Mauritius since the last ice age: paleoecology and climate of an oceanic island
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Citation for published version (APA):
de Boer, E. J. (2014). Mauritius since the last ice age: paleoecology and climate of an oceanic island

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INTRODUCTION AND THESIS OUTLINE
1.1 AN ISLAND OF CONTRASTS

Welcome to Mauritius. To a newly wedded couple this island is a paradise: its tropical climate, magnificent white beaches, turquoise oceans, volcanic landscape, rich culture, and relative stable government allow honeymooners to indulge themselves in unparalleled luxury (more information at tourism-mauritius.mu). To biologists, however, Mauritius is the home of the dodo: a flightless pigeon that became the icon of extinction and representing the destructive impact of human societies on the Earth’s system. Indeed, Mauritius has lost more than 95% of its natural vegetation cover to sugar cane plantations, tea fields, urbanized areas and luxurious tourist resorts. The last 2% of relatively undisturbed forest is under threat of exotic invasive plant and animal species, as well as the construction of new golf courses. In that respect, Mauritius is a predicament of what will happen in the rest of the world if appropriate conservation measures are not taken soon (Florens et al., 2012; Florens 2013).

The different views of tourists and biologists is not the only contrast in Mauritius. In the following sections I will introduce several concepts related to the natural history of Mauritius: (1) the fragility of insular species to human influence vs. the stability/resilience of species to persist on remote islands; and (2) oceanic climate buffering vs. extreme climatic events. These contrasts set the stage for a number of island biogeographical and paleoecological, and paleoclimatological related questions, which are discussed in the different chapters of this thesis.

1.2 MAURITIUS BEFORE AND AFTER AD 1638

Colonized by the Dutch in AD 1638, Mauritius was one of the last places on Earth to be inhabited by humans (Burney and Flannery, 2005). It took the Dutch, the French, and the British less than four centuries to almost completely deforest the island. As a consequence, our knowledge of the natural vegetation distribution relies, until this far, on historical records from early ship logs and small remnants of degraded natural vegetation: the pristine island was fringed by a variety of coastal vegetation communities such as mangroves, coastal marshes, and vegetation types associated with basaltic cliffs and coralline sand dunes (Cheke and Hume, 2008). Palm woodland occurred behind a strip of coastal vegetation on the driest parts of the island. Semi-dry evergreen forest including ebony (Diospyros) forest was the dominant biome in the lowlands and occurred further inland (Vaughan and Wiehe, 1937; Cheke and Hume, 2008). Wet forest occurred on slopes and higher and wetter grounds and covered about 50% of the island. Azonal plant communities included heath formation or thickets on shallow rocky soils, and in the wet areas on poorly drained soils grew marshes with screw pine (Pandanus) (Vaughan and Wiehe, 1937; Cheke and Hume, 2008). Dense, stunted vegetation grew on exposed mountainous ridges with sparse herbaceous and scrubby vegetation occurred on the steeper cliffs.
Currently, the number of introduced plants (1675 species; Kueffer and Mauremootoo, 2004) far outnumbers the number of native species (691 species; Bosser et al., 1976-onwards). From the 691 angiosperms native to the island, 39.5% are endemic and 61.2% are endemic to the Mascarene archipelago including Réunion, Mauritius and Rodrigues. The observed extinction rate for endemic angiosperms reach 10.9% (Baider et al. 2010). Being within a biodiversity hotspot (Myers et al., 2000) Mauritius has high priority for conservation. Its flora has been ranked as the second most threatened worldwide (Walter and Gillet, 1998). However, there is few published data on current species diversity of the main native vegetation types (Florens et al., 2012). In addition, early travellers had difficulty identifying the hundreds of new species and focused instead on those species valuable to them, such as ebony, screw pine, and palms (Cheke and Hume, 2008). More reliable botanical surveys were performed only after large areas (of predominantly the lowlands) were destroyed, preventing reconstructions of the distribution and composition of the main natural vegetation types. Gaps in the current botanical knowledge are underlined by the recent discovery of species new to the Mauritian flora (Florens and Baider, 2006; Le Péchon et al., 2011; Baider et al., 2012, 2013; Baider and Florens, 2013).

The general aim of this thesis is to reconstruct the distribution of main vegetation types and the natural vegetation dynamics since the last glacial maximum (21,000 years ago) from terrestrial sediment cores. Palynological and macrofossil analysis provide information on vegetation composition and vegetation change, whereas local environmental and regional conditions are derived from pollen and diatom assemblages, ostracod-based isotope analysis, and granulometric and geochemical analyses. These vegetation and climate reconstructions provide an understanding of the long-term ecosystem dynamics of the forests and climate of Mauritius.

1.3 THE PARADIGM OF ISLAND STABILITY

Islands are considered stable environments (MacArthur and Wilson, 1967; Heaney, 2007). This classic view is mainly fuelled by species that have gone extinct on continents, but have persisted on islands. Mascarene examples are Monimia (Monimiaceae) and Hyophorbe (Arecaceae), which have closest relatives in respectively East Australia and Chile (Renner et al., 2010), and Central America (Dransfield et al., 2008). Persistence on islands, or in other words lower extinction rates, are hypothesized to be derived from the following factors: a lower amount of species on islands compared to continents results in fewer species interactions and hence lower interspecific competition (Cronq, 1997). Secondly, stability is promoted on remote islands as the chance of invasion of immigrating species from the continent is relatively low (Cronq, 1997). In addition, stable environments are enhanced by the buffering effect of the surrounding oceanic waters (Whittaker and Fernandez-Palacios, 2007).
However, despite an increase in paleoecological studies on remote islands during the last decade (Burney and Pigott-Burney, 2007; Van Leeuwen et al., 2008; De Nascimento et al, 2009; Rull et al., 2010; Connor et al., 2012; Nogué et al., 2013; Proske and Haberle, 2012; Froyd et al., 2013), only few studies so far have sufficient resolution and pollen preservation, without interfering human activity, to identify ecological processes driving/controlling composition changes. High-resolution palynological records from Mauritius offer great potential in this matter due to the historically documented and late colonization date, and could potentially provide essential information on its long-term forest dynamics.

1.4 CLIMATE IN THE SW INDIAN OCEAN

To understand the long-term ecological processes in the Mauritian forests, we need to determine the nature of local environmental dynamics and regional climate change. Local environmental dynamics is reflected in terms of the hydrology of the wetland, and soil properties and topography of the field site; climate change is reflected in terms of glacial/interglacial dynamics, precession-driven monsoon precipitation variability, and decadal- to centennial-scale climate anomalies. As detailed reconstructions of climate change in the western Indian Ocean south of the equator are rare (Gasse and Van Campo, 1998; Burney et al., 2004; Virah-Sawmy et al., 2009), Mauritius can fill a blank spot on the map. Mauritius is presently situated at the extreme southern end coverage of the annual cycle of the intertropical convergence zone (Senapathi et al., 2010) reflecting a pivotal location to record meridional precipitation shifts. In addition, climate reconstructions in the SW Indian Ocean are in itself important as the oceanic island setting allows for an unprecedented integration of terrestrial and marine climate records, as island ecosystems are predominantly affected by external oceanic dynamics with little effect of the hinterland.

1.5 THESIS OUTLINE

Chapters 2 to 5 are based on published papers; chapter 6 is submitted. The synthesis (chapter 7) contains elements of two papers in progress.

Chapter 2 explores the natural history of Mauritius from a volcanic crater in the central uplands (Van der Plas et al., 2012). The 36,500 year long pollen record from Kanaka Crater documents for the first time the vegetation and climate history of Mauritius since the last ice age. The main aim of this chapter is to provide a framework that can be used to better understand how in a small island a high level of diversity is conserved across a transition from glacial to interglacial conditions.

The resolution of the Kanaka Crater pollen record has been increased up to threefold in Chapter 3 to capture the rate of change of forest communities (De Boer et al., 2013a). The pollen record shows steady states and regime shifts giving arguments to address the paradigm of island stability. We hypothesize on the external (climate)
and internal (species interactions) drivers involved causing a complex regime shift at the onset of the Holocene, and we pose the question whether this regime shift could be a functional answer to climate change on remote islands.

In chapter 4 we try to answer the question ‘what is natural?’, by reconstructing the biotic and abiotic environments before and after human colonization from pollen, diatoms, and grain-size distributions (De Boer et al., 2013b). What is the past distribution of the azonal upland communities of ericaceous heathland, Sideroxylon thicket, and Pandanus marsh, and what factors determine this distribution?

Spectra of pollen, diatoms, ostracods, stable isotopes and sediment compositions in combination with hydrological measurements were analyzed in chapter 5 to reconstruct the environmental history of the Mauritian lowlands (De Boer et al., 2014). This multi-proxy approach is used to disentangle the changes of local wetland development during rising sea levels, environmental climate change in the lowlands, and climate mechanisms operating in the SW Indian Ocean. Key is to determine how Mauritian climate was related in the past to the climate of Eastern Africa, the Arabian Sea, Asia, Australia and the Pacific Ocean, and which climate mechanisms were involved. We tried to explain observed millennial-scale monsoon changes and decadal-centennial climate anomalies.

Chapter 6 describes the sequence of events that caused a mass mortality event of vertebrates in the wetlands of Mare aux Songes, 4200 years ago (De Boer et al., subm.). We reconstruct the development of this coastal wetland and we use the climate reconstruction from chapter 5 to understand how this rich fossil bed was formed. Questions we try to answer are: what were environmental conditions that preceded the mass mortality event, and is a drought the ultimate factor behind this catastrophe? Why did this mass mortality event happen in this particular wetland in the southeastern lowlands and what lessons can we learn from the impact of natural catastrophes on insular fauna?

The synthesis, chapter 7, addresses the contrasts discussed in this introduction. The studied sediment cores are divided into upland and lowland archives according to differences in sensitivity and resilience to climatic perturbations and interspecific competition.

REFERENCES


