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Conserving Egypt's reptiles under climate change

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ABSTRACT

Climate change has caused range shifts and extinctions of many species in the recent past. In this study, the effects of climate change on Egyptian reptiles were investigated for the first time using species distribution models. Maxent was used to model the current and future distributions of suitable habitats for 75 terrestrial reptile species from Egypt. The modelled distribution for current suitable conditions for each species was projected into the future at three time slices using two emission scenarios from four global circulation models and under two assumptions of dispersal ability. Climate change is expected to vary in its effects spatially, with some areas characterized by increased species richness while others show declines. Future range changes vary among species and different future projections, from the entire loss to large gains in range. Two species were expected to become extinct in at least one future projection, and eight species were expected to lose >80% of their current distribution. Although Protected Areas have greater conservation value, on average, compared to unprotected areas, they appear inadequate to conserve Egyptian reptiles under expected climate change.

1. Introduction

Over the last century, relatively rapid changes of the Earth's climate have been recorded with warmer temperatures accompanied by altered geographical and seasonal distributions of precipitation (Araújo and Rahbek, 2006; Thuiller, 2007). There is widespread agreement that climate change will have a large impact on the survival of populations, species and communities (Suarez and Tsutsui, 2004), and that biodiversity is continually being transformed in response to it (Hannah et al., 2005). Over the last 40 years climate change has been implicated as the main cause for distributional shifts and extinctions (Thomas et al., 2004), with a particularly strong impact on butterflies, birds and species at high altitude (Hannah, 2011). Although the recorded effects of climate change on biodiversity seem in general to materialize rather slowly, its effects are expected to become increasingly prominent over the next 50 years and beyond (Thuiller, 2007). Some climate change model forecasts suggest that 15–37% of current species will be committed to extinction by 2050 (even without taking into consideration the biological factors of competition and evolutionary history) (Thuiller, 2007), making it essential to involve measures for mitigating its potential impacts in future conservation plans.

Detailed information on the ecological and geographical distributions of species is essential for conservation planning and forecasting (Elith et al., 2006) especially where species face multiple conservation problems. Species Distribution Models (SDMs) quantify the relationship between species' occurrence and environmental variables and allow users to extrapolate this relationship to new areas or time periods. SDMs have been widely used to estimate the potential impacts of climate change on species distributions and ecosystems (Franklin, 2009) and estimate potential future extinction risks. Once a model has been calibrated for current climate conditions, it can be used to estimate potential distributions at different time periods (in the future or the past) by using information on expected climates, or to different study areas in order to assess the potential locations where invasions are more

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likely to establish (Franklin, 2009). This helps to manage species facing possible future threats by identifying biological corridors for dispersal, determining sites for re-introduction and areas require more protection measures (Thuiller, 2007).

Climate change will potentially affect the biodiversity and species composition of Egyptian ecosystems (Tolba and Saab, 2009), but only a handful of quantitative studies of the local fauna/flora have been conducted using SDMs. This may be because the models are relatively new and because until very recently reliable comprehensive biodiversity records for the Egyptian fauna and flora were not available. As a developing country, Egypt lacks a recording scheme to collate species sightings (either at national or even at local Protected Area level). Between 2004 and 2008, all available biodiversity records were collated by the BioMAP project (see: http://www.biomapegypt.org/), and studies of butterflies and mammals using SDMs became possible (Gilbert and Zalat, 2008; Basuony et al., 2010; Newbold, 2009; Newbold et al., 2009a,b). A few other SDM studies have been published: El Alqamy et al. (2010), to estimate the potential distribution of the Nubian Ibex (*Capra nubiana*) in South Sinai; Soultan (2011), to test the potential impact of climate change on the distribution of four Egyptian antelope species; and Leach et al. (2013), who assessed the effect of climate change on the future effectiveness of the Protected Area network, using data on Egyptian butterflies and mammals. The only other study of the effects of climate change in Egypt, by Hoyle and James (2005) on the world's smallest butterfly, the Sinai Baton Blue (*Pseudophilotes sinaicus*), used an occupancy-based Population Viability Analysis.

The global current Protected Areas seem not to overlap well with areas of high biodiversity value, and are traditionally determined spatially and environmentally under the assumption of relatively low changes in species distribution in the future (Araújo, 2009; Leach et al., 2013). As climate change is expected to affect the future distribution/range of many species globally (potentially moving some species out from Protected Areas; Hannah et al. 2007), it challenges the future effectiveness of current Protected Areas. Future conservation investments should be effectively prioritized due to the limited resources available (Wilson et al., 2009; especially in the developing countries), and early actions may be more effective and less costly than delayed or no actions (Hannah et al. 2007). Conservation prioritization can be at taxonomic (for the protection of some rare or endangered species) or spatial (conserving a particular habitat type or species rich areas, e.g. potential Protected Areas) scale. Spatial conservation prioritization uses spatial quantitative data to identify areas of high conservation priority (Wilson et al., 2009), and some techniques have been available recently; e.g. Zonation (Moilanen et al., 2012) and Marxan (Ball et al., 2009). Some of those techniques can use spatial outputs from SDMs to prioritize areas for conservation under current and future climates.

To date, there are 30 Protected Areas in Egypt covering >15% of its total area. Their distribution shows good spatial coverage, although some areas of high diversity importance (especially at the Nile Valley and Delta) are not yet protected (Newbold et al., 2009a). They were declared relatively recently (first in 1983) and were determined mainly based on experts' known knowledge of the country biodiversity (Newbold et al., 2009a). The capacity of current Protected Areas in Egypt to mitigate for potential impacts of climate change on different species groups is not well-investigated yet and a qualitative assessment of their future effectiveness is highly required. Also, spatial prioritization of the Egypt's landscape (inside and outside the Protected Areas) is required to identify potential locations for future Protected Areas and identify current Protected Areas need more conservation effort in the future.

As a developing country, Egypt lacks enough good-quality data to be used directly for spatial conservation prioritization, but SDMs can provide valuable estimates for species suitabilities in the space. In this study, we use data for the Egyptian reptiles, for the first time, to run SDMs (as a representation group for the Egyptian fauna). Baha El Din (2001, 2006) presented a geographic interpretation of Egypt's herpetofaunal distribution, qualitatively identifying priority conservation areas, but very little has been published on how the Egyptian herpetofauna may respond to climate change. We used Maxent to model the distribution of Egyptian reptiles under current climate conditions, then models are projected into the future to show how collectively and individual species are expected to respond to future climate change under different assumptions. For each species, future expected range change (% loss or gain of currently suitable habitats) is estimated, aiming to shed light on some species require more strict conservation actions. Expected reptiles' species richness (under current and future climates) is estimated to identify areas of current high reptile suitability and areas expected to undergo much changes in suitability in the future. Model predictions were used for prioritizing the Egyptian landscape under current and future climates. We used Zonation software (Moilanen et al., 2012) to assess the likely effectiveness of Egypt's Protected Area network under current and future climate. Outputs from Zonation represent hierarchic ranking of the landscape for conservation and can be easily visualized as maps. We hope the results of the current study to be useful for biodiversity conservation in Egypt and (along with the results of relative studies) to be taken into account by the decision makers in future national conservation plans.

2. Methods

2.1. Study area and presence records

According to Baha El Din (2006), Egypt has at least 109 species of reptiles: 61 lizards, 39 snakes, a crocodile, seven turtles and a tortoise, and *Acanthodactylus aegyptius* has been added as a distinct species since (Baha El Din, 2007). The main source of species location records was the BioMAP (www.biomapegypt.org) database of Egyptian biodiversity records; with our own records, the data are comprehensive for the herpetofauna. Records for marine or aquatic species from the Nile were excluded because of the lack of GIS predictor layers for aquatic environments.

The taxonomic and georeferencing accuracy of these records were exhaustively checked, assessed and revised. We limited our scope to species with at least eight unique pixels (at a resolution of 2.5 arc minutes) to avoid over-fitting (Baldwin, 2009): this meant that a total of 75 species were processed (49 lizards, 25 snakes, and a tortoise: Table S1). The coverage of the records is good (Fig. S1a); they include most of Egypt's landscape and habitats. There was an inevitable bias in recording effort (represented by the number of valid records) towards the main cities and populated areas (Fig. S1b): unsurprisingly, the highest collection effort was found around the greater Cairo district, followed by South Sinai (the St Katherine area), the Alexandria area, some areas around Fayoum and Wadi El-Natrun and small patches near El-Arish and Mersa Matruh. (Figs. S2–S3 show a map of Egypt overlaid with geographical locations of areas mentioned in this study and the locations of currently established Protected Areas, respectively).

2.2. Environmental predictor variables

Climate data for the near past (1950–2000) were downloaded from WorldClim Global Climate Data v1.4 (release 3 – see http://www.worldclim.org/bioclim) (Hijmans et al., 2005). These data