Dramatic change in local climate patterns in the Amboseli basin, Kenya

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Abstract

The Amboseli basin, a semi-arid, open savannah area of southern Kenya, has experienced extensive changes in habitat since the early 1960's. The present report documents patterns of air temperature and rainfall in Amboseli for the 25-year period beginning 1976. Daily temperatures increased dramatically throughout this time period, at a rate almost an order of magnitude greater than that attributed to global warming. Mean daily maximum temperature increased more than did daily minimum (0.275 vs. 0.071 °C per annum). Although increases in mean daily maxima were documented for all months of the year, they were greatest during the hottest months, February and March. Annual rainfall varied more than four-fold ($\bar{x} = 346.5$ mm, SD = 120.0, range 132.0–553.4 mm), yet did not exhibit any directional or other regular pattern of variability among years over this same 25-year period. Empirical as well as theoretical investigation of relations between such changes in climatic conditions and habitat characteristics are needed at local and regional as well as global scales.

Key words: Amboseli, increasing temperature, climate, global warming

Résumé

Le Bassin d'Amboseli, une zone de savane ouverte, semi aride, du sud du Kenya, a subi des changements importants de son habitat depuis le début des années 1960. Le présent rapport documente les schémas de la température de l'air et des chutes de pluies à Amboseli pour la période de vingt-cinq années qui commence en 1976. Les températures diurnes ont augmenté de façon spectaculaire pendant cette période, à un rythme presque plus rapide que celui qui est attribué au réchauffement global. La température quotidienne maximale moyenne a plus augmenté que la température minimale moyenne (0.275 °C *vs* 0.071 °C par an). Bien qu'on ait relevé des augmentations des maxima quotidiens moyens chaque mois de l'année, elles étaient plus importantes pendant les mois les plus chauds, février et mars. Les chutes de pluies ont varié d'un ordre de plus de 1 à 4 ($\bar{x} = 346.5$ mm, DS = 120.0, écart 132.0–553.4 mm).

Introduction

Weather patterns, landscape characteristics and animal distributions are intimately, albeit complexly, related on various spatial scales, from highly local to global (eg. Kullman, 1996; Le Houerou, 1989; Lean & Warrilow, 1989; Shukla *et al.*, 1990). The Amboseli basin area of southern Kenya has experienced extensive habitat changes since the early 1960's. These include dramatic loss of tree and shrub cover, the spread of halophytes, increase in areas of open all-year water, and concomitant changes in population of large mammals and water birds (eg. Western & van Praet, 1973; Struhsaker, 1976; Young & Lindsay, 1988; Altmann, 1998). Here we report for the first time, patterns of temperature and rainfall in Amboseli for the 25-year period beginning in 1976. These data were gathered to evaluate the direct and indirect effects of weather on the Amboseli baboons, *Papio cynocephalus* (Altmann, 1980, 1998; Stelzner & Hausfater, 1986; Stelzner, 1988; Bronikowski & Altmann, 1996) as part of a long-term investigation into the biology of that population.

Methods

Records of temperature and rainfall were obtained on a daily basis at our field camp. From 1971 to 1991, the

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weather station was in Ol Tukai at 37M 0308933E, 9704836N (UTM notation). Beginning in 1991 it was in a nearby open *Acacia tortilis* woodland at 37M 0301789E, 970307N; the close location of these two sites and simultaneous recording at both sites for a month at the transition, assured the comparability of the data. At the beginning of each day we noted the minimum and maximum temperature from the previous 24 h, which had been recorded on a minimum–maximum thermometer, and the total rainfall that had accumulated in a rain gauge during that period. Directional changes across years were evaluated using regression programs in SAS statistical software.

Results and discussion

As expected for this arid tropical environment, the variability across months in average daily maximum (or minimum) temperature was less than the difference between the average minimum and average maximum within any month (Fig. 1a). Most remarkable, however, is the dramatic increase in temperature from 1976 through to 2000 (Fig. 1b). Moreover, the average daily maximum increased by 0.275 °C per annum, almost fourfold the increase of 0.071 °C in the daily minimum ($P < 0.001$ difference in slopes). Although significant increases occurred in all months of the year, the increases were greater in those months with higher average maximum temperatures (Fig. 1c). Although the linear trend does not account for all the variance across years (see Fig. 1b), more complex models are not currently justified given the available information.

Rainfall exhibited the expected patterns of high variability across the months and among years (Fig. 2). June through to late October, usually referred to as the long dry season, was consistently a rainless period. The remaining months were more variable (Fig. 2a). In some years, rain fell in the pattern typically described for the area, in which one rainy season occurs in November and December and a second occurs in March or April through May. Often, however, the long, dry season was preceded by the failure of one or both of the previous rainy seasons. At the other extreme, significant amounts of rain sometimes fell not only during the two usual seasons but also to varying degrees in January and February. The consequences of this variability are apparent by comparing Fig. 2b with Fig. 2c, in which annual rainfall is plotted by hydrological years, November through October

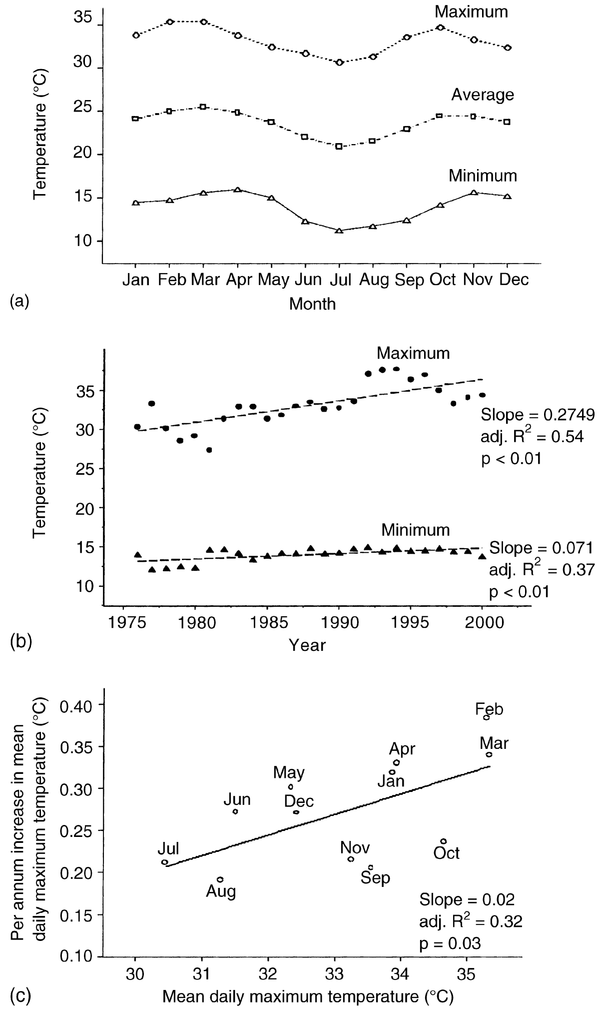

Fig 1 Mean daily temperature in Amboseli. (a) Mean daily maximum, minimum and average temperature by month, 1976–2000. For each day, the minimum and the maximum were averaged to estimate the average for that day. (b) Change in mean daily maximum and minimum temperature, 1976–2000. (c) Per annum increase in average maximum temperature for different calendar months as predicted by the month's average daily maximum temperature; hotter months tended to experience greater increases from 1976 to 2000

(see also the captions to Fig. 2). In contrast to temperature, rainfall did not show a directional change over this 25-year period ($P = 0.33$; Fig. 2b).

The increase in daily maximum temperature in Amboseli was an order of magnitude greater than the 0.2–0.3 °C rise attributable to global warming (IPCC, 1996). To what extent this change in temperature might bear a

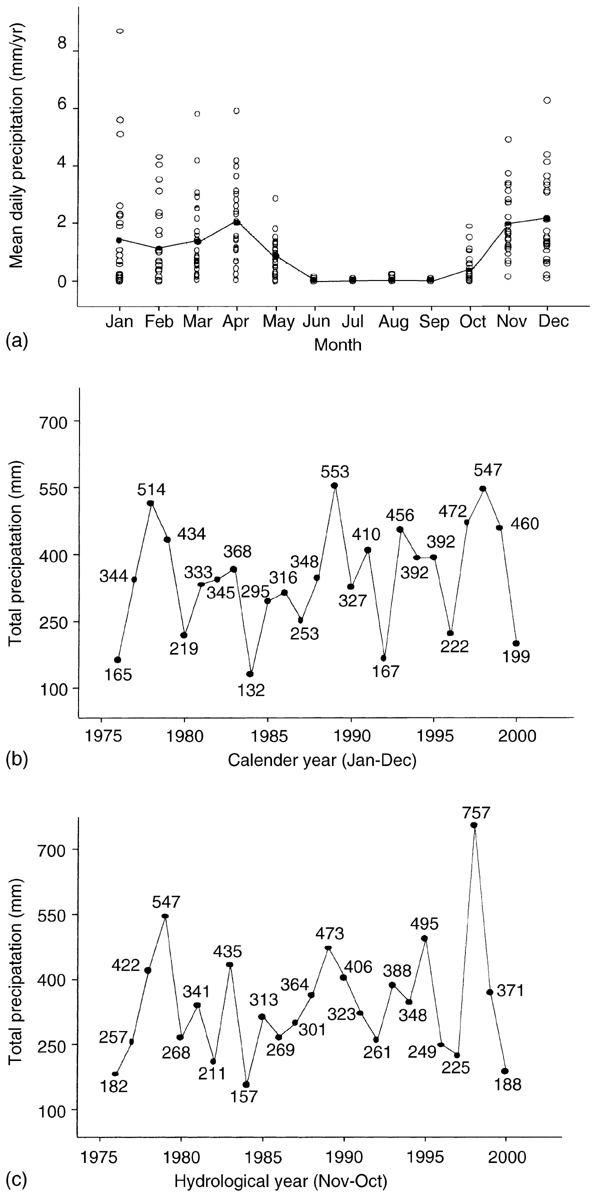

Fig 2 Rainfall in Amboseli, Kenya, 1976–2000. (a) Mean daily precipitation, 1976–2000, by month. Values for individual years are indicated by open circles, the mean across years for each month by closed circles. In some years, the rains began in the last few days of October, accounting for virtually all of the October rainfall that appears here. (b) Total annual precipitation, 1976–2000, by calendar year. (c) Total annual precipitation, 1976–2000, by 'hydrological year' (November through the next October); see text. Not surprisingly, the onset of the rains does not perfectly correspond to a single calendar month. Because October rainfall occurred almost entirely within the last few days of the month and in only some years, using November as the first month of the hydrological year best captured the actual rainfall pattern

causal relationship, in either direction, to concomitant changes in the landscape remains an open question. Amboseli lies a few kilometres from the northern base of Mt. Kiliminjaro; both its weather and its permanent water are highly affected by the conditions on the mountain. Viewed from Amboseli, both the mountain snowcap and the forest cover on the slopes have visibly decreased over the period covered in this report, and the land at the base has increasingly been turned to agricultural use. Recent research also documents dramatic decreases in the size of the glaciers on the mountain (Thompson, 2001). The basin area itself has experienced an extensive loss of the trees and associated shrubs that constituted the *Acacia* (*xanthophloea* and *tortilis*) woodland component of this savanna habitat (Western & van Praet, 1973; Altmann, 1998). Rather than the previous woodland–grassland mosaic, in 2001 the basin vegetation was characterized primarily by open grassland and an increased area of open water and salt pan, with the shrubs now dominated by halophytes. The loss of woodlands in Amboseli has been attributed variously to a rising water table and to the concomitant rise of the salt layer in the soil, to grazing patterns, to a natural ageing of the woodlands, and to damage from an increasing, and increasingly resident, elephant population (e.g. Western & van Praet, 1973; Young & Lindsay, 1988), a debate that cannot be resolved by publicly available data. Each of these has probably contributed to varying degrees over different time periods. In addition, however, the temperature changes reported here may constitute a previously unconsidered causal factor in the landscape changes, and/or the temperature pattern may itself have been caused by the landscape changes. The roles of temperature and rainfall in shaping the landscape have long been recognized; more recently both empirical evidence and mathematical models have highlighted the reciprocal impact of landscape changes on weather patterns (e.g. Lean & Warrilow, 1989; Shukla *et al.*, 1990; Xue & Shukla, 1993; Zhang & Henderson-Sellers, 1996; Pielke *et al.*, 1998, 1999; Wang & Eltahir, 2000). Whether such reciprocal effects are occurring in Amboseli and other similar areas in the region remains an open and important question.

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