

# Current and Future Distribution of Nymphaeaceae in Sardinia under Global Change

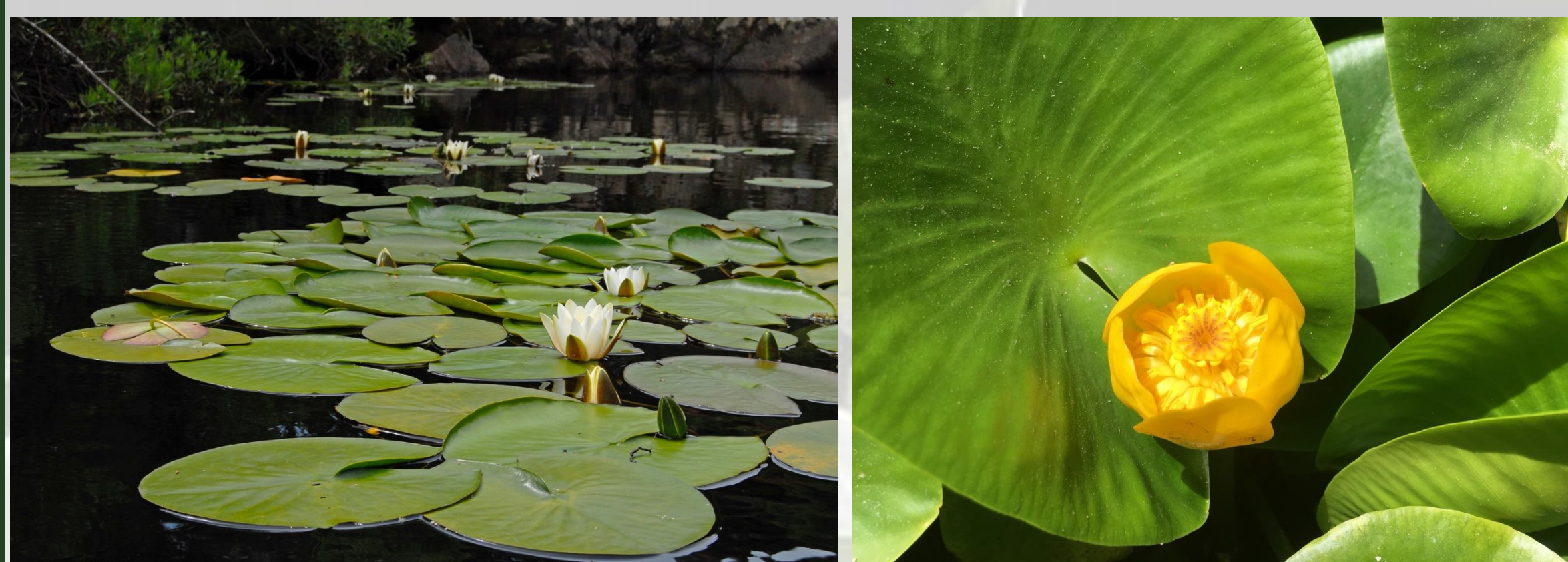
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## Background

The populations of native Nymphaeaceae, namely *Nymphaea alba* and *Nuphar lutea*, growing in Sardinia have been thoroughly studied. After a campaign from monitoring campaign spanning 1991-2025, we recorded and mapped for *N. alba* 165 different sites in Sardinia, distributed in 11 different river basins and 19 watercourses. Most of them are concentrated in the northern half, whilst only a few stations in South Sardinia have been confirmed after more than a century. Regarding *Nuphar lutea*, its 37 growing stations are all concentrated in the Coghinas river basin, in the northern part, while the only known station in the South has recently disappeared.

- **Species records:** 165 collected for *N. alba* and 38 for *N. lutea*. After removing duplicates (same 40 m<sup>2</sup> pixel) and low-accuracy points (< 40 m), the validated dataset included **150 records of *N. alba*** and **38 of *N. lutea***.
- **Predictor groups:**
  - **Bioclimatic variables** – 19 standard predictors from a high-resolution climatic dataset (40 m; Bazzato et al., 2021).
  - **Topographic variables** – Derived from a 10 m DTM (RAS, 2017): elevation, slope, aspect, flow direction, and weighted flow accumulation (functions *terrain* and *flowAccumulation* in *raster* and *terra*; Hijmans, 2023, 2024).
  - **Lithological variables** – From the 1:25,000 regional lithological map (RAS, 2019); eight Level I classes, converted to raster and summarized as percentage per 5 × 5-pixel window (0.5 ha).
- **Data processing:** All predictors were harmonized to **WGS84 (EPSG:4326)** and **resampled to 40 m resolution** to ensure spatial consistency. Species distribution modeling was performed using the **SDMtune** package (Vignali et al., 2020).



## Methodological approach

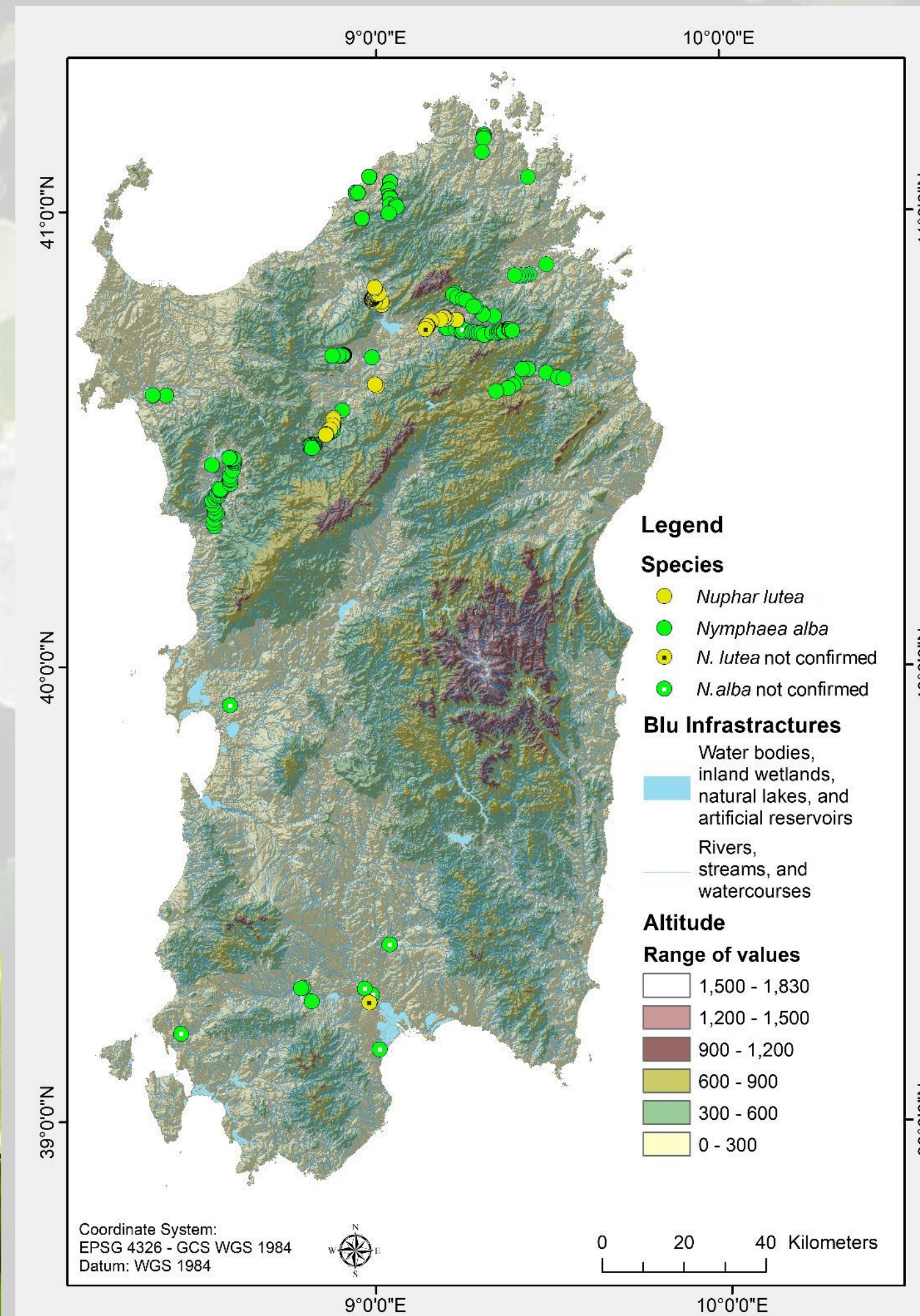


Fig. 1. Study area with the current species distribution

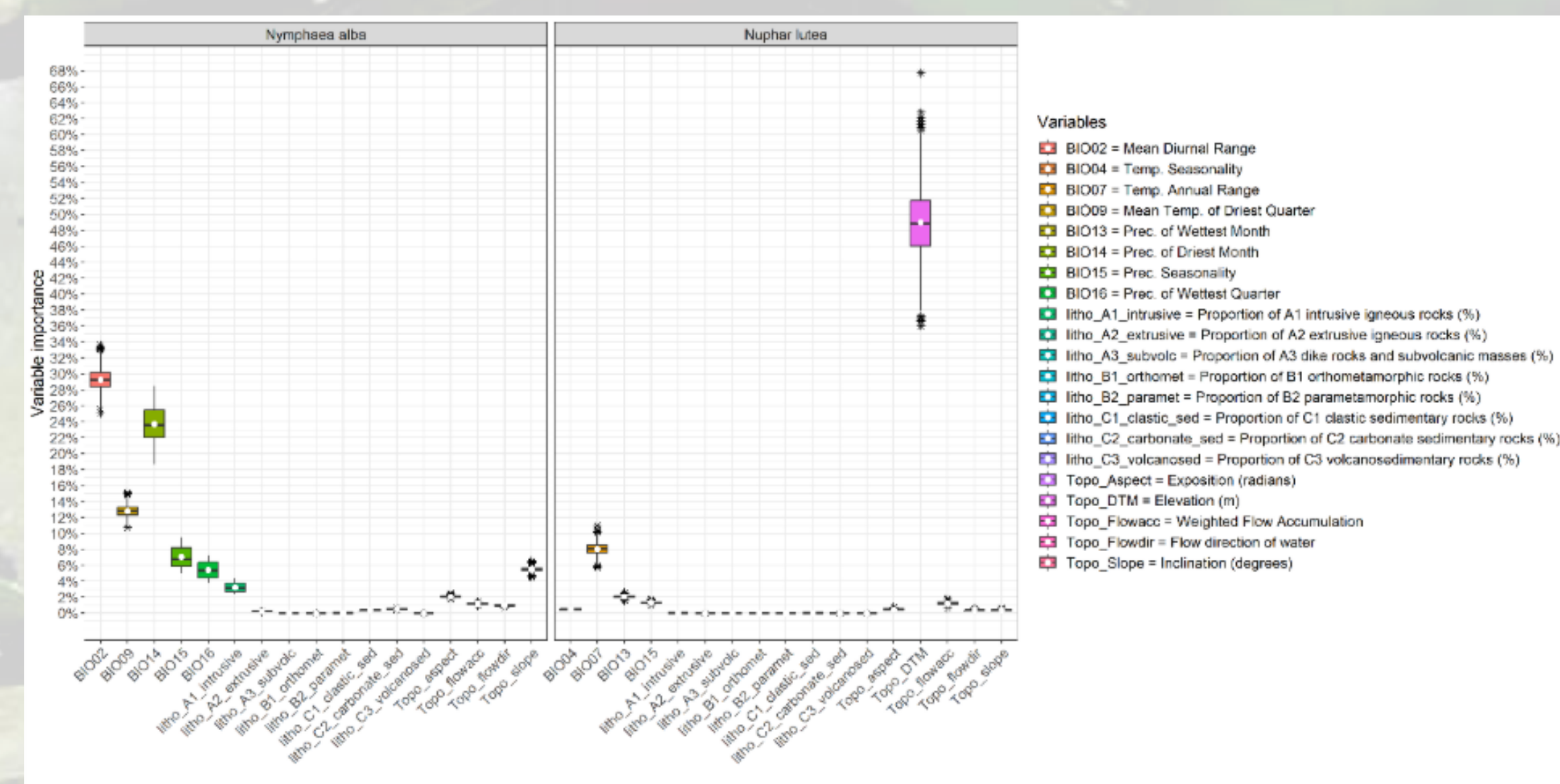
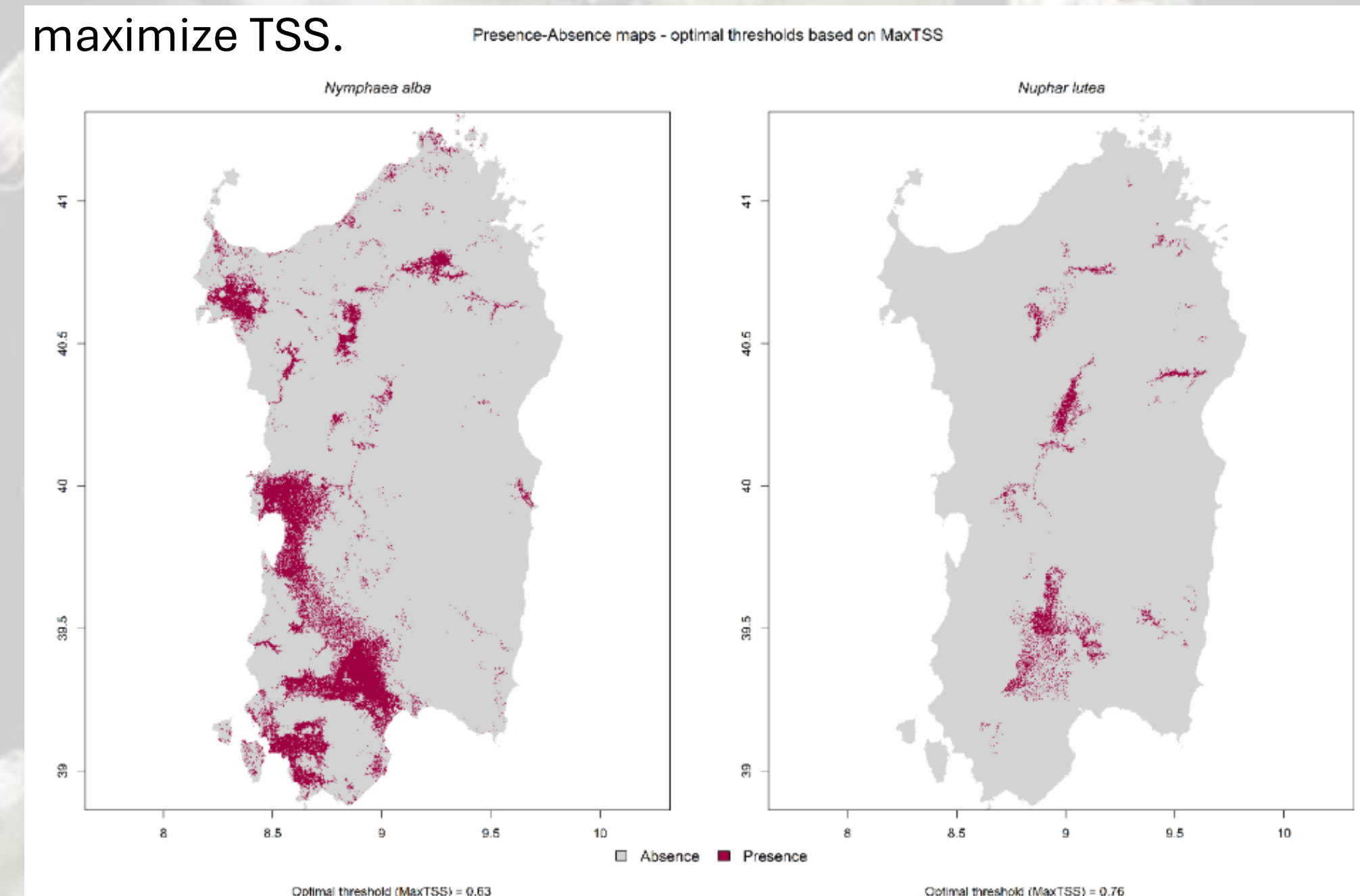


Figure 2. Box plots showing the relative contributions of predictors to the ensemble models for both species, calculated using 999 permutations. Boxes indicate the 25<sup>th</sup>-75<sup>th</sup> percentiles, whiskers span the 10<sup>th</sup>-90<sup>th</sup> percentiles, the horizontal line is the median, the white dot the mean, and stars denote outliers.

Figure 3. Binary maps indicating presence/absence for *N. alba* and *N. lutea* under current conditions. Areas are classified as “presence” where occurrence probabilities exceed 0.63 for *N. alba* and 0.76 for *N. lutea* (corresponding to 63% and 76%), according to thresholds that maximize TSS.



## Results and discussion

The findings of this study on the status of the native Nymphaeaceae in Sardinia provide a significant contribution to the floristic knowledge of rare aquatic macrophytes, emblematic representatives of freshwater wetlands, which are among the most globally threatened ecosystems. *Nymphaea alba* and *Nuphar lutea*, are confirmed to be present in Sardinia, and their predicted potential distribution addresses a critical knowledge gap and provides valuable tools for the effective conservation of Sardinia's native Nymphaeaceae species and their associated habitats.

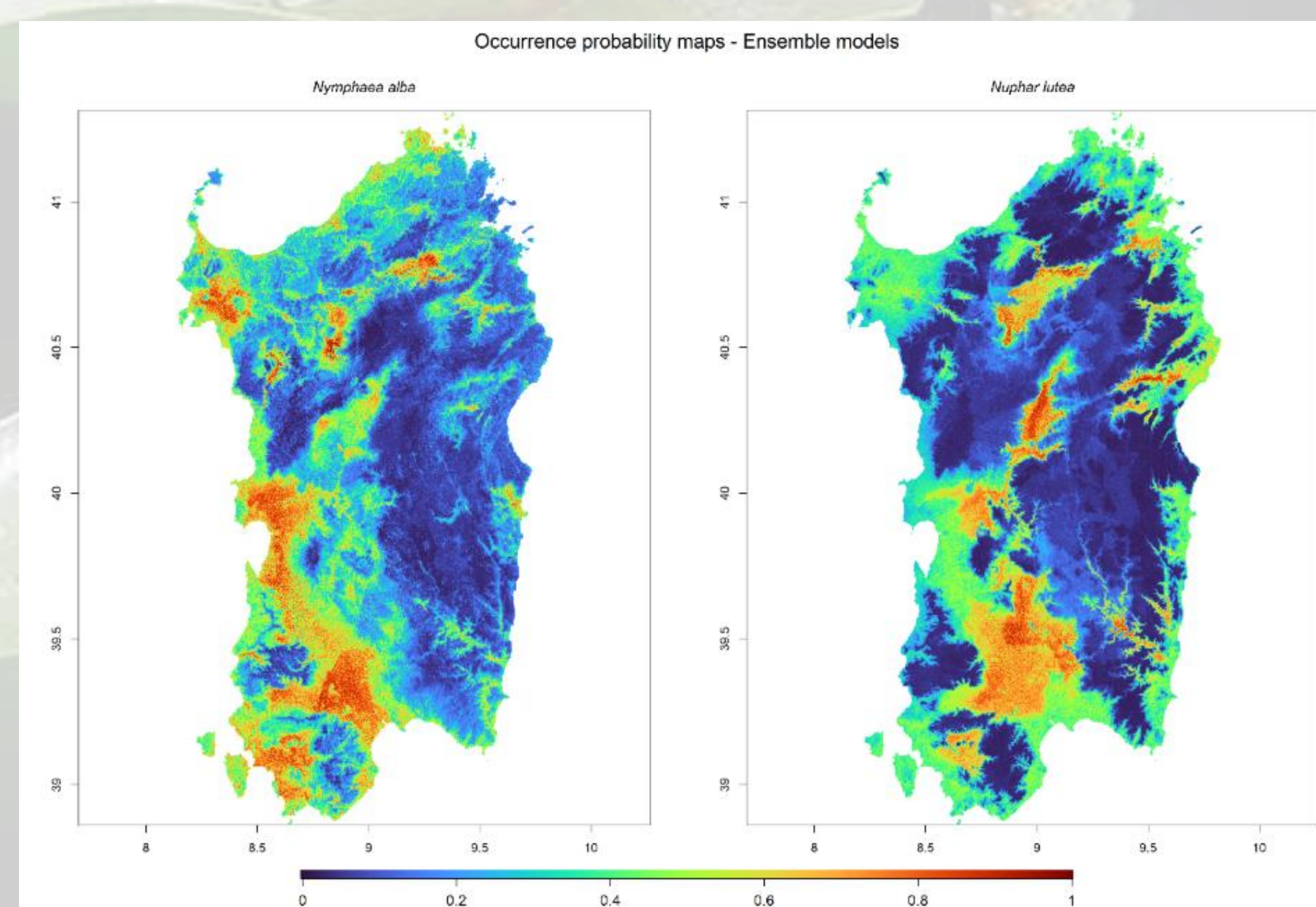


Figure 4. Maps showing areas with high potential suitability for *Nymphaea alba* and *Nuphar lutea* under current conditions. High suitability is defined by occurrence probabilities exceeding 0.63 for *N. alba* and 0.76 for *N. lutea* (i.e., 63% and 76%, respectively), based on thresholds that maximize the True Skill Statistic (TSS).

## REFERENCES:

- Bazzato, E., Rosati, L., Canu, S., Fiori, M., Farris, E., Marignani, M. 2021 *Ecol. Model.* 441: 109354.  
Hijmans, R. J., Bivand, R., Dyba, K., Pebesma, E., Sumner, M. 2023: *Terra [R Package]. R Programming Language.*  
Hijmans, R. J., Barbosa, M., Ghosh, A., Mandel, A. 2024: Package 'geodata'. CRAN.  
Vignali, S., Barras, A.G., Arlettaz, R., Braunisch, V. 2020: *Ecol. Evol.* 10.20: 11488-11506.