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Original investigation

What bite marks can tell us: Use of on-fruit tooth impressions to study seed consumer identity and consumption patterns within a rodent assemblage

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ABSTRACT

Rodents have a highly specialized dentition, and incisor dimensions are very characteristic within each group. In this study we field-tested a rarely-used methodology – using marks left by rodent incisors in fruits and seeds to identify them. The width of the incisors marks made in Plasticine™ blocks using skulls from museum collections, were compared with the marks left on field-collected fruits and seeds. We confirmed the existence of allometric relationship between incisors width and body size. Furthermore larger and harder fruits showed larger bite marks compared with smaller and soft fruits/seeds, indicating the importance of fruit size and hardness in rodent food-plant selection. Based on tooth width measurements, the results also showed that smaller fruits/seeds are used by fewer rodent species, in comparison to fruits of larger size, these being more likely to be consumed and/or predated. Due to an overlap in body size between species, the method did not provide precise identifications of the rodent species consuming particular items, although it does reduce the likely suite of species responsible. However, when used in conjunction with the more commonly deployed tools, this method is highly viable due to easy use and low cost. Future studies using bite marks images and a greater range of morphological features could increase the precision of this technique.

Introduction

Rodent assemblages are often species rich, ranging from 4 to 6 sympatric species in temperate areas to 15 or more in the tropics (Glanz, 1982). At sites in the tropics it is common for rodents to range in size across an order of magnitude (e.g. *Oligoryzomys microtis*, 14–23 g; Bonvicino et al., 2008; *Cuniculus paca*, 6–14 kg; Eisenberg and Redford, 2000). A specialized dentition allows these animals to feed on hard fruits and seeds, in addition to performing some non-food functions that require bite force, such as building dams, colony defense and breaking compacted soils for digging tunnels (Lessa, 1989b; Becerra et al., 2011). However, the prime use of incisors in food processing means both their shape and size are often highly characteristic for a given rodent species. Consequently, tooth size and shape are frequently considered key in the ecological structuring of species assemblages (Moshe and Dayan., 2001). Incisor dimensions may distinguish sympatric congenerics (Dayan and Simberloff, 1994), and is likely to scale allometrically with the body dimensions (Creighton, 1980; Creighton and Strauss, 1986). In addition, within a sympatric rodent assemblage, there may be consistent variations in incisors morphology between species of the same size class due to phylogeny or dietary specialization (Samuels, 2009). The variation in incisor dimensions within rodent assemblages opens the possibility of identifying species' presence and consumed items from bite marks on food remnants alone.

The identification of rodent species from bite marks is of potential value as a field technique since determining their diets has generally involved analysis of faecal pellets (Pulliam and Brand, 1975; Meserve, 1981), stomach contents (Taylor and Green, 1976; Barnett et al., 2000; Gebresilassie et al., 2004), or material obtained from stomach pumping (Kronfeld and Dayan, 1998). However, all three methods suffer from problems with comminution, so that the material analyzed consists of small particles that are easier to assign to a food type, but often hard to assign taxonomically to a genus or species (Hansson, 1970; Barnett and Dutton, 1995), espe-

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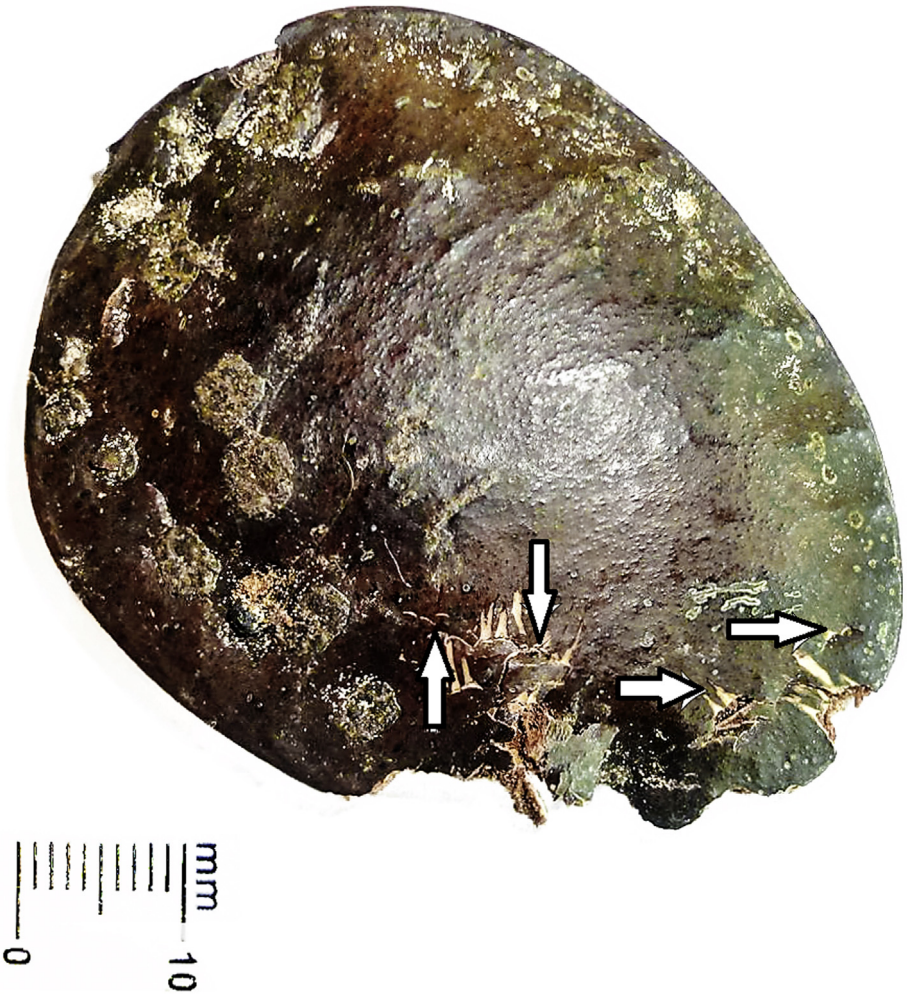

Fig. 1. The fruit of *Macrolobium acaciifolium* showing damage patterns typically caused by rodent bites. The arrows indicate marks left by the incisors that can be used for species identification.

cially when the ingested material is seed or fruit pulp (Barnett et al., 2000). This methodological shortfall is unfortunate since, in many ecosystems, rodents are one of the major seed and fruit predators and dispersers (Forget, 1993; Jansen et al., 2004; Sunyer et al., 2013; see Hulme, 1998 for review).

When rodents gnaw an object, the upper incisor is pressed against the object, leaving a pair of rounded hallmarks (Bang and Dahlstrom, 1974). There are variations in the way different species gnaw seeds/fruit and access their internal content, but the marks left by upper incisors are characteristic and also distinct from those left by the lower ones (Collinson and Hooker, 2000). Such bite marks on seeds and fruits (Fig. 1) leave a record that should allow which rodent species were visiting an area to be determined, and also permit the identification of which plant species the rodents were eating (e.g.Van Roosmalen, 1985; Cornejo and Janovec, 2010). Also, it offers a way to gain additional information on rodent species distribution, abundance, habitat use and natural history. Using bite marks is simple and non-invasive, compared to other identification methods, which may requires cytogenetic and molecular techniques (Aniskin and Volobouev, 1999), in addition to the animal capture and handling. From a botanical perspective, this technique is also advantageous as it should also allow the nature and extent of seed predation by rodents to be quantified with some precision. This technique has already proved efficient for identification of foods eaten by adult pacas (*Agouti paca*), which incisors marks are larger than 4 mm (Beck-King et al., 1999). To extend this application, we set out to test the viability of rodent bite marks as indicators of seed/fruit consumer species identity across an entire rodent assemblage.

Methods

Study site

The study was undertaken in terra firme (non-flooded) and igapó (seasonally flooded) forests (sensu Prance, 1979) in Jaú National Park (JNP), a 2,700,000-ha protected area in central Amazonian, Brazil. Major vegetation types at JNP include terra firme forest (70%) and igapó forest (12%) (Borges et al., 2004). The study site was located between Cachoeira do Jaú (01°53.21″S, 61°40.43″W) and Patuá village (01°53.16″S, 61°44.31″W) (Fig. 2)

Seeds were collected from the floor of unflooded igapó forest as part of a study of terrestrial seed feeding by the golden-backed uacari (*Cacajao ouakary*, Primates: see Barnett et al., 2012). Seeds were collected in 17 500 × 100 m areas centered on sites where terrestrial uacari feeding observations occurred. In each, the area was quartered by walking back and forth across the forest floor until the entire area had been subject to an acute visual search. All found seeds were visually examined for feeding damage and those that bore rodent bite marks (Fig. 3A) were bagged and identified later