

Short Note

New records and a revision of the actual and potential distribution of *Discoglossus montalentii* to facilitate future conservation assessments

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Abstract. The Corsican Painted Frog *Discoglossus montalentii* has received little research attention since its discovery, which creates uncertainty about its distribution and conservation status. We here use a combination of field surveys, ecological niche modelling (ENM) and niche overlap analyses to (i) update the *D. montalentii* distribution; (ii) determine its potential range, and (iii) assess if presence of *Discoglossus sardus* influences that of *D. montalentii*. Our surveys reveal presence of *D. montalentii* at low and mid-altitudes throughout Cap Corse and near the north-western coast, while ENMs suggest that similar climatically and topographically suitable habitats occur beyond the confirmed range in northern- and westernmost Corsica. No evidence for competitive exclusion by *D. sardus* was found, with both species displaying broad niche overlap at macroscale. Whether potential differences between these species do exist at microhabitat level remains worth exploring. We finally review the conservation status of *D. montalentii*, and assemble practical knowledge to inform future conservation assessments.

Keywords: amphibian, Cap Corse, Corsica, *Discoglossus montalentii*, ecological niche model, niche overlap.

The Corsican Painted Frog *Discoglossus montalentii* Lanza, Nascetti, Capula & Bullini, 1984 is a monotypic alytid endemic to the French island of Corsica (Delaugerre and Cheylan, 1992; Salvidio, 2012). Whereas long regarded as part of the morphologically similar Tyrrhenian Painted Frog *Discoglossus sardus* Tschudi in Otth, 1837, *D. montalentii* is a relict that became isolated from other painted frogs in the Miocene (Zangari, Cimmaruta and Nascetti, 2006; Biton et al., 2013). Our current understanding on the distribution and ecology of *D. montalentii* originates from a handful of studies, which show that this species is largely restricted

to forested mountain streams and their vicinities in central Corsica (Clarke and Lanza, 1990; Emanuelli et al., 1998; Fleuriau and Bosc, 2015). A robust, contemporary overview of the status and abundance of *D. montalentii* populations throughout Corsica is however lacking, which hampers conservation assessments. This uncertainty is fuelled by ongoing ambiguity about the distribution of *D. montalentii* (Delaugerre and Cheylan, 1992; Fleuriau and Bosc, 2015).

We here aim to resolve several uncertainties pertaining to the distribution of *D. montalentii*. First, despite the presence of suitable habitat, *D. montalentii* is assumed to be absent from the long, northward pointing peninsula of Cap Corse (Delaugerre and Cheylan, 1992; Vences, Glaw and Hirschberger, 1996; Fleuriau and Bosc, 2015). Two other Corsican endemic amphibians that often occur in syntopy with this species, *Salamandra corsica* Savi, 1838 and *Euproctus montanus* (Savi, 1838), do occur throughout Cap Corse which makes absence of

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D. montalentii surprising and in need of confirmation (Salvidio, 2012). Second, while *D. montalentii* is believed to predominantly occur at higher altitudes at least one population occurs near sea level on the western coast (Vences, Glaw and Hirschberger, 1996). Existence of other populations at lower altitudes could considerably increase the range of *D. montalentii* with implications for its conservation status (IUCN, 2018). Finally, several authors have noted that interactions and the level of competition between *D. montalentii* and *D. sardus* remain unknown, even though local co-occurrence is not uncommon (Delaugerre and Cheylan, 1992; Salvidio, 2012). If, and how presence of *D. sardus* influences that of *D. montalentii* remains unknown.

To tackle these subjects, we use a combination of field surveys, ecological niche modelling (ENM) and niche overlap analyses. We review and update the distribution and conservation status of *D. montalentii*, and assemble practical knowledge to inform future conservation assessments.

Field surveys were performed by G.B. in September 2013 and April and August 2016. Each survey consisted of opportunistic diurnal and nocturnal visual searches along stagnant and slow-running sections of streams, nearby rock ponds and stream banks. The location of encountered *Discoglossus* spp. was recorded with a Garmin eTrex 10 GPS, while each individual was photographed and identified following Clarke and Lanza (1990). Species identification was validated by M. Delaugerre.

We summarized and updated the distribution of *D. montalentii* (fig. 1A) by obtaining additional records from literature and various collaborators (supplementary table S1). A total of 51 records with positional accuracy exceeding 1000 m were selected for ecological niche modelling (supplementary table S1). While building ENMs, these records were partitioned in training and testing bins using the 'block' method in the R (v.3.5.3) package ENMeval (Muscarella et al., 2014) to reduce spatial autocorrelation.

We assembled an environmental dataset that covers climate variation, extremes, and topography under the rationale that amphibian occurrence is modulated by temperature and humidity (Buckley and Jetz, 2007; Cunningham et al., 2016), while local changes in altitude and particularly slope may capture additional variation typical of the *D. montalentii* habitat (Vences, Glaw and Hirschberger, 1996). Specifically, we first obtained WorldClim2 bioclimatic predictors describing temperature variability and temperature and precipitation seasonality (respectively bio02, bio04 and bio15, Fick and Hijmans, 2017). WorldClim2 also includes selected monthly or quarterly minima and maxima (e.g. 'maximum temperature of the warmest month'), but, these have been calculated across a global extent and do not necessarily match with periods in which the concerning extremes occur

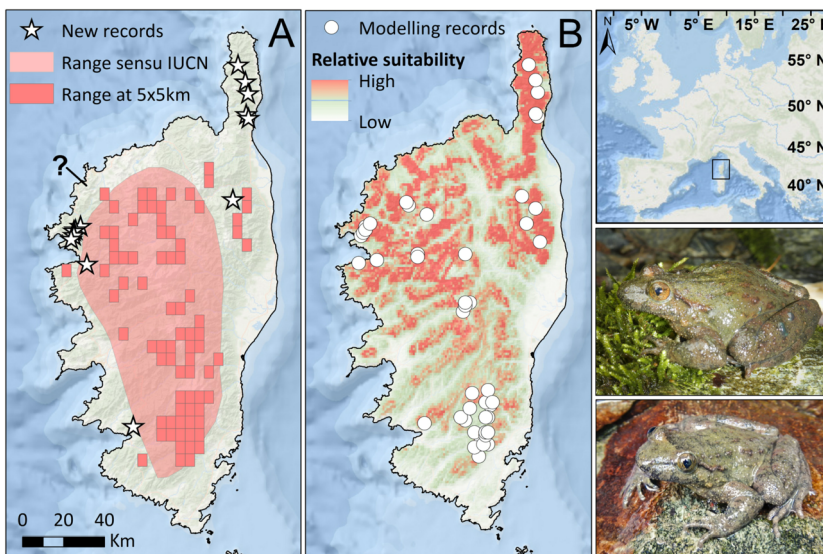


Figure 1. (A) The confirmed distribution of *Discoglossus montalentii* on Corsica displayed as a 5×5 km grid and according to IUCN (2018), along with new and uncertain records discussed in the current study. (B) Relative habitat suitability for *D. montalentii* produced by Maxent; warmer colours indicate higher suitability. Insets on the right show the location of Corsica in Europe and *D. montalentii* encountered at the new sites on Cap Corse.

Table 1. New records for *Discoglossus montalentii* collected during the current study.

Locality	Lat	Long	Height (m)	Area
Porto river. Custarella. Ota	42.2556	8.7218	80	NW coast
Forêt de Tetti. Galéria	42.3794	8.6938	176	NW coast
Spergane. Luri	42.9046	9.3856	179	Cap Corse
Mandriale. Santa Maria di Lota	42.7443	9.4212	232	Cap Corse
Surroundings of Ravin de Mulinara. Osani	42.3373	8.6528	233	NW coast
Forêt des Quatre Communes du Vianu	41.7212	8.9255	257	SW Corsica
Lapedina. Pietracorbara	42.8500	9.4179	266	Cap Corse
Rau de Tuara. Osani	42.3496	8.6649	270	NW coast
Barrigioni. Sisco	42.8116	9.4291	279	Cap Corse
Ruisseau de Macchiu. Galéria	42.3677	8.672	299	NW coast
Ruisseau de Lucciola. Galéria	42.3641	8.665	327	NW coast
Penta-Acquatella	42.4667	9.3628	380	NE Corsica
Canale. San Martino di Lota	42.7318	9.4313	406	Cap Corse

on Corsica. We therefore calculated average maximum temperature of the warmest quarter (comprising June–August in our study area) and solar radiation during the warmest quarter ourselves based on monthly WorldClim2 data. Soil water balance was added through the Priestley–Tallor Alpha Coefficient, which is the ratio of actual evapotranspiration over potential evapotranspiration (Trabucco and Zomer, 2019). To assess influence of the *D. sardus* distribution on that of *D. montalentii* we added presence/absence of the former sensu Fleuriau and Bosc (2015) as a categorical parameter. Altitude (SRTMv.4.0) and a derived slope parameter were added to complete the dataset. All parameters were resampled to a resolution of 30 arc seconds ($\sim 1 \times 1$ km) and cropped to the combined distribution of *D. montalentii* and *D. sardus* (sensu IUCN, 2018) to assess relative suitability for the former on Sardinia as well. Calculating pairwise Pearson correlations (r) between the parameters revealed that altitude and the Priestley–Tallor Alpha Coefficient were highly correlated; the former was hence removed from the final dataset of seven parameters, which show $r < 0.75$.

We built ENMs using Maxent (Phillips, Anderson and Schapire, 2006). To optimally balance model goodness-of-fit with complexity we ran Maxent 3.4.1 in R through the *dismo* 1.1.4 package in ENMeval (Muscarella et al., 2014). Accordingly, we ran a series of candidate models in parallel while manipulating the regularization multiplier values (0.5 to 4.5 with increments of 0.5) and feature combinations (linear (L), linear and quadratic (LQ), and linear, quadratic and product (LQP)), after which an optimal model was selected following Akaike's information criterion corrected for small samples sizes (AICc). Pseudoabsences ($n = 10\,000$) were drawn from the entire environmental background.

Ecological niche overlap between two entities may be measured using ENMs in geographical space, or through ordination in environmental (principal component-bound) space (reviewed by Guisan et al., 2014). Different pros and cons characterise these two approaches; we here use ordination using the R package *ecospat* 3.0 (Di Cola et al., 2017) based on preference to compare environmental values at actual presence sites rather than across a predicted suitability map. Distribution records of *D. sardus* ($n = 102$) summarized by Fleuriau and Bosc (2015) were used to determine

overlap with those of *D. montalentii* (supplementary table S1). Similarity tests were used to assess if the niches of both species were more or less similar than expected in respect to their environmental background (Di Cola et al., 2017).

Thirteen new distribution records for *D. montalentii* were obtained during field surveys (table 1), which reveal widespread occurrence on Cap Corse and presence in north-western and southwestern Corsica (fig. 1A). The new records confirm presence at altitudes as low as 80 m (Porto River near Custarella, Ota; see also Vences, Glaw and Hirschberger, 1996; Fleuriau and Bosc, 2015). We did not find *D. montalentii* at 50 m in the Ruisseau du Maestru (D. Seglie, pers. comm.; fig. 1A, question mark) and 40 m in La Figarella (Kostenzer, 2007), both in the municipality of Calenzana, where its presence was suggested based on tadpoles and juveniles that are difficult to separate from *D. sardus*. Similarly, we did not encounter *D. montalentii* in the north Corsican Désert des Agriates, which was recently included within its distribution by Fleuriau and Bosc (2015). Inquiry with the Direction Régionale de l'Environnement, de l'Aménagement et du Logement (DREAL) revealed that *D. montalentii* records in this area are the result of a database error (C. Eggert, pers. comm.), which we therefore did not include in our distribution map. All new records will be shared with the Société Herpétologique

de France to contribute to the Atlas of Amphibians and Reptiles of France (<https://atlas.lashf.org/>).

The potential distribution of *D. montalentii* was obtained by selecting the Maxent model with the lowest AICc score, which allowed linear, quadratic and product feature combinations and has a regularization multiplier of 0.5 (supplementary fig. S1, supplementary table S2). Relative low actual evapotranspiration in respect to potential evapotranspiration (summarised in the Priestley-Talor Alpha Coefficient) mainly drives relative suitability for *D. montalentii* (supplementary fig. S2, supplementary table S3). In other words, habitat suitability at macro level is highest in more humid areas, which largely coincide with mountains and hills in central and especially northern Corsica (fig. 1B). Permutation importance of all other environmental parameters remains below 10%. Similar climatic and topographic conditions found to be inhabited by *D. montalentii* on Cap Corse and near Galéria also occur along hilly areas near the northern and western coast (fig. 1B). Relative habitat suitability on Sardinia was overall low due to a higher amount of soil water evaporation compared to Corsica (results not shown). No evidence for competitive exclusion by *D. sardus* at macro level was found, of which presence did not influence *D. montalentii* habitat suitability (supplementary fig. S2), while its percent contribution and permutation importance to the model remained below 1% (supplementary table S3). This result was not unexpected, given that *D. sardus* and *D. montalentii* regularly co-occur (Delaugerre and Cheylan, 1992; Fleuriau and Bosc, 2015). Similarly, no significant (dis)similarity was found between the ecological niches of *D. sardus* and *D. montalentii*; the niche of the former largely overlaps with that of the latter (supplementary fig. S3). We nevertheless stress that the above results pertain to macroecological analyses. Whether potential differences between these species do

exist at microhabitat level (e.g. Salvidio, Sindaco and Emanuelli, 1999) remains worth exploring.

In addition to significantly increasing the range of *D. montalentii*, most new records presented here are located under the IUCN-maintained lower altitude limit of 300 m (table 1; Miaud, Cheylan and Sindaco, 2009). This result supports earlier findings which suggested that when suitable, shaded stream habitat is available, *D. montalentii* may occur down to sea level (Vences, Glaw and Hirschberger, 1996). That *D. montalentii* is not exclusively a mountain taxon has however been shown before, notably in a conservation assessment performed two decades ago in light of the European Habitat Directive (Emanuelli et al., 1998). About thirty populations were known at that time, ranging in altitude between 100-1800 m with an extent of occurrence (EOO) estimated to cover approximately 4000 km². Emanuelli et al. (1998) argued that repeated visits to a handful of *D. montalentii* populations (e.g. L'Ospedale, Vizzavona) shaped the idea that this species predominantly occurs in mountains; yet, it should rather be seen as a stream specialist that occurs along a wide altitudinal range (Clarke and Lanza, 1990). These specialized ecological requirements in turn restrict the area occupied by *D. montalentii* within its range, which is fragmented and much smaller compared to the estimated EOO currently set at 5000 km² (Miaud, Cheylan and Sindaco, 2009). Support for significant, ongoing population isolation was recently provided by Bisconti, Canestrelli and Nascetti (2013) who showed that *D. montalentii* comprises at least three distinct evolutionary significant units that diverged during the Pleistocene. Introduction of fish and habitat modification threaten persistence of various populations (Emanuelli et al., 1998; Miaud, Cheylan and Sindaco, 2009).

In conclusion, we argue that our results are a confirmation of the habitat specificity of *D. montalentii*, rather than a simple indication that

the species is much more widespread than previously thought. The current expert-drawn EOO of *D. montalentii* maintained by IUCN measures about 4000 km² (fig. 1A), but is erroneously registered as covering 5000 km² (Miaud, Cheylan and Sindaco, 2009). The range extensions presented here support maintaining the EOO at 5000 km², and correcting the altitudinal range to 80–1900 m. While the occupied area within this EOO is likely much smaller, divided into several fragments and under pressure of several threats, no information on population sizes or trends is available. Additional population- and distribution surveys are therefore needed before the conservation status of *D. montalentii* can be reassessed (as e.g. proposed by Bisconti, Canestrelli and Nascetti, 2013), which may be guided by the ENM results presented here.

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References

- Bisconti, R., Canestrelli, D., Nascetti, G. (2013): Has living on islands been so simple? Insights from the insular endemic frog *Discoglossus montalentii*. *PLoS ONE* **8**: e55735.
- Biton, R., Geffen, E., Vences, M., Cohen, O., Bailon, S., Rabinovich, R., Malka, Y., Oron, T., Boistel, R., Brumfeld, V., Gafny, S. (2013): The rediscovered Hula painted frog is a living fossil. *Nat. Commun.* **4**: 1959.
- Buckley, L.B., Jetz, W. (2007): Environmental and historical constraints on global patterns of amphibian richness. *Proc. R. Soc. B* **274**: 1167–1173.
- Clarke, B.T., Lanza, B. (1990): Notes on the morphology and distribution of the Corsican Painted Frogs: *Discoglossus sardus* Tschudi and *D. montalentii* Lanza, Nascetti, Capula and Bullini. *Bull. Mus. reg. Sci. nat. Torino* **8**: 531–544.
- Cunningham, H.R., Rissler, L.J., Buckley, L.B., Urban, M.C. (2016): Abiotic and biotic constraints across reptile and amphibian ranges. *Ecography* **39**: 1–8.
- Delaunay, M., Cheylan, M. (1992): Atlas de répartition des Batraciens et Reptiles de Corse. Parc Naturel Régional de la Corse, Ajaccio.
- Di Cola, V., Broennimann, O., Petitpierre, B., Breiner, F.T., D’Amen, M., Randin, C., Engler, R., Pottier, J., Pio, D., Dubuis, A., Pellissier, L., Mateo, R.G., Hordijk, W., Salamin, N., Guisan, A. (2017): ecospat: an R package to support spatial analyses and modeling of species niches and distributions. *Ecography* **40**: 774–787.
- Emanueli, L., Recorbet, B., Salvidio, S., Sindaco, R. (1998): Studies on the ecology and conservation of the Corsican endemic *Discoglossus montalentii* in the framework of the 92/43/EEC Habitats Directive. In: 9th Ordinary General Meeting SEH, pp. 99–103. Miaud, C., Guyétant, R., Eds, Chambéry, France.
- Fick, S.E., Hijmans, R.J. (2017): WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *Int. J. Climatology* **37**: 4302–4315.
- Fleuriau, R., Bosc, V. (2015): Suivi des populations de discoglosses sur la zone d’emprise du barrage du Rizzanese en vue de leur conservation – Phase 2. Conservatoire d’espaces naturels de Corse, Ajaccio/Borgo.
- Guisan, A., Petitpierre, B., Broennimann, O., Daehler, C., Kueffer, C. (2014): Unifying niche shift studies: insights from biological invasions. *Trends Ecol. Evol.* **29**: 260–269.
- IUCN (2018): The IUCN Red List of Threatened Species, version 2018-2. <http://www.iucnredlist.org>.
- Kostenzer, J. (2007): Données complémentaires sur la répartition de *Discoglossus montalentii* et *Discoglossus sardus* (Amphibiens, Anoures) en Corse. *Bull. Soc. Herpetol. Fr.* **122**: 19–31.
- Miaud, C., Cheylan, M., Sindaco, R. (2009): *Discoglossus montalentii*. The IUCN Red List of Threatened Species: e.T6714A12798994. <http://dx.doi.org/10.2305/IUCN.UK.2009.RLTS.T6714A12798994.en>. Downloaded on 19 June 2019.
- Muscarella, R., Galante, P.J., Soley-Guardia, M., Boria, R.A., Kass, J.M., Uriarte, M., Anderson, R.P. (2014): ENMeval: an R package for conducting spatially independent evaluations and estimating optimal model complexity for Maxent ecological niche models. *Meth. Ecol. Evol.* **5**: 1198–1205.
- Phillips, S.J., Anderson, R.P., Schapire, R.E. (2006): Maximum entropy modeling of species geographic distributions. *Ecol. Model.* **190**: 231–259.
- Salvidio, S., Sindaco, R., Emanueli, L. (1999): Feeding habits of sympatric *Discoglossus montalentii*, *Discoglossus sardus* and *Euproctopus montanus* during the breeding season. *Herpetol. J.* **9**: 163–167.
- Salvidio, S. (2012): *Discoglossus montalentii* Lanza, Nascetti, Capula & Bullini, 1984. In: Atlas des Amphibiens et des Reptiles de France, pp. 94–95. Lescure, J., de Massary, J.-C., Eds, Biotope, Mèze; Muséum national d’Histoire naturelle, Paris.

- Trabucco, A., Zomer, R.J. (2019): Global Soil Water Balance Geospatial Database. CGIAR Consortium for Spatial Information. Published online, available from the CGIAR-CSI GeoPortal at <https://cgiarcsi.community>.
- Vences, M., Glaw, F., Hirschberger, K. (1996): Auf der Suche nach roten Scheibenzüngler. D. Aquar.-Terr. Z. **49**: 44-47.
- Zangari, F., Cimmaruta, R., Nascetti, G. (2006): Genetic relationships of the western Mediterranean painted frogs based on allozymes and mitochondrial markers: evolutionary and taxonomic inferences (Amphibia, Anura, Discoglossidae). Biol. J. Linn. Soc. **87**: 515-536.

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