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Source: Mammalian Species, 55(1025) : 1-8

Published By: American Society of Mammalogists

URL: <https://doi.org/10.1093/mspecies/seac013>

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Nelsonia goldmani (Rodentia: Cricetidae)

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Abstract: *Nelsonia goldmani* Merriam, 1903 is a cricetid rodent commonly called Goldman's diminutive woodrat. It is a woodrat of medium size with grayish dorsal pelage; the characteristic long tail is covered with long hairs and ends with a black tip. *Nelsonia goldmani* is one of two species in the genus *Nelsonia*. It is endemic to the central-west highlands of Mexico, recorded in a few localities of the Trans-Mexican Volcanic Belt at elevations from 2,000 to 3,100 m. It inhabits areas near rocky ravines, cliffs, and hillsides with coniferous, pine–oak, and cloud forests. *Nelsonia goldmani* is listed as “Endangered” (EN) by the International Union for Conservation of Nature and Natural Resources due to its fragmented distribution and the decrease in the quality and extent of its habitat.

Key words: Galushamyina, Goldman's diminutive woodrat, highlands, Neotominae, Neotomini, rata enana michoacana, Trans-Mexican Volcanic Belt

Resumen: *Nelsonia goldmani* Merriam, 1903 es un roedor cricétido nombrado comúnmente rata enana de Goldman. Es una rata de tamaño mediano con el pelaje dorsal grisáceo; su larga cola característica está cubierta con pelos largos que terminan en una punta negra. *Nelsonia goldmani* es una de las dos especies del género *Nelsonia*. Es endémico de las montañas del centro-oeste de México, registrado en pocas localidades de la Faja Volcánica Transmexicana a elevaciones de 2,000 a 3,100 m. Habita en áreas cercanas a barrancos rocosos, acantilados y laderas con bosques de coníferas pino–encino y bosque de niebla. *Nelsonia goldmani* es considerada como “En peligro” (EN) por la Unión Internacional para la Conservación de la Naturaleza y Recursos Naturales a causa de su distribución fragmentada y la disminución en la calidad y extensión de su hábitat.

Palabras clave: Faja Volcánica Transmexicana, Galushamyina, Montañas, Neotominae, Neotomini, rata enana de Goldman, rata enana michoacana

Synonymies completed 27 March 2019

DOI: 10.1093/mspecies/seac013

Version of Record, first published online February 1, 2023, with fixed content and layout in compliance with Art. 8.1.3.2 ICZN.

Nomenclatural statement.—A life science identifier (LSID) number was obtained for this publication: urn:lsid:zoobank.org:pub:7C7CF48F-C83E-4FF1-83ED-4C53CB569DDC

Nelsonia Merriam, 1897

Nelsonia Merriam, 1897:278. Type species *Nelsonia neotomodon* Merriam, 1897, by original designation.

CONTEXT AND CONTENT. Order Rodentia, family Cricetidae, subfamily Neotominae, tribe Neotomini, subtribe Galushamyina (Martin and Zakrzewski 2019; León-Tapia and Cervantes 2021; Kelly and Martin 2022). The synonymy was modified from Musser and Carleton (2005). *Nelsonia* consists of two species, *N. neotomodon* and *N. goldmani* (Musser and Carleton 2005; Burgin et al. 2020; León-Tapia and Cervantes 2021).

Nelsonia goldmani Merriam, 1903

Goldman's Diminutive Woodrat

Nelsonia goldmani Merriam, 1903:80. Type locality “Mt. Tancitaro, Michoacan, Mexico.”

Nelsonia neotomodon goldmani: Hooper, 1954:7. Name combination.

Nelsonia neotomodon cliftoni Genoways and Jones, 1968:97. Type locality “2.5 mi. ENE Jazmin, 6,800 ft, Jalisco,” Mexico.

Nelsonia goldmani goldmani: Engstrom, Sánchez-Herrera, and Urbano-Vidales, 1992:880. Name combination.



Fig. 1.—An adult female *Nelsonia goldmani cliftoni* from El Nevado de Colima, 1.5 km SE El Izote, San Gabriel, Jalisco, México, 12 December 2012 (CNMA [Colección Nacional de Mamíferos] 46614). Photograph by MAL-T.

Nelsonia goldmani cliftoni: Engstrom, Sánchez-Herrera, and Urbano-Vidales, 1992:880. Name combination.

CONTEXT AND CONTENT. Context as for genus. Currently two subspecies are recognized (Musser and Carleton 2005; Burgin et al. 2020; León-Tapia and Cervantes 2021):

N. g. cliftoni (Genoways and Jones, 1968:97). See above.

N. g. goldmani Merriam, 1903:80. See above.

NOMENCLATORIAL NOTES. *Nelsonia* is considered a member of the Neotomini tribe based on morphological similarities with *Neotoma*, *Xenomys*, and *Hodomys* (Musser and Carleton 2005). However, recently genetic analysis and morphological characteristics of *Nelsonia*, including fossil information of its likely closest relatives, revealed that *Nelsonia* is the unique, current living member of the Galushamyina subtribe (Martin and Zakrzewski 2019; León-Tapia and Cervantes 2021; Kelly and Martin 2022). The first members of this genus were collected by E. W. Nelson and E. A. Goldman. The generic name *Nelsonia* honors one collector (Merriam 1897), whereas the species name, *goldmani*, honors the other (Merriam 1903). The subspecies *cliftoni* honors

the collector P. L. Clifton (Genoways and Jones 1968). Another common name is rata enana michoacana (Spanish—Álvarez-Castañeda and González-Ruiz 2018).

DIAGNOSIS

Nelsonia goldmani resembles *N. neotomodon* (western diminutive woodrat), but can be distinguished by a set of morphological characters. The dorsal pelage of *N. goldmani* is grayish with a fulvous lateral line (Fig. 1) versus the lighter cinnamon-buff line present in *N. neotomodon*. The dorsal surface of the hind feet in *N. goldmani* are blackish instead of white as in *N. neotomodon*. The tail is indistinctly bicolored in *N. goldmani* with a tip that is slightly darker than dorsal color of the tail (Fig. 2), whereas in *N. neotomodon* the tail is bicolored and has a white tip (Engstrom et al. 1992; León-Tapia and Cervantes 2019a). The juvenile dorsal pelage in *N. goldmani* is dark slate, whereas in *N. neotomodon* it is buffy grayish (Merriam 1903; Hooper 1954). Cranially, the zygomatic plate is wider in *N. goldmani* (3.0–3.8 mm) than in *N. neotomodon* (2.6–3.1 mm), when like age groups are compared. The two species are distinguished by the presence of a distinct anterior notch in the zygomatic plate of *N. goldmani* and its absence (a conservative character in neotomine–peromyscine rodents) in *N. neotomodon*, suggesting a shift in the position of the anterior slip of the masseter lateralis muscle and changes in associated patterns of mastication between the species (Engstrom et al. 1992).

Finally, the basic shape of the phallus is distinct; in *N. goldmani* the shape resembles a bottleneck, compared to the finger-like shape in *N. neotomodon*. The total length and diameter of the phallus in *N. goldmani* are slightly greater than in *N. neotomodon*, in a proportion of 6 to 5. The baculum of both species is different in shape and location; in *N. goldmani* the proximal section is rounded and extends to 1.76 mm before the distal section, whereas in *N. neotomodon* the proximal section of the baculum lies below the base and extends to the distal section of the organ (León-Tapia and Cervantes 2019a).

GENERAL CHARACTERS

Nelsonia goldmani is a medium-sized woodrat with vibrissae extending to the lumbar region (Hooper 1954). There is no sexual dimorphism in the specimens examined to date (Engstrom et al. 1992; León-Tapia and Cervantes 2019b). The dorsal pelage is dark slate-gray with a fulvous lateral line. The tail length is almost one-half the total length with a blunt end, covered with short black hairs becoming gradually paler ventrally, and with a black terminal pencil. The ventral pelage is white with a plumbeous underfur (Merriam 1903). The juvenile pelage is dark slate (Merriam 1903). The hind foot is dusky-colored above and the length is 25–30 mm (Hooper 1954; Engstrom et al. 1992). Mean external measurements (mm $\pm$ SD) of five adult specimens



Fig. 2.—An adult female *Nelsonia goldmani goldmani* from Las Peñas 2.6 km SE Dexcaní Alto, Jilotepec, Estado de México, México, 17 October 2010 (CNMA [Colección Nacional de Mamíferos] 46292). Photograph by MAL-T.

(two males; three females) recently collected in Jalisco and Estado de México states were: total length 249 ± 8.63 , tail length 123.2 ± 12.5 , length of hind foot 25.4 ± 1.52 , and ear length 23.6 ± 2.19 . The mean body mass of these specimens was 50.52 g (León-Tapia and Cervantes 2019b).

The skull of *N. goldmani* is flattened between the orbits, deeply concave laterally with the zygomatic arches slightly extended anteriorly, and with a well-developed anterior zygomatic notch (Fig. 3). The occlusal surface of the upper molars is flat-crowned with deep reentrant angles (Merriam 1903; León-Tapia and Cervantes 2019b). Mean skull measurements (mm $\pm$ SD) for the same five specimens mentioned previously were: greatest length of skull 32.77 ± 0.33 ; zygomatic breadth 16.76 ± 0.31 ; interorbital constriction 4.63 ± 0.1 ; length of rostrum 13.26 ± 0.19 ; breadth of rostrum 5.22 ± 0.2 ; mastoid breadth 13.79 ± 0.15 ; length of interparietal bone 4.5 ± 0.38 ; width of interparietal bone 10.69 ± 0.37 ; breadth of zygomatic plate 3.88 ± 0.17 ; length of palate 6.33 ± 0.24 ; length of maxillary tooththrow 6.44 ± 0.29 ; breadth across molars 6.26 ± 0.25 ; length of auditory bulla 5.4 ± 0.2 ; depth of skull 10.32 ± 0.19 , and length of mandibular tooththrow 6.97 ± 0.24 (León-Tapia and Cervantes 2019b). Five age classes were described based on the degree of eruption and wear of the upper molars (Engstrom et al. 1992).

The two subspecies of *N. goldmani* differ in coloration (Fig. 4): *N. g. goldmani* has dark gray dorsal pelage and is paler laterally, whereas *N. g. cliftoni* is distinguished by paler and more fulvous pelage both dorsally and laterally (Engstrom et

al. 1992). The only skull difference is a greater length of the rostrum in *N. g. cliftoni* (12.6–13.7 mm) than *N. g. goldmani* (11.6–13.2 mm).

DISTRIBUTION

Nelsonia goldmani is endemic to the highlands of central Mexico (Fig. 5), where its geographic distribution is fragmented and limited to elevations of suitable habitat in an area of 19,533 to 20,225 km² (León-Tapia and Cervantes 2019b). It is known from only 15 localities in the highlands of the central-west of the Trans-Mexican Volcanic Belt biogeographic region in central Mexico (González-Cózatl et al. 2016; León-Tapia and Cervantes 2019b; León-Tapia 2021). The localities where specimens of *N. goldmani* were collected range in elevation from 2,000 to 3,100 m. *Nelsonia g. goldmani* is distributed in Michoacán, Estado de México, and Morelos states, and *N. g. cliftoni* found in only a few localities in Jalisco state, so as presently understood, their geographic distributions do not overlap (León-Tapia and Cervantes 2019b; León-Tapia 2021). No fossils are known.

FORM AND FUNCTION

The pelage of *Nelsonia goldmani* contains guard hairs that are characterized by an abrupt enlargement in the distal part of



Fig. 3.—Dorsal, ventral, and lateral views of skull and lateral view of mandible of an adult female *Nelsonia goldmani cliftoni* (CNMA [Colección Nacional de Mamíferos] 46614) from El Nevado de Colima, 1.5 km SE El Izote, San Gabriel, Jalisco, México. Occipitonasal length is 32.66 mm.

the stem; the medulla has cortical intrusions. Based on optical microscopy analyses of the pelage, the mean total length ($\mu\text{m} \pm \text{SD}$) of the hair (middle part) is 13.86 ± 1.11 , diameter 0.056 ± 0.003 , and medulla diameter 0.05 ± 0.003 (Monroy-Vilchis and Rubio-Rodríguez 2003). The dental formula is $i \ 1/1, c \ 0/0, p \ 0/0, m \ 3/3$, total 16. Molars are prismatic, the occlusal surface of the upper molars is flat-crowned, presenting deep reentrant angles of enamel occupying one-half of the tooth width, and the third molar is without the inner fold (Merriam 1903; Hooper 1954; León-Tapia et al. 2019b).

The skull of *N. goldmani* is flattened between the orbits with a wide zygomatic plate, is deeply concave laterally with

the zygomatic arches slightly extended anteriorly and has a well-developed anterior zygomatic notch. There is a stapedial and sphenofrontal foramen on the anterior part of the braincase and laterally there is a well-developed groove on the squamosal bone. The lacrimal bone is scarcely evident dorsally (Merriam 1903; León-Tapia et al. 2019b). The palatine is narrow and rough, and does not lie immediately below the palatine foramina, which is situated posteriorly. The incisive foramina are large and open, and broader anteriorly. The angular process of the dentary bone is directed posteriorly in the same plane as the ascending ramus (Merriam 1897, 1903; Hooper 1954; Carleton 1980; Engstrom et al. 1992). The postcranial skeleton contains 13 thoracic, 6 lumbar, and 32–36 caudal vertebrae. The second thoracic vertebra has a well-developed neural spine (Carleton 1980). The ilium and ischium of the pelvis are slender, and the neck of scapula is broad and short (Hooper 1954).

The stomach of *N. goldmani* is bilocular–discoglandular and the incisura angularis is deep and projects beyond the esophageal opening. The fornix ventricularis arches are located closer to the esophageal opening than the incisura angularis and are slightly curved toward the esophagus. The corpus is elongated horizontally. The antrum walls of the inner stomach are muscular, more visible near the pyloric opening. A bordering fold surrounds the glandular region, and cornified squamosal epithelium coats the remaining areas of the antrum and corpus (León-Tapia et al. 2018).

The reproductive structures were described from one adult male collected in Estado de México and showed that externally the phallus was simple, compared to the forms and ornamentations presented in other species of the subfamily Neotominae, with a length of 9.5 mm and shaped like an elongated bottleneck, being broad and cylindrical at the base and narrowing in diameter toward the tip (León-Tapia et al. 2019a). The external surface of the phallus is rigid with one-quarter of the surface bare, whereas the remainder of the surface is dotted with conical tubercles or spines surrounded in a circular depression. The spines are larger at the base of the organ (0.31 mm) and double in size compared those on the distal area (0.15 mm—León-Tapia et al. 2019a). The baculum of *N. goldmani* has 7.74 mm of length and consists of two sections: an osseous structure and a cartilaginous part in the distal section. The osseous structure has a length of 6.59 mm and is simple in form; its proximal portion is concave, becoming narrower toward the distal end. The cartilaginous part is approximately one-sixth the total length of the baculum resembling a cone. The inner position of the baculum is the same as the phallus and the proximal section is the same as the base of the phallus (León-Tapia et al. 2019a). Sperm are large (mean length $182.58 \mu\text{m} \pm 1.615 \text{ SD}$), have asymmetric heads, and are rounded at the base with a slight depression; the acrosome extends as a strong and large recurved hook. The middle piece is separated clearly from the head by a narrower section; its length is four times that of the head. The tail of the sperm is long, comprising 85% of total length (León-Tapia et al. 2019a).



Fig. 4.—Color differences in dorsal pelage between female adults of *Nelsonia goldmani*. *Nelsonia g. cliftoni* (left) from El Nevado de Colima, 1.5 km SE El Izote, San Gabriel, Jalisco, México, 14 December 2011 (CNMA [Colección Nacional de Mamíferos] 46290) and *N. g. goldmani* (right) from Las Peñas 2.6 km SE Dexcaní Alto, Jilotepec, Estado de México, México, 17 October 2010 (CNMA 46292). Photographs by MAL-T.

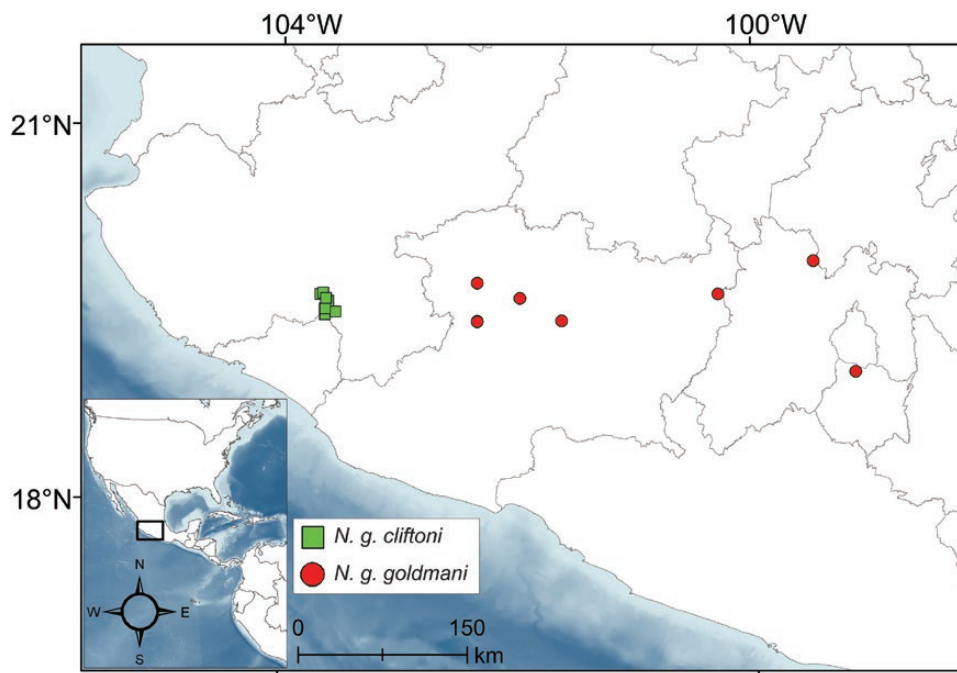


Fig. 5.—Known geographic distribution of *Nelsonia goldmani*. The localities where *N. goldmani* has been collected are indicated on the map. The subspecies are *N. g. cliftoni* (squares) and *N. g. goldmani* (circles). Map redrawn from León-Tapia and Cervantes (2021) and León-Tapia (2021).

ONTOGENY AND REPRODUCTION

One adult male was collected in October 2010 with scrotal testes, 10.94 mm in length and 7.47 mm in breadth, with a

paired weight of 0.79 g; the testicular volume was 319.64 mm³ and 1.34% of gonadal somatic index (León-Tapia and Cervantes 2019a). Histological analysis showed active spermatogenesis (León-Tapia and Cervantes 2019a). One adult female collected

in December 2012 showed prominent nipples and signs of active nursing (León-Tapia and Cervantes 2019b).

ECOLOGY

Nelsonia goldmani is rare or uncommon in all localities where it occurs. Specific data on population sizes are unknown, but fewer than 50 specimens have been collected since its description (León-Tapia and Cervantes 2019b). *Nelsonia goldmani* appears to be ecologically specialized and is strongly associated with rocky slopes and ravines with high moisture, dense herbaceous cover, mushrooms, ferns, lichen, and moss. The climate preferences are related to temperate conditions and high precipitation, in the montane cloud, pine, fir, and oak forests (Genoways and Jones 1968; Glendinning 1992; Orduña-Trejo et al. 2000; Carleton et al. 2002; León-Tapia and Cervantes 2019b; León-Tapia 2021). The subspecies *N. g. cliftoni* was collected 2.5 and 4 mi ENE El Jazmin in Jalisco state with cool, pine-oak forest in an area that was recently logged and contained scattered cornfields (Genoways and Jones 1968) and at El Nevado de Colima, 1.25 km El Izote in Jalisco state in a low deep ravine with dense herbaceous cover and few trees (León-Tapia and Cervantes 2019b). The subspecies *N. g. goldmani* was reported in a pine-oak and fir (*Abies religiosa*) forest at San Marcos mountain in western Michoacán (Orduña-Trejo et al. 2000); at 4 mi S Pátzcuaro in central Michoacán individuals were reported in pine forest (*Pinus leiophylla*, *P. pseudostrobus*, *P. montezumae*, *P. devoniana*), fir forest (*A. religiosa*), and oak forest (*Quercus castanea*, *Q. crassipes*, *Q. dysophylla*, *Q. laurina*, *Q. obtusata*, and *Q. rugosa*—León-Tapia and Cervantes 2019b); and at Arroyo Zapatero, Sierra Chincua near Angangueo in eastern Michoacán it was reported in fir forest (*A. religiosa*), with an undergrowth of several species of *Senecio*, *Satureja macrostema*, *Acaena elongata*, *Stevia monardaefolia*, and *Salvia cardinalis* (Glendinning 1992). At

Las Peñas, 2.6 km SE Dexcaní Alto in Estado de México, *N. goldmani* was captured in a deep ravine (Fig. 6) with a mix of a few oak trees (*Quercus* sp.), fir (*Abies* sp.), and cloud forest with *Ilex tolucana*, *Garrya lauzrifolia*, *Cornus disciflora* along with some madroños (*Arbutus* spp.), and tepozanes (*Buddleja americana*; Engstrom et al. 1992; Carleton et al. 2002; León-Tapia and Cervantes 2019b). Finally, at 6.5 km E Coajomulco in Morelos state, *N. goldmani* was collected in oak forest (*Q. rugosa* and *Q. castanea*), and with other tree species typical of cloud forests, including *Clethra mexicana*, *Styrax ramirezii*, and *Symplocos prionophylla* (González-Cózatl et al. 2016). In one specimen from Las Peñas in Estado de México, several food items of plant origin were found in the stomach contents, such as epidermal tissue of stems and leaves, pollen of gymnosperms, spores of ferns, and fungi; a few animal tissues, for example, mouth appendages and legs of insects were also identified in the stomach contents (León-Tapia et al. 2018).

At El Jazmin in Jalisco state, *N. goldmani* was captured with *Heteromys irroratus* (Mexican spiny pocket mouse), *Peromyscus hylocetes* (Transvolcanic deer mouse), *P. labecula* (southern deer mouse), and *Neotoma mexicana* (Mexican woodrat—Genoways and Jones 1968). At El Nevado de Colima in Jalisco state, *N. goldmani* coexists with *Cryptotis alticola* (Popocatepetl broad-clawed shrew), *Sorex saussurei* (Saussure's shrew), *Microtus mexicanus* (Mexican vole), *Reithrodontomys sumichrasti* (Sumichrast's harvest mouse), Mexican woodrat, and Transvolcanic deer mouse (León-Tapia and Cervantes 2019b). At Arroyo Zapatero, Sierra Chincua in Michoacán, *N. goldmani* was captured with Saussure's shrew, Mexican vole, Sumichrast's harvest mouse, *P. melanotis* (black-eared deer mouse), and Transvolcanic deer mouse (Glendinning 1992). In the eastern-most part of its distribution at Las Peñas in Estado de México, *N. goldmani* coexists with Saussure's shrew, *Sylvilagus floridanus* (eastern cottontail), Mexican spiny pocket mouse, Mexican woodrat, *P. levipes* (nimble-footed deer mouse), and *P. difficilis* (southern rock deer mouse—León-Tapia and Cervantes 2019b).



Fig. 6.—Mountainous landscape (left) and typical vegetation in ravine bottom (right) of *Nelsonia goldmani goldmani* habitat at Las Peñas 2.6 km SE Dexcaní Alto, Jilotepec, Estado de México, México. Photographs by MAL-T taken August and October 2010, respectively.

Other species collected in this locality were *R. fulvescens* (fulvous harvest mouse) and *Habromys delicatulus* (delicate deer mouse—Carleton et al. 2002). Lastly, at Coajomulco in Morelos state, *N. goldmani* was captured with Mexican vole, *R. microdon* (small-toothed harvest mouse), southern rock deer mouse, and Transvolcanic deer mouse (González-Cóztatl et al. 2016).

GENETICS

A description of the karyotype of *Nelsonia goldmani* is not available. The diploid number (2n) for *Nelsonia neotomodon* is 48 chromosomes and the fundamental number (FN) is 46. These are similar to that proposed as plesiomorphic (primitive) for neotomine–peromyscine rodents based on comparisons of g-banded chromosomes (Engstrom and Bickham 1983) and consistent with the hypothesis that *Nelsonia* is an outlier to neotomine–peromyscines and a distinct subtribe (Martin and Zakrzewski 2019; León-Tapia and Cervantes 2021; Kelly and Martin 2022).

Intraspecific relationships analyzed with mitochondrial markers revealed four highly divergent major clades, potentially representing different species within *N. goldmani* (León-Tapia and Cervantes 2021). One lineage encompassed individuals of the subspecies *N. g. cliffoni* and three lineages within *N. g. goldmani*. These molecular data support the hypothesis that *Nelsonia* diverged from *Neotoma*, *Hodomys*, and *Xenomys* during the middle to late Miocene. This biogeographic hypothesis supports that the ancestor of *N. goldmani* and *N. neotomodon* invaded the Western Sierra Madre Mountains and the Trans-Mexican Volcanic Belt and later the two species diverged during the late Miocene. Finally, during the Pliocene, the four lineages of *N. goldmani* within the Trans-Mexican Volcanic Belt diverged (León-Tapia 2021; León-Tapia and Cervantes 2021).

CONSERVATION

Nelsonia goldmani occurs in three protected areas, El Nevado de Colima National Park in Jalisco state, and Pico de Tancitaro Flora and Fauna Protection Area and Sierra Chincua Monarch Butterfly Biosphere Reserve in Michoacán State (Álvarez-Castañeda and Castro-Arellano 2019; León-Tapia and Cervantes 2019b). It is present in similar habitats to those frequented by monarch butterflies (*Danaus plexippus*) during the winter (Glendinning 1992) and efforts to preserve the butterfly's sanctuaries in Michoacán could indirectly benefit *N. goldmani* (Álvarez-Castañeda and Castro-Arellano 2019). However, some areas at El Nevado de Colima in Jalisco state are disturbed by livestock activity and farming, including corn fields and plum and hawthorn orchards (León-Tapia and Cervantes 2019b). Because *N. goldmani* populations require particular environmental characteristics and undisturbed habitat, it is suggested that microhabitat conservation across the Trans-Mexican Volcanic Belt could be the most appropriate conservation measure for this species (León-Tapia and Cervantes 2019b).

Nelsonia goldmani is listed in the Official Mexican Standard and it is regarded as of “Special Protection” (Pr) and listed as “Endangered” (EN) by the International Union for Conservation of Nature and Natural Resources because its area of occupancy is less than 500 km², all individuals collected are localized in a few localities, and there is a continuous deterioration in the quality and extent of its habitat due to deforestation generated by timber extraction and agriculture, which could reduce their population size (Álvarez-Castañeda and Castro-Arellano 2019). Volcanic activity, climate change, contamination, the invasion of exotic species, forest fires, pests, and pathogens are also potential threats to *N. goldmani* (Álvarez-Castañeda and Castro-Arellano 2019; León-Tapia and Cervantes 2019b).

ACKNOWLEDGMENTS

I thank Virginia Hayssen for providing help with the synonymies. To Meredith J. Hamilton, Robert K. Rose, and two anonymous reviewers whose comments enriched and improved this manuscript.

CONFLICT OF INTEREST

None declared.

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Associate Editor was ROBERT K. ROSE. Editor was MEREDITH J. HAMILTON.