Biological Conservation 220 (2018) 67–75

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Conservation of the endemic species of the Albertine Rift under future climate change

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ARTICLE INFO

Keywords:
Climate change
Albertine Rift
Africa mountains
Biodiversity
Species distribution modelling, habitat loss

ABSTRACT

The Albertine Rift region of Africa is one of the most biodiverse areas on the planet, with more threatened and endemic vertebrates than elsewhere on the continent. Many of the endemic species are confined to montane forest or alpine areas. We assessed impacts of loss of habitat to agriculture and predicted impacts from niche modelling of climate change to the endemic species of the Albertine Rift. Modelling species distributions for 162 endemic terrestrial vertebrates and plants, we estimated the average percentage of habitat already lost to agriculture at 38% across all species. However, of the remaining suitable habitat the average percentage protected is currently 46%, greatly increased by the recent establishment of Itombwe, Kabobo and Ngandja Reserves in eastern Democratic Republic of Congo from 30%. Species ranges in 2080 were estimated using climate models and predicted to lead to an average loss of an additional 75% of remaining suitable habitat across all species. An estimated 34 endemic species were predicted to lose > 90% of their current remaining suitable habitat. The percentage of the total suitable habitat protected in parks or reserves increases under future climate change to 56% because as ranges contract more of the remaining area occurs within existing protected areas. This indicates that the protected area coverage is reasonably well located for future climate change. Based on these data we estimate that 46% of the endemic species we assessed would qualify for threatened status on the global Red List.

1. Introduction

The Albertine Rift region, an ecoregion bordering the Democratic Republic of Congo, Uganda, Rwanda, Burundi and Tanzania, contains more endemic and globally threatened vertebrates than any other ecoregion on the African continent (Plumptre et al., 2007), and is part of the eastern Afromontane hotspot (Plumptre et al., 2004). Many of these species are found only on the mountains and massifs bordering Lake Albert in the north to Lake Tanganyika in the south. The Albertine Rift ranges in altitude from 600 m to 5100 m a.s.l and contains a wide variety of habitats from lowland rainforest, through medium altitude semi-deciduous rainforest, savanna grasslands and woodlands, Miombo woodland, *Oxytenanthera* bamboo, papyrus wetlands, *Carex* wetlands, montane forest, *Sinarundinaria* bamboo, *Hagenia-Hypericum* woodland, giant heather, giant *Senecio* and *Lobelia*, alpine moorland, up to bare rock at the summits of some mountains. It is this diversity of habitats which has contributed to the diversity and endemism of this region.

The conservation of the Albertine Rift started in 1925 with the establishment of Africa's first national park, the Virunga National Park in eastern Democratic Republic of Congo (Languy and de Merode, 2009). Subsequent protected areas were established in Uganda, Rwanda, Burundi and Tanzania in the 1930s and several of these were upgraded from reserves or hunting concessions to national parks in the 1950s and 1960s in Uganda and Tanzania and later in Rwanda and Burundi (Olupot et al., 2010). Much of the creation of the protected areas was aimed at protecting large mammals such as elephants (*Loxodonta africana*), hippopotamuses (*Hippopotamus amphibius*), mountain gorillas (*Gorilla beringei beringei*) and lions (*Panthera leo*), following observations of declining numbers due to human hunting (Willock, 1965). Recognition of the rich biodiversity of the region became apparent following surveys of Virunga National Park by Belgian scientists in the 1930s and 1940s (Languy and de Merode, 2009), and subsequent surveys of other sites from the 1960s onwards. More recently new forested national parks have been created such as Nyungwe National Park in Rwanda, and Bwindi Impenetrable National Park and Rwenzori Mountains National Park in Uganda, established from existing forest reserves.

The impacts of climate change on species and ecosystems are already evident in many ecosystems (Tingley et al., 2009; Pearce-Higgins et al., 2015). Even if CO_2 emissions were curtailed today, it would take

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https://doi.org/10.1016/j.biocon.2018.02.001
Received 30 June 2017; Received in revised form 12 January 2018; Accepted 1 February 2018

centuries to reverse the impacts of the accumulated greenhouse gases (Solomon et al., 2009). It is estimated that climate change could surpass habitat destruction as a leading cause of extinction in species (Leadley et al., 2010). High latitude and high elevation ecosystems, and those with abrupt land use boundaries, are particularly vulnerable to predicted climate change (Parmesan, 2006; Sala et al., 2000). Temperature decreases by 5.2–6.5 °C with each 1000 m increase in altitude on mountains in the Tropics (Colwell et al., 2008) and consequently species can move upslope to maintain the same climate envelope with global warming (Anderson et al., 2013; Root et al., 2003). However, cases have already been documented where species were pushed up to a point where they could not move higher (Pounds et al., 1999).

Current climate forecasts suggest the Albertine Rift will become warmer and wetter in the future, with greater differences between wet and dry seasons and increasing likelihood of flash floods and landslides in the September–November wet period (Seimon et al., 2011; Seimon and Picton Phillipps, 2010; Picton Phillipps and Seimon, 2010). This information, together with advances in methods to undertake species distribution modelling (Elith et al., 2006, 2011; Phillips et al., 2004; Phillips et al., 2006) over the past 10 years, now makes an assessment of predicted climate change impacts on species in the Albertine Rift possible.

A preliminary trait-based assessment of species likely to be impacted by climate change in the Albertine Rift was made by Carr et al. (2013). They assessed 2358 species for traits that would likely make them susceptible to climate change and found 31 amphibians (28% of those assessed), 199 birds (20%), 31 freshwater fish (6%), 107 mammals (30%), 79 plants (39%) and 70 reptiles (42%) were likely to be most vulnerable to climate change. However, their study did not model species distributions to make predictions of the impacts of climate change from changes in niche suitability. Instead they used the IUCN Red List Extent of Occurrence polygons/range maps for estimating species distributions.

Conservation planning should incorporate the impacts of future climate change if species are to be conserved in the long term (Groves et al., 2012). The narrow range of habitats on mountains in the Albertine Rift is likely to make them vulnerable to climate change and here we use species distribution modelling to predict the probable impacts on endemic mammals, birds, reptiles, amphibians and plants. We assess how well the existing protected area network conserves species in the future and also assess the impact of the recent creation of three new protected areas in eastern Democratic Republic of Congo (DR Congo).

2. Materials and methods

2.1. Species records

We estimated the current and future distributions for 162 endemic species using location data. Species occurrence records for 119 species across 5 taxa: birds (27), mammals (18), plants (49), reptiles (11) and amphibians (14) were obtained from Wildlife Conservation Society biodiversity survey data, the Tanzanian mammal atlas, Global Biodiversity Information Facility (GBIF 2012: http://www.gbif.org), records of amphibian collections made by Mathias Behangana (Makerere University), Michele Menegon (Trento Science Museum) and Eli Greenbaum (University of Texas at el Paso), and small mammal collections by Julian Kerbis Peterhans (Chicago Field Museum). A total of 32,854 presence records were used in the modelling process, birds (8765), large mammals (17,345), small mammals (1448), plants (4473), reptiles (436) and amphibians (387) (see Fig. S1 (a–c) in Ayebare et al., 2018). The sample size used for model parameterization varied between 10 and 1200 localities per species.

For species that had fewer than 10 presence records we used the altitudinal ranges recorded for the species to estimate area of occupancy (AOO) within the extent of occurrence (EOO) or range provided by the IUCN Red List. We randomly selected point locations within this region to develop a species distribution model (see below). The distribution areas for 43 endemic species; birds (13), amphibians (15) and small mammals (15) were estimated using these randomly generated presence records from species' suitable altitude range maps.

2.2. Species distribution modelling

Maximum Entropy Species Distribution Modelling (hereafter 'Maxent', Maxent version 3.3.3e; Phillips et al., 2006), was used to estimate the current and future ranges for endemic and threatened species in the Albertine rift. Maxent uses a machine learning approach, and requires only species' presence data and environmental variables (Phillips et al., 2006). It has been shown to perform better than most other species distribution modelling methods (Phillips et al., 2006; Elith et al., 2006). Maxent makes inferences from incomplete information and estimates species' distributions by generating a probability distribution of maximum entropy (ie: closest to uniform), subject to constraints imposed by the information regarding presence records and the background information across the study area (Phillips et al., 2006; Elith et al., 2011). Maxent default parameters (Auto features, convergence threshold of 0.00001, maximum number of background points = 10,000, regularization multiplier = 1) were used to fit the models. However, about a third of the species that had few presence records (10 to 20) were fitted using hinge features (Elith et al., 2011). Hinge features are functions for piecewise linear splines and fit models closely related to Generalized Additive Models (Elith et al., 2011). Modelled species ranges are provided in Ayebare et al. (2018).

2.2.1. Current suitable habitat predictor variables

Climate layers at a spatial resolution of ~1 km^2 were obtained from the WorldClim database (Hijmans et al., 2005; http://www.worldclim.org). We selected 17 Worldclim variables relating to climate that are likely to influence the distribution of the birds, mammals, plants, reptiles and amphibians in the Albertine Rift. All the predictor variables were clipped to the area of interest and a pairwise Pearson correlation between predictor variables were obtained using ENMTOOLs (Warren et al., 2010; http://purl.oclc.org/enmtools). To minimize the effect of multi-collinearity and overfitting, only seven variables with less than (± 0.75) correlation were retained (See Table S1 in Ayebare et al., 2018).

2.2.2. Future predictor variables

To assess the impact of climate change on the future estimates of suitable habitat for endemic and threatened species in the Albertine rift, three General Circulation Models for the year 2080 under the A2a storyline were used;

i. CCCMA: CGCM2, simulated at the Canadian Centre for Climate Modelling and Analysis.
ii. CSIRO: MK2, simulated at the Commonwealth Scientific and Industrial Research Organization.
iii. HADCM3, simulated at the Hadley Centre for Climate Prediction and Research.

These models were developed under the framework of the Coupled Model Intercomparison Project Phase 3 (CMIP3) for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessement report (AR4).

There are four storylines (A1, A2, B1 and B2) in the Special Report on Emissions Scenarios (SRES) that describe images of the future in relation to a wide range of demographic, economic and technological driving forces and how greenhouse-gas (GHG) emissions are likely to vary (IPCC, Special Report on Emissions Scenarios, 2000). The A2a storyline describes a very heterogeneous world, that is self-reliant, with a high rate of population growth, slow economic development that is