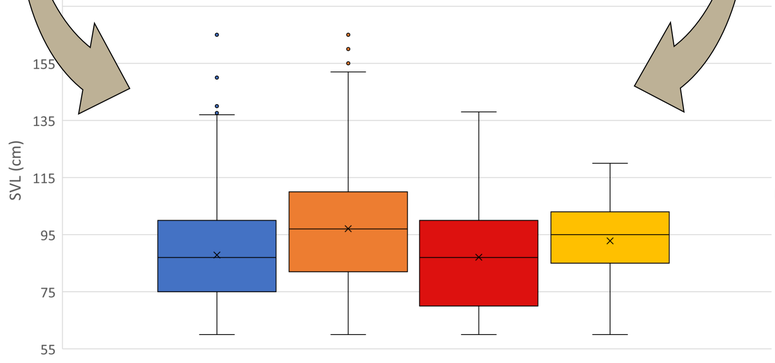


Fig 5. Current invasive populations [up] and mean and SD of SVL in each invasive population ($F_{4,5891}$ = 56.52; P = <2e^{-16}) [down] . Graphs are shown with raw values while statistics were done with log_{10}-transformed data.

Only sex (P = 8.878e-^{13}), population (P = < 2.2e^{-16}) and their interaction (P = 0.0005) contributed to understand differences on SVL

Normal snakes are significantly larger than albinos

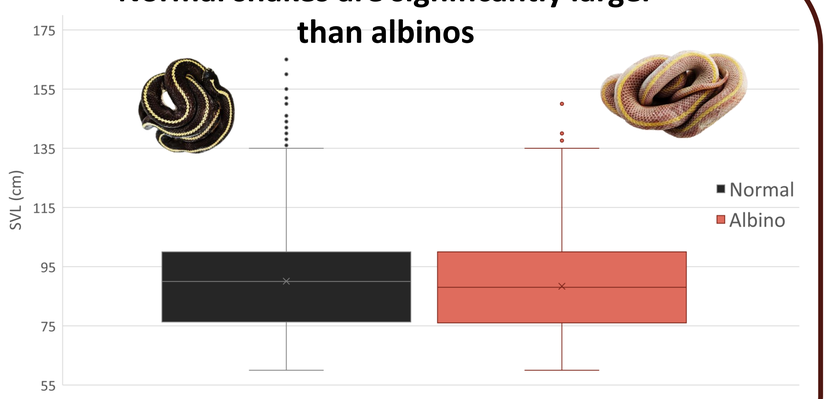


Fig 3. Mean and SD of SVL in normal and albino morphs ($F_{1,6021}$ = 9.627; P = 0.00193). Graphs are shown with raw values while statistics were done with log_{10}-transformed data.

Banded, aberrant and stripped snakes follow a trend from larger to smaller

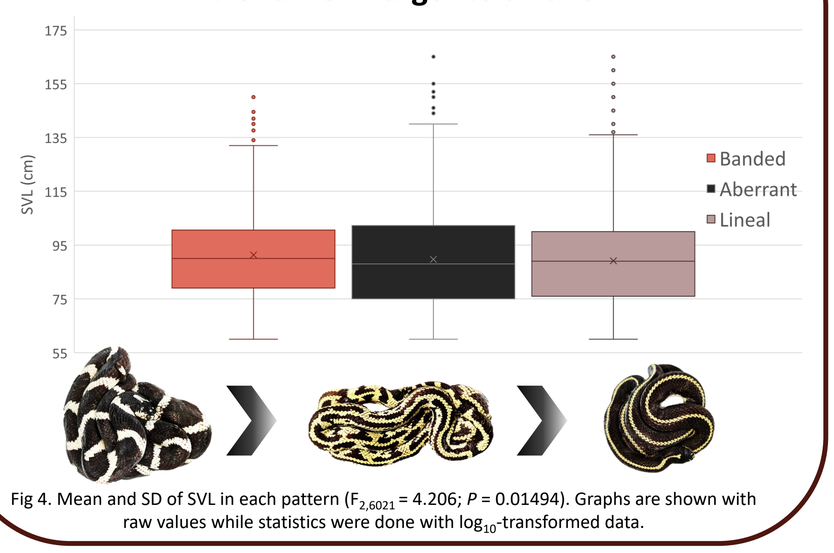


Fig 4. Mean and SD of SVL in each pattern ($F_{2,6021}$ = 4.206; P = 0.01494). Graphs are shown with raw values while statistics were done with log_{10}-transformed data.

Snakes are currently smaller than at the initial stages of the invasion

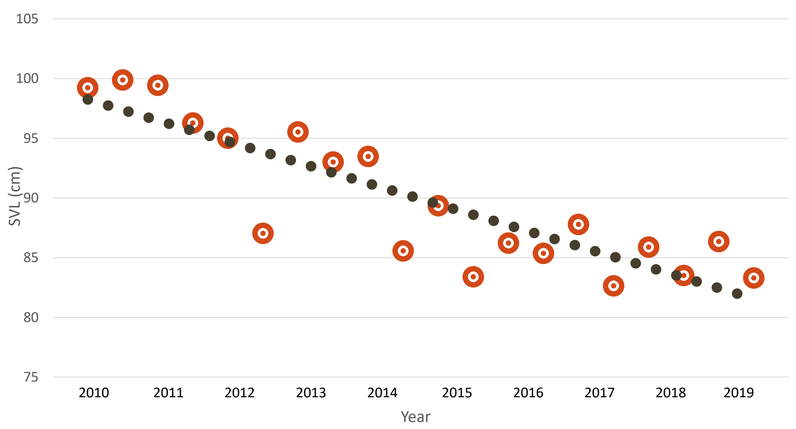


Fig 6. Temporal trend of snake SVL in Gran Canaria (Tau = -0.673, P = 3.78e-^{05}).

Discussion and conclusions

- Our results confirm the existence of sexual, spatial and temporal differences in snakes phenotype.
- We found sexual dimorphism in the invasive population of Gran Canaria, which contradicts the general information available on this species[4]. SVL differences between sexes may be a result of a selection force on larger females with increased fecundity[5].
- Body size differences among invasive populations and morphs might be the result of the two independent and genetically different introductions of the species in the island, as the number of albino individuals is different among areas[6] .
- SVL decreasing trend during this 10-years period could be a result of a phenotypic adaption in response to (1) a higher snake density and (2) the subsequent decrease on the preferred preys[6,7]. Another possible explanation could be that this species tends to reach smaller sizes, as snakes bigger than 1 m reduce their sizes on islands[8]
- **These results provide strong evidence of phenotypic changes in an invasive snake as a result of the adaptation to its new environment.**

References

[1]NAGANUMA KH, ROUGHGARDEN JD. 1990. *Ecological Monographs*. 60:239-256; PYRON RA, BURBRINK FT. 2009. *Molecular Ecology* 18:3443-3457; [3]PETHER J, MATEO JA. 2007. *Boletín de la Asociación Herpetológica Española* 18:20-23; [4]HUBBS B. 2009. Tricolor books; [5]SHINE R. 1994. *Copeia* 326-346; [6]MONZÓN-ARGÜELLO C, et al. 2015. *Conservation Genetics* 16:1225-1241; [7]PIQUET JC, et al. 2018. Unpublished report; [8]BOBACK SM, GUYER C. 2003. *Evolution* 57:345-451.

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