

## Correspondence

## ‘Chamaliens’ on the Hawaiian Islands: spatial risk assessment for the invasive Jackson’s chameleon (Chamaeleonidae)

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Alien species are of major concern to conservation biology, agriculture and the human society, as they may become invasive and successfully compete with native species, negatively influence crop production, and cause health problems. Several reptile species are considered invasive alien species, but most of them are little studied (KRAUS 2009). Amongst these species are a few chameleons. Apparently, several of the *Chamaeleo chamaeleo* (LINNAEUS, 1758) populations in the Mediterranean (e.g. Crete, Malta, Sicily) are non-autochthonous and their presence can be linked to historical trade routes (e.g. KLAVER 1981). *Chamaeleo africanus* LAURENTI, 1768 from northern Africa was translocated from the Nile delta onto the Peloponesos where it has maintained reproducing populations perhaps since antiquity (e.g. BÖHME et al. 1998, BÖHME 2000). More recently, the Malagasy *Furcifer pardalis* (CUVIER, 1829) has become invasive on Réunion Island (e.g. BOURGAT 1970).

One of the most successful invasive chameleons is Jackson’s chameleon, *Trioceros jacksonii* (BOULENGER, 1896), which is native to Afrotropical Kenya and Tanzania (Fig. 1). Popular as a pet and commonly traded and imported by the thousands from Kenya and Tanzania (CARPENTER et al. 2004), this species was introduced to Oahu, Hawaiian Islands in 1972 (e.g. MCKEOWN 1991, WARING 1997). Apparently, established populations are referable to the large, up to 35 cm in total length, subspecies *T. j. xantholophus* (EASON, FERGUSON & HEBBARD, 1988) from Kenya and Tanzania (MCKEOWN 1991) (Fig. 2). As a result of inter-island transport which has only been restricted since 1997, Jackson’s chameleon currently has established wild populations on all the main islands including the island of Hawaii, Maui and Kauai as a result of multiple introductions and subsequent spread (Fig. 1; WARING 1997 cited in HAGEY et al. 2010). The species is especially common in wetter habitats at elevations from 100–1,000 m above sea level (MCKEOWN 1996, HOLLAND et al. 2009) and inhabits disturbed habitats as well as forested areas (MCKEOWN 1991, WARING 1997). The ecological impact of Hawaiian *T. jacksonii* has not been studied. Only recently, HOLLAND et

al. (2009) documented predation on endemic snail and insect species, including some threatened with extinction, and HAGEY et al. (2010) commented on its foraging strategy. Further studies on the natural history and distribution of *T. jacksonii* on Hawaiian Islands, coupled with monitoring and management efforts, are required.

GIS-based Species Distribution Models (SDMs) are a helpful tool towards these goals, as they focus on species’ potential distributions. In the case of invasive alien species, they can be understood as spatial risk assessments. Technically, a SDM assesses a species’ ecological niche and projects it into geographical space (RÖDDER et al. 2010a). Niche information is obtained at presence and sometimes absence sites of the study species; climatic niche information has been demonstrated to be a good predictor for invasion success in alien reptile species (e.g. BOMFORD et al. 2009; RÖDDER et al. 2009b). The resulting map shows similarities with the niche elsewhere, e.g. by different grid values, interpreted as ‘likelihood’ of the species’ potential occurrence (e.g. PETERSON & VIEGLAIS 2001, RÖDDER & LÖTTERS 2010). Projecting SDMs onto past or future climate scenarios may allow simulations of a species’ potential response to environmental changes (e.g. RÖDDER & SCHULTE 2010). For example, RÖDDER (2009) provided a spatial risk assessment for the invasive non-autochthonous frog *Eleutherodactylus coqui* on the Hawaiian Islands, suggesting range allocation towards higher elevations under future anthropogenic climate change, thus affecting protected areas.

In this paper, we develop SDMs for Jackson’s chameleon in the Hawaiian Islands under current and future climates based on the species’ climatic envelope at its invaded and native African distribution ranges. The goal is to appreciate the geographical potential of this species in its invaded range.

For SDM building, we used presence data from the native African and the invaded Hawaiian ranges of *Trioceros jacksonii* as available via the Global Biodiversity Information Facility (<http://www.gbif.org>) and HerpNet ([Correspondence](http://</a></p>
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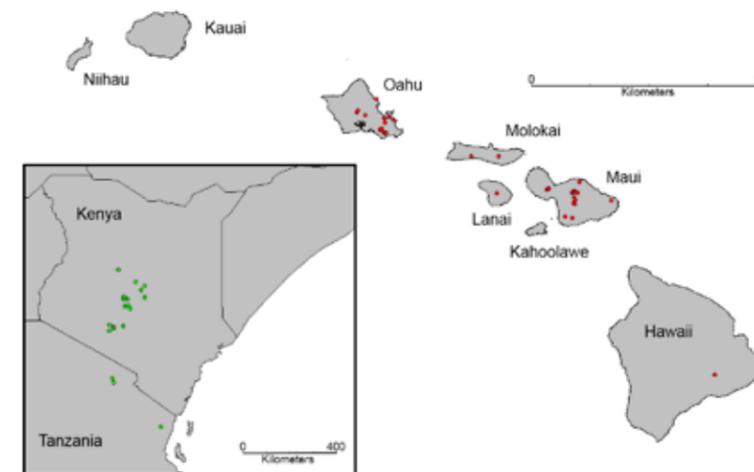


Figure 1. Species records used for model building in *T. jacksonii*’s invaded Hawaiian range and its native range in Kenya and Tanzania (insert).

[www.herpnet.org](http://www.herpnet.org)). When necessary, georeferencing of locality data was conducted with the BioGeoMancer (<http://bg.berkeley.edu/latest/>). DIVA-GIS 7.1.6 (HIJMANS et al. 2002; <http://www.diva-gis.org>) was used to check accuracy



Figure 2. Non-collected male *Trioceros jacksonii xantholophus* from Parklands in Nairobi.

of coordinates. Records were only considered if they could be unambiguously assigned to a single grid cell, leaving a total number of 81 presence records for modelling (Fig. 1).

Information on current climate, i.e., for the period 1950–2000, was obtained from the WorldClim database at a spatial resolution of 30 arc sec (HIJMANS et al. 2005; <http://www.worldclim.org>). For future climate, as expected for the year 2080, we downloaded interpolations of three different global change scenarios of the third and fourth assessments of the IPCC (2007); spatial resolution 30 arc sec (RAMIREZ & JARVIS 2008; <http://gisweb.ciat.cgiar.org/GCMPPage>). These anthropogenic climate change predictions, simulating conditions as expected in the two IPCC story lines A2a and B2a, were derived from simulations of three climate models CCCma-CGCM2 (FLATO et al. 2000, FLATO & BOER 2001), CSIRO-MK2 (GORDON & O’FARRELL 1997), and UKMO-HadCM3 (GORDON et al. 2000, POPE et al. 2000). Climate variables comprised monthly minimum and maximum temperatures, and average precipitation per month. Based on these, we computed 19 ‘bioclimatic’ variables with DIVA-GIS; these are commonly used for species distribution modelling (e.g. BUSBY 1991, BEAUMONT et al. 2005). Since multicollinearity of predictor variables may hamper successful SDM projection through space or time (e.g. HEIKKINEN et al. 2006), we extracted all ‘bioclimatic’ values from the species records and performed a pair-wise correlation analysis based on Pearson’s correlation coefficient with XLSTAT 2010 (<http://www.adinsoft.com>). For SDM computation, only variables with  $R^2 < 0.75$  were considered, resulting in a final variable set comprising ‘mean monthly temperature range’, ‘temperature seasonality’, ‘maximum temperature of the warmest month’, ‘minimum temperature of the coldest month’, ‘annual temperature range’, ‘annual precipitation’, ‘precipitation in the wettest month’, ‘precipitation seasonality’, ‘precipitation in the warmest quarter’ and ‘precipitation in the coldest quarter’. It was suggested that these variables describe environmental conditions that are physiologically important to *T. jacksonii* (BENNETT 2004, ANDREWS 2008, LIN 1979, LIN & NELSON 1980).