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Seasonal changes in stable carbon and nitrogen isotope compositions of bat guano (Guadeloupe)

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ABSTRACT

Stable isotope compositions of fossil bat guano have recently been developed as a proxy for reconstructing terrestrial paleoenvironments. However, our understanding of exactly how accurately these isotope compositions reflect seasonal variations remains limited. Here, we present a study of modern guano of phytophagous bats collected monthly over a one-year period at two roosting sites in Guadeloupe. The aim is to assess the degree to which seasonal climate and environmental variations are reflected in carbon and nitrogen isotope compositions from bat guano, as well as to evaluate the potential use of guano from phytophagous bats as a paleoenvironmental record. Our results show that stable isotope compositions vary locally, suggesting that guano of phytophagous bats accurately records local environmental conditions. Additionally, stable isotope compositions reflect seasonal variations influencing bat diet that lead to modifications of up to 2‰ of the carbon isotope compositions from feces. However, these variations are not correlated solely with climate variables as there is no straightforward relationship between climate, vegetation and bat diet over a one-year period. Moreover, these seasonal variations drive one of the bat colonies to occasionally consume insects, which can be traced as a seasonal shift in %N (up to 4.5%) and carbon isotope compositions (up to 5.6‰). Seasonal changes in isotope compositions are still lower than expected variations from fossil feces, confirming the potential use of feces from phytophagous bats as a reliable paleoenvironmental proxy.

1. Introduction

Over the last fifty years, numerous climate proxies have been developed for reconstructing continental paleoclimate and paleoecological conditions based on different data sources, including lacustrine deposits (e.g. Hodell et al., 1991, 2008; Bertran et al., 2004; Stansell et al., 2010; Malaizé et al., 2011), speleothems (e.g. Lachniet et al., 2004, 2009; Fensterer et al., 2013), faunal remains (e.g. Pregill and Olson, 1981; Olson, 1982; Emery and Kennedy Thornton, 2008) or fecal deposits (e.g. Chase et al., 2012). Guano deposits constitute valuable millennial-scale terrestrial paleoenvironmental records, derived from either palynological data (Carrión et al., 2006; Maher, 2006; Geantă et al., 2012) or stable isotope compositions (Des Marais et al., 1980; Wurster et al., 2010b). The abundance of laminated guano in Quaternary deposits potentially provide a high resolution record of continental climate change, notably in subtropical and tropical areas, where these types of deposit are most abundant (Mizutani et al., 1992a,b; McFarlane et al., 2002; Wurster et al., 2008, 2010a).

In addition to reconstructing paleoenvironments, stable isotope compositions of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$) are commonly used to study terrestrial animal ecology (e.g. Fleming et al., 1993; Herrera et al., 1993; Hobson, 1999; Popa-Lisseanu et al., 2015) given that (a) specific dietary regimes produce distinct carbon and nitrogen isotope signatures and that (b) the isotope signature of the food source is incorporated into the consumer's tissues (e.g. Bender, 1971; Smith and Epstein, 1971; De Niro and Epstein, 1981; Kelly, 2000). Stable isotope compositions from mammal feces (Sponheimer et al., 2003; Hwang et al., 2007), such as bat guano, have been shown to reliably reflect diet (Herrera et al., 2001a,b; Painter et al., 2009; Soto-Centeno et al., 2014). For example, Wurster et al. (2007) have demonstrated the guano of insectivorous bats to record local vegetation and climate giving a strong relationship between $\delta^{13}C$ values, the local abundance of dominant plant functional types (plants C3, C4 and CAM) and insects that feed on local vegetation, which therefore reflect local environmental conditions. These plant functional types are associated with different carbon isotope signatures due to distinct photosynthesic fractionation, with $\delta^{13}C$ values of C3 and C4 plants ranging from to −32 to −20‰ and −15 to −9‰, respectively (Bender, 1971; Smith and Epstein, 1971). Moreover, plants exhibiting C3 and C4 photosynthesis respond differently to ambient light conditions, temperature, pCO_2 and humidity (e.g. Smith et al., 1976; Farquhar et al., 1989; Ehleringer et al., 1997). Local vegetation also varies seasonally, especially in tropical areas, where strong seasonal variations (dry and wet periods) are largely

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controlled by rainfall. These seasonal variations should produce important changes in stable isotope ratios from feces of phytophagous bats, a likelihood that up until now has not been thoroughly explored.

In fact, guano of phytophagous bats has received little attention despite the presence of significant deposits in several Neotropical areas, such as the Guadeloupe in the Lesser Antilles, which potentially represent unique sources of Pleistocene and Holocene paleoenvironmental data (Lenoble et al., 2009; Bochaton et al., 2015). The present paper aims to investigate the $\delta^{13}C$ and $\delta^{15}N$ values of phytophagous bat guano collected regularly over a one-year period from two roosting sites in Guadeloupe in order to document seasonal variations and their amplitude, as well as correlate with climatic factors. Finally, we discuss the implications of these results for paleoenvironmental reconstructions.

2. Materials and methods

2.1. Study areas

The study was carried out on the island of Guadeloupe (Lesser Antilles, Caribbean), which has a tropical climate, primarily influenced by the seasonal changes in the Bermuda-Azores High and the Intertropical Convergence Zone (ITCZ) (Portecop, 1982). The island is characterized by a marked seasonality with (1) a dry period extending from December to May, where monthly mean temperatures are close to 25 °C and monthly mean amounts of precipitation range between 50 and 200 mm, and (2) a wet period, extending from July to November, where monthly mean temperatures reach 27–28 °C and then progressively decrease. The island receives the most rainfall during September and October, with an average of more than 200 mm per month (Lassere, 1961). Relative humidity remains high throughout the year and fluctuates a little, a trait typical of sub-equatorial climates. Easterly trade winds, which are less intense during the dry period, regulate climate conditions and attenuate high temperatures. The two halves of Guadeloupe, Basse-Terre and Grande-Terre, are characterized by distinct geographical and topographical contexts (Fig. 1), producing two different climates (Portecop, 1982; Rousteau et al., 1996) (Fig. 2). The relatively flat Grand-Terre is directly exposed to an easterly wind that affects surface water availability and thus favors the expansion of the deciduous dry forests. On the other hand, trade winds blow across the more mountainous Basse-Terre leading to greater rainfall and the development of seasonal evergreen tropical forest or rainforest at higher elevation (Fig. 1).

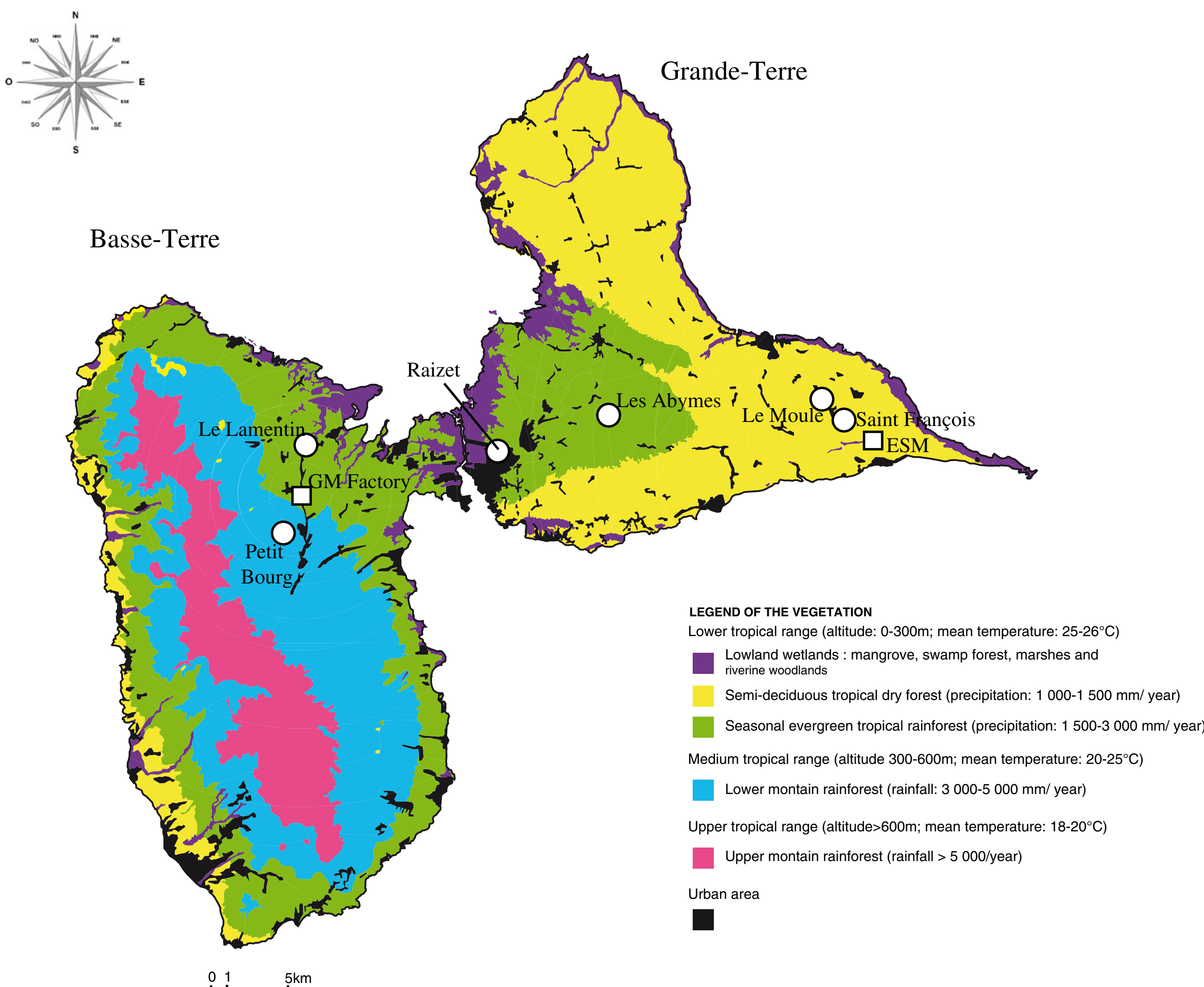

Fig. 1. Location of both sites (squares) Ecurie Sainte-Marthe (ESM) and Grosse Montagne Factory (GM Factory), as well as the location of the *Météo-France* weather stations of Météo-France (circles) on the vegetation map of the Guadeloupe (Lesser Antilles, Caribbean, France).
Modified after Rousteau et al. (1996) and Sastre et al. (2007).