Modelling the future niche distribution of venomous snakes under climate change: a case study of the Greater Black Krait (*Bungarus niger*), a recently identified cause of neuro-myotoxic envenoming in Bangladesh

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1. Introduction

Snake bite envenoming, one of the most neglected diseases, causes massive morbidity, mortality and disability among the rural poor in subtropical and tropical countries, and thereby causes and perpetuates poverty. Climatic factors strongly influence the survival and activity of snakes. Thus, climate change will significantly impact on their diversity, distribution and abundance, leading to extinctions, range shifts, and corresponding changes in health risks.

Here, we address this topic with a case study on the Greater Black Krait (*Bungarus niger*), a species that was recently found to cause fatal envenoming in Bangladesh by destroying the nerves and muscles of bite victims (Faiz *et al.*, 2010).

2. Methods

We use a set of six ecological niche models of the BIOMOD package (Thuiller, 2003) and a new approach (GPDF), which assumes that a taxon is normally distributed in its ecospace (Micheels *et al.*, in prep.). According to the GPDF model, the relevant ecospace parameters are described using Gaussian probability density functions.

We calibrate our set of seven niche models using the WorldClim data set (*http://www.worldclim.org/*), representing the terrestrial climatology of 1950–2000 in a high spatial resolution of 10 arc minutes (Hijmans *et al.*, 2005). Based on statistical analysis and ecological aspects, we choose five climate parameters that are relevant to describe the modern distribution of *B. niger*: maximum temperature of the warmest month, precipitation of driest and warmest quarter, mean diurnal temperature range, and annual precipitation.

Future projections of the distribution of *B. niger* are based on climate simulations with the regional climate model COSMO-CLM for the IPCC emission scenarios SRES B1, A1b and A2 for the periods 2046–2065 and 2080–2099 relative to the present-day control experiment (Dobler & Ahrens, 2010; Dobler *et al.*, submitted).

3. Results

Fig. 1 illustrates that the niche models are able to represent the modern distribution of *B. niger*. The "binary" overlap of all models (fig. 1 middle) covers the observation localities well.

In projections of future conditions (fig. 2), the sum of all models shows moderate changes for 2046–2065 under all scenarios compared to the present. For the period 2080–2099, changes in the scenarios relative to the modern conditions are more pronounced. Under the SRES B1 scenario, changes are still moderate, suggesting that *B. niger* is not much affected by climate change. However, under the scenarios SRES A1b and A2, there is a strong influence of climate change limiting the distribution area of *B. niger*.

The results from GPDF (fig. 3) suggest less favourable conditions for *B. niger* in Bangladesh under the SRES A1b and A2 scenarios. In northern India and Nepal, suitable habitats experience a northward shift. In the eastern part of the model domain (north-eastern India, Myanmar), we observe increased probabilities of occurrence. Overall, GPDF represents a north-eastward shift of the potential distribution of *B. niger*. This trend is less prominent under the scenario SRES B1 and more pronounced under the scenarios SRES A1b and A2. The other ecological niche models support the results obtained with the computationally less demanding and robust GPDF approach.

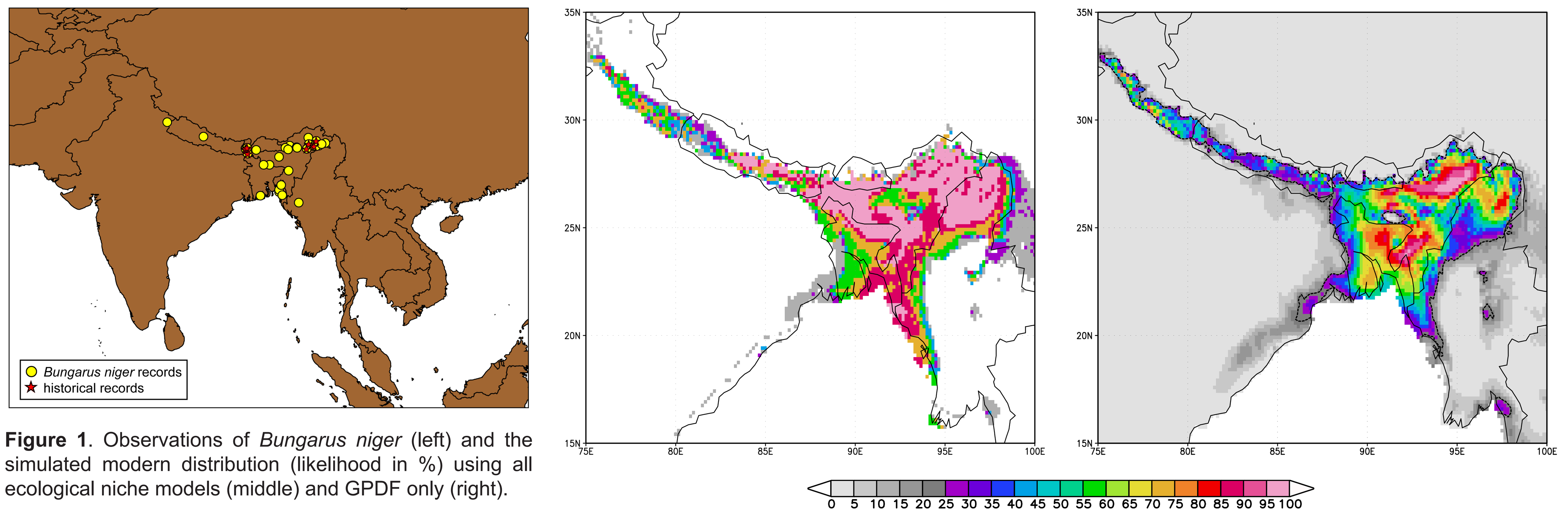

Figure 1. Observations of *Bungarus niger* (left) and the simulated modern distribution (likelihood in %) using all ecological niche models (middle) and GPDF only (right).

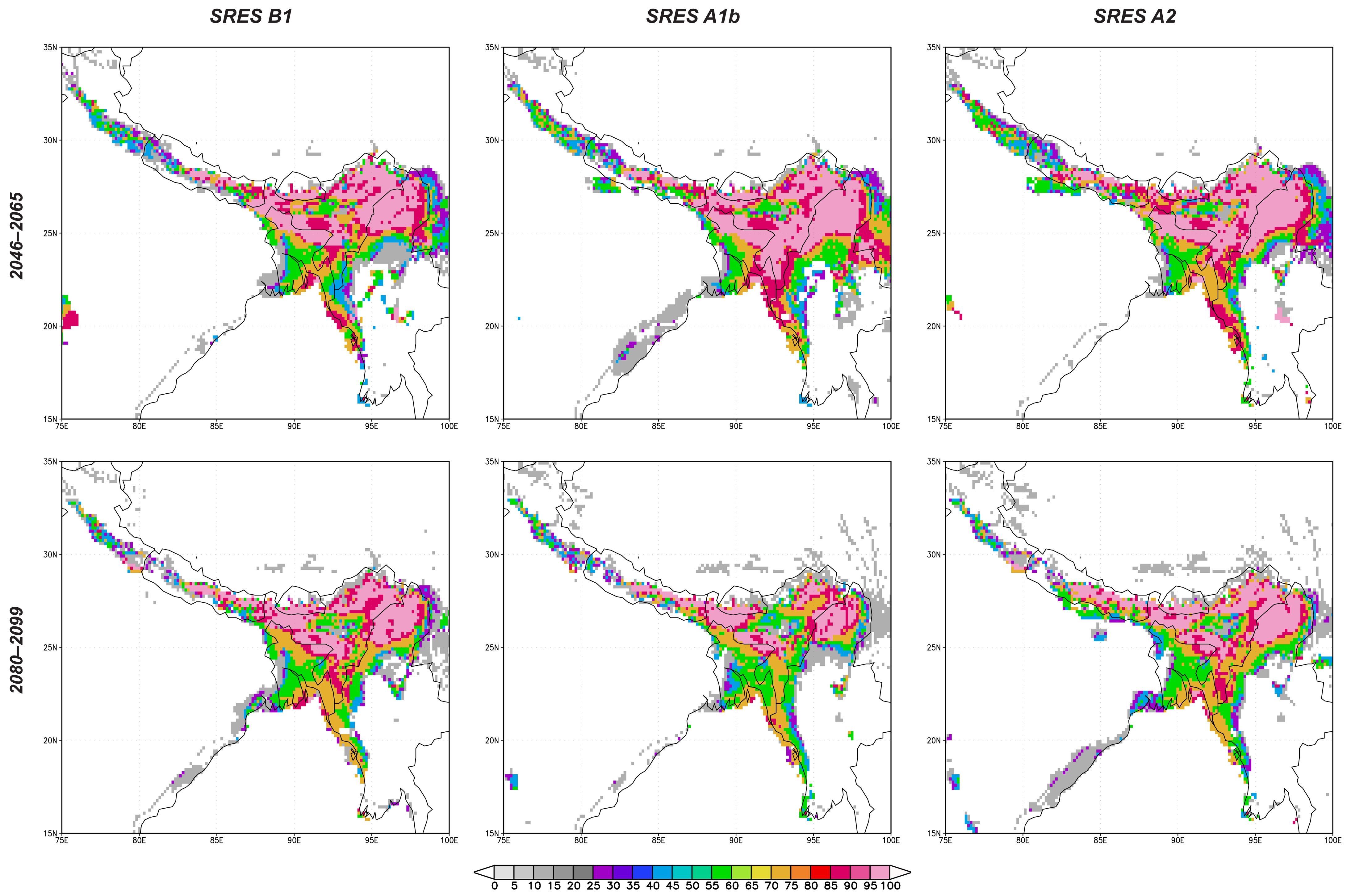

Figure 2. Simulated future distributions (likelihood in %) of *Bungarus niger* for the periods 2046–2055 (top) and 2080–2099 (bottom) for the scenarios SRES B1 (left), A1b (middle), and A2 (right) based on all ecological niche models.

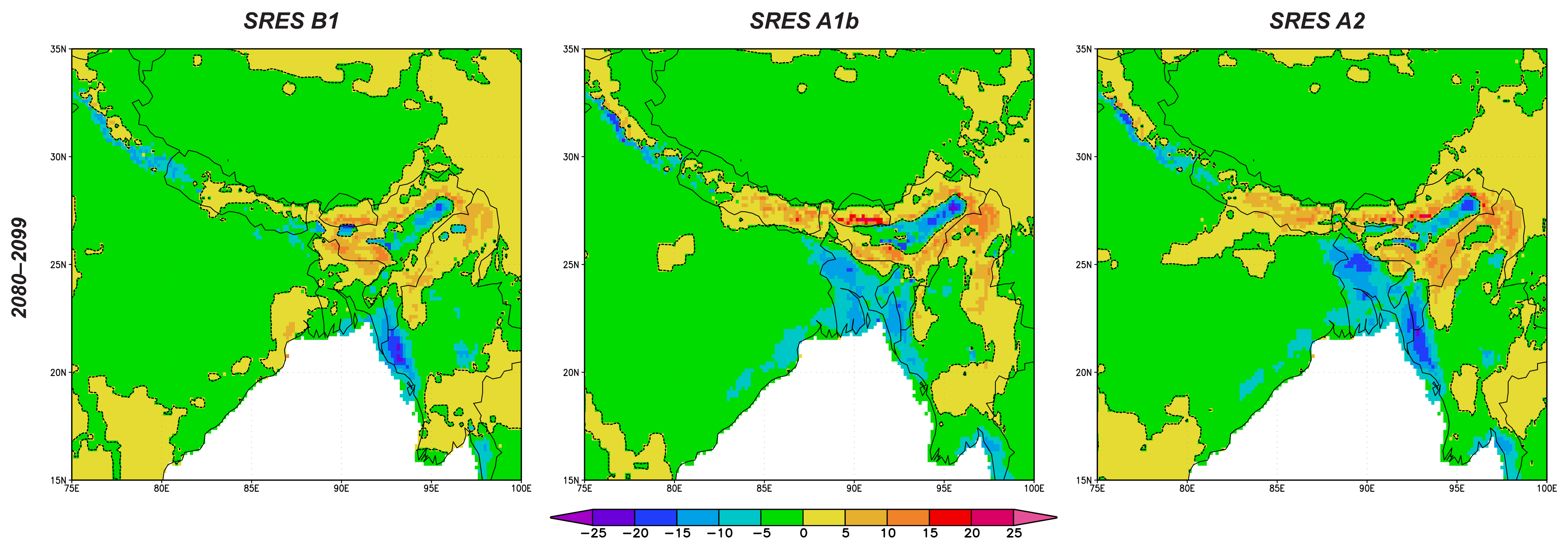

Figure 3. Changes of the simulated future distributions (likelihood in %) of *Bungarus niger* for the period 2080–2099 for the scenarios SRES B1 (left), A1b (middle), and A2 (right) relative to present (cf. fig. 1) based on GPDF.

4. Conclusions

The present potential distribution of *B. niger* covers much of Bangladesh. Thus, the species may occur throughout the country, with lower probabilities in the west. This has important medical implications because envenoming by this species is rarely diagnosed as such, and there is no specific antivenom to treat it.

In the future, *B. niger* appears to be a "loser" of climate change in Bangladesh. Although *B. niger* can survive in its core area based on climate alone, its north-eastward range shift is limited by topographic barriers. Together with competition from species that are better adapted to wet and hot conditions, or changes in human land-use, climate change may have overall negative effects on its distribution area.

More accurate geographical data based on new, verifiable physical specimens in museum collections are required to better understand the present and future distribution of the venomous snakes of Bangladesh. Field collections should go hand in hand with studies on the movement ecology and niche competition of these animals since such biotic data are essential for improving model projections.

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