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# Morphology and stomach content of the Goldman's diminutive woodrat *Nelsonia goldmani* (Cricetidae: Neotominae)

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Goldman's diminutive woodrat (*Nelsonia goldmani*) is an endemic rodent that inhabits the temperate and humid environments of the central highlands of Mexico. This species is considered uncommon because of the scarce and dispersed information about specimens collected across the Faja Volcanica Transmexicana. Therefore, it is crucial to generate new information about the basic biology of *N. goldmani*, which so much is unknown thus far. We present the morphological description of the stomach and its content from one specimen of *N. goldmani*. We performed a longitudinal bisection and washing of stomach from one adult male collected at the Natural Park "Las Peñas" in the municipality of Jilotepec, Estado de México, Mexico. The macroscopic structures of the stomach were described by observation in a stereoscopic microscope. The stomach content was mounted on sliders and its components were identified and photographed with an optical microscope. According to the gastric glandular epithelium distribution, *N. goldmani* have a bilocular-discoglandular stomach with a characteristic *fornix ventricularis* slightly elongated horizontally. The stomach content was composed by several plant items: epidermal tissues of stem and leaves of angiosperms, pollen of gymnosperms, spores of ferns, fungi and animal tissue like mouth appendages and legs of insects. The stomach morphology was similar to the *N. neotomodon* and the peromyscine *Neotomodon alstoni* described previously, but the flattened and elongated *fornix ventricularis* found in *N. goldmani* was distinctive. Nonetheless, this structure can vary between individuals and mainly depends of the amount of food before dissection. The plant material found in the stomach was similar to that reported in other rodents that inhabit in similar environments to the highlands of central Mexico, such as *Peromyscus aztecus*, *P. difficilis* and *Reithrodontomys fulvescens*.

La rata enana michoacana (*Nelsonia goldmani*) es un roedor endémico que habita en los ambientes templados y húmedos de la zona montañosa del centro de México. Esta especie es considerada como poco común debido a la escasa información disponible para los especímenes colectados en la Faja Volcánica Transmexicana. Por lo tanto, es indispensable generar información nueva de la biología básica de *N. goldmani* mucha de la cual se desconoce hasta el momento. Presentamos la descripción morfológica del estómago y su contenido en un ejemplar de *N. goldmani*. Se realizó un corte longitudinal y un lavado del estómago de un macho adulto colectado en el Parque Natural "Las Peñas" en el Municipio de Jilotepec, Estado de México, México. Se describieron las estructuras macroscópicas del estómago por observación en un microscopio estereoscópico. El contenido estomacal fue montado en laminillas y sus componentes fueron identificados y fotografiados en un microscopio óptico. Según la distribución del epitelio glandular gástrico, *N. goldmani* tienen un estómago bilocular-discoglandular con un característico *fórnix ventricularis* ligeramente alargado horizontalmente. El contenido estomacal estuvo compuesto por varios elementos vegetales: tejido epidérmico de tallos y hojas de angiospermas, polen de gimnospermas, esporas de helechos, hongos y tejido animal de aparatos bucales y patas de insectos. La morfología estomacal fue similar a la de *N. neotomodon* y el peromyscino *Neotomodon alstoni* descritos previamente, pero el *fórnix ventricularis* aplanado y alargado encontrado en *N. goldmani* fue distintivo. Sin embargo, esta estructura puede variar entre individuos y depende principalmente de la cantidad de alimento antes de la bisección. El material vegetal estomacal encontrado fue similar al reportado en otros roedores que habitan en ambientes similares a las zonas altas del centro de México como *Peromyscus aztecus*, *P. difficilis* y *Reithrodontomys fulvescens*.

**Keywords:** Cloud forest; Estado de México; feeding; rare species; rodentia.

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## Introduction

Mexico hosts a wide diversity of rodents with an estimated number of 233 species, which 140 belongs to the family Cricetidae (Ramírez-Pulido *et al.* 2014). Nevertheless, most of these species have scarce information about its basic biology, such as demography, ecological role in their communities, and history life, to mention some examples (Fernández *et al.* 2014). Furthermore, some of these rodents are listed under some category of extinction risk, and for which the lack of information is critical, for instance, for the develop-

ment of plans aimed to their habitat conservation (SEMAR-NAT 2010).

One of these species is the Goldman's diminutive woodrat *Nelsonia goldmani* Merriam 1903, an endemic taxon that inhabits temperate and humid regions of highlands of central Mexico. It is considered an uncommon species due to few specimens collected after being discovered and its fragmented geographical distribution across the biogeographical region known as Faja Volcánica Transmexicana (León-Tapia 2013). As well, this species is under "Special

Protection" by the NOM-059-SEMARNAT-2010 (SEMARNAT 2010) in Mexico and "Endangered" by the by the International Union for Conservation of Nature (IUCN; Álvarez-Castañeda and Castro-Arellano 2008).

Most of the basic aspects of the biology of this species is unknown, mainly related to the few biological material available of this rodent and making difficult to carry out some studies such as particular internal morphology and the diet. Therefore, in this study we describe for first time the macroscopic stomach morphology and its content from one individual of *N. goldmani* in order to provide information related to the digestive system morphology and the food items consumed by the rodent.

## Materials and Methods

One adult male of *N. goldmani* was collected with the authorization FAUT-0002 on October 16 2010 and vouchered in the Colección Nacional de Mamíferos (CNMA 46291), at the Natural Park "Las Peñas", Jilotepec, Estado de México, Mexico (Figure 1; León-Tapia 2013). The vegetation at the collecting locality was mainly oak forest (*Quercus* sp.) with some areas with fir and montane cloud forests (Engstrom et al. 1992; Carleton et al. 2002).



**Figure 1.** Geographic location of the specimen of *Nelsonia goldmani* (CNMA 46291) collected at the Faja Volcánica Transmexicana in México (yellow polygon). The green dot shows the collecting locality of the specimen close to the main towns of the region in purple polygons.

From this specimen we removed the stomach *in situ* cutting the end of the esophagus and duodenum, immediately preserved it in 70 % alcohol, and posteriorly stored it at -72 °C. For the stomach description and the terminology of the structures, the classical methodology stated by Careton (1973) was used. The stomach was placed in a laboratory dish and a ventral bisection was made in a horizontal plane, the stomach content was extracted with 70% alcohol and conserved at 4 °C for posterior analyses. We carried out the observation of stomach in a stereoscopic microscope (Nikon SMZ445) and the illustration of stomach and structures was made.

The stomach content was analyzed according to the procedure used to determinate the diet of *Peromyscus difficilis* (Morales-Medina 2010; Peralta-Juárez 2015). The stomach material was disaggregated on a glass slide, covered with a coverslip and sealed for its preservation. Subsequently, observations were carried out in an optic microscope Zeiss Axiophot 7082 in order to locate the stomach items. During this process, pictures were taken with a digital microscope camera Moticam 2000 and the software Motic Image Plus 2.0. We used different colored filters in addition to black and white filters for color investment in order to highlight the desired stomach items. Finally, the pictures were edited for emphasizing some structural features of such items in order to taxonomically identify them using specialized literature (Linconff 1988; Andrews and Caballero 1989; Phillips 1991; Guzmán 1998; Palacios-Vargas et al. 2014).

## Results

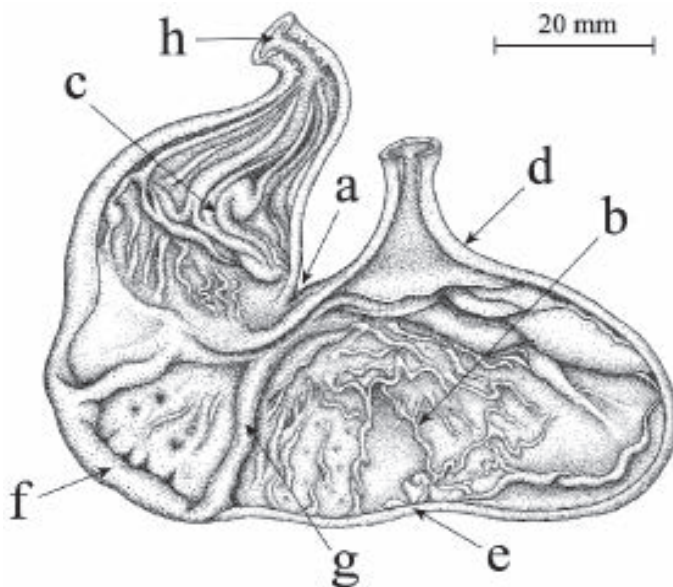
The specimen of *N. goldmani* was taxonomically identified by both external and internal characteristics (Figure 2). According to the color nomenclature (Ridgway 1912), we determined that it was dark dorsally (buffy olive at tips and blackish slate at base), white ventrally, laterally olive lake and the hind feet white with olive lake color at the upper parts. The tail was large with long liver brown hairs dorsally



**Figure 2.** Photographs of the *Nelsonia goldmani* (CNMA 46291). From top to bottom: individual feeding on seeds of oak (*Quercus* sp.), dorsal, ventral and lateral view of the skull.

and cream color ventrally, but not completely bicolored and with a distinctive terminal tuft of hair. The external measurements in mm were: total length 260, tail length 140, hind foot length 25 and ear length 24. The skull was flattened with the presence of the diagnostic anteorbital zygomatic notch and the singular prismatic molar pattern. The cranial measurements according to [González-Cózatl et al. \(2016\)](#) were: greatest length of skull 32.8, length of rostrum 13.11, breadth of zygomatic plate 3.76, mastoid breadth 14, zygomatic breadth 16.67, interorbital constriction 4.63, breadth of rostrum 5.51, width of interparietal bone 10.24, breadth across molars 6.33 and depth of skull 10.39.

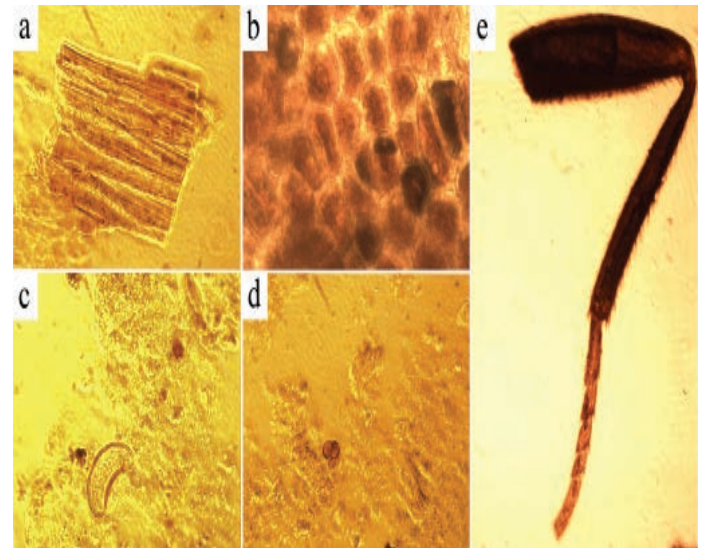
**Stomach description.** According to the gastric glandular epithelium arrangement, *N. goldmani* has a bilocular-discoglandular stomach (Figure 3). The *incisura angularis* is deep and projected beyond the esophageal opening forming the stomach bilocular condition well defined. The *fornix ventricularis* archs are located further from the esophageal opening and slightly curved to the esophagus. The size of *corpus*, mainly in *fornix ventricularis* section, is elongated horizontally. The *antrum* walls are muscular, more visible near the pyloric opening. A bordering fold surrounds the glandular epithelium, and restricted by a small curved area



**Figure 3.** Illustration of the macroscopic bilocular-discoglandular stomach structures of the Nelson and Goldman's woodrat *Nelsonia goldmani* (CNMA 46291). a) *incisura angularis*, b) *corpus*, c) *antrum*, d) *fornix ventricularis*, e) cornified squamous epithelium, f) glandular epithelium, g) bordering fold, and h) anterior end of duodenum.

on the left side of the glandular zone at the bottom of the stomach. The cornified squamous epithelium coats the remaining areas of the *antrum* and *corpus*.

**Stomach content.** Several food items of plant origin were detected in the stomach content, such as epidermal tissue mainly consisting of stems and leaves, pollen of gymnosperms and spores of ferns and fungi. Likewise, animal tissues were observed, such as mouth appendages and legs of insects (Figure 4). The plant tissues were most frequent in the analyzed samples, and the spores were scarce.



**Figure 4.** Pictures from optical microscopy at 40x of food items found in a stomach of the Nelson and Goldman's woodrat *Nelsonia goldmani* (CNMA 46291). a) epidermal tissue from stems, b) epidermal tissue from leaves, c) fern spores, d) gymnosperms pollen, and e) leg of an insect.

## Discussion

The stomach morphology of *N. goldmani* was similar to its sister species *N. neotomodon*, described previously by [Careton \(1973\)](#), with the exception of the *fornix ventricularis*, which is further flattened and elongated. Nonetheless, it has been shown that this structure can vary between individuals and mainly depends of the amount of food before dissection. [Hooper \(1954\)](#) pointed out that some stomach structures like the pronounced *incisura angularis* in rodents as *N. goldmani*, with a bilocular stomach, could increase the area for intensive mixing and reworking of the food bolus. However, this information is limited to make inferences about feeding.

Regarding to the stomach content, it was possible to identify that this individual ingested mainly plant items. Similarly, the insect items could indicate that were occasionally ingested by the specimen. These results were similar to the observations reported for *N. neotomodon* from one specimen from San Luis, where the mainly food items were a green mass with the appearance of fir (*Pseudotsuga menziesii*) or junipers (*Juniperus* sp.) needles ([Hooper 1954](#)).

Prior to the capture of the specimen of *N. goldmani*, we observed the individual feeding on lichens on the bark of trees and photographed it eating seeds of *Quercus* sp. (Figure 2). These observations could indicate that this species likely eats a wide plant resource available in the locality. However, it is indispensable to carry out specific studies throughout the years in order to have an approximation about its diet.

The diet for the two species of the genus *Nelsonia* is unknown mainly due to the difficulties to capture these rodents. Even so, the findings in this study contribute to the knowledge of the basic biology of *N. goldmani* and the results are comparable to those reported for other rodent species that inhabit environments apparently similar in the

highlands of central Mexico, such as *Peromyscus aztecus*, *P. difficilis* and *Reithrodontomys fulvescens*. These rodents feed preferentially upon plant material of different composition according to the conservation condition of their habitat (Vázquez et al. 2004; Peralta-Juárez 2015).

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