**Evaluation of Risk of Extinction (MER)**

**Scientific name**

*Habromys chinanteco* (Robertson & Musser, 1976)

**Common names**

* Ratón trepadaor chinanteco, Chinanteco deer mouse

**Taxonomic classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Rodentia

Family: Cricetidae

**Rationale for the proposal**

The Chinanteco deer mouse (*Habromys chinanteco*) is an endemic rodent from the high mountains of Mexico that only occurs on the Gulf-facing, North Slope of Cerro Pelón, Sierra de Juárez in Ixtlán de Juárez Municipality, Oaxaca (Robertson & Musser, 1976). This species inhabits in the most threatened ecosystem of Mexico, the cloud forest (CONABIO, 2010). In addition, *Habromys chinanteco* is listed in the IUCN Red List of Threatened Species under the category of critically endangered (CR B1ab(iii)), as its extent of occurrence is less than 100km2, all individuals inhabit in one location and there is a continuing decline in the extent and quality of their habitat (Álvarez-Castañeda *et al.,* 2008a).

**MER** (Risk of Extinction Assessment Method)

**Criterion A: distribution**

 Distribution

*Habromys chinanteco* is an endemic rodent found only in one location, the high mountains of Mexico on the Gulf-facing, North Slope of Cerro Pelón, Sierra de Juárez, in Ixtlán de Juárez Municipality, Oaxaca (Robertson & Musser, 1976). This species occurs between 2,000 and 2,650 msl (Robertson & Musser, 1976; Carleton, Sánchez & Urbano Vidales, 2002), in an area that comprises about 1700km2. During 2005 - 2006 a field trip took place in the same area, and a new record from the species appeared in the same location (Briones-Salas *et al*., 2012)

 Map construction and evaluation

The map indicates the currently known distribution of *Habromys chinanetco* (Figure. 1a main text), records were obtained from CONABIO’s databases (SNIB). We created the map with ArcMap V. 10.2 (ESRI, 2011) using Mexico’s Digital Map from the National Institute of Statistics and Geography (INEGI, acronym in Spanish) as base layer. To calculate the species’ distribution range we employed IUCN’s methodology (IUCN, 2012), using a 2 km grill (a cell area of 4 km2), as this scale is more accurate for species with small distributions.

*Habromys chinanteco* scores 4 points in Criterion A, due to its very restricted distribution (less than 5% of Mexico’s territory).

**Criterion B: habitat**

Habitat

Chinanteco deer mouse inhabits the cloud forest of Oaxaca at Sierra de Juárez. The weather in this specific region of Ixtlan’s municipality is temperate with abundant summer rains C(m)( (INEGI, 2010a; García, 1988). Temperature and precipitation range between 12°C to 16°C and 1200mm to 2000mm respectively. Briones-Salas *et al*., (2012), recorded this species in the transition zone between Pine-Oak forest and cloud forest, with similar vegetation like Robertson & Musser (1976) described. Trees covered with mosses, bromeliads, orchids and epiphytes. In addition, besides pines (*Pinnus ruddis*, *P. devoniana*, *P. montezumae*), and oaks (*Quercus laurina*, *Q. rugosa*) there are *Magnolias spp*. ferns, epiphytes, and gymnosperms (CONABIO, 2014) <http://www.biodiversidad.gob.mx/ecosistemas/bosqueNublado.html>).

 Diagnosis of the present habitat situation

This species has only been found in one location, and one vegetation type, in the transition zone between Pine-Oak forest and cloud forest of the Sierra de Oaxaca (Briones-Salas *et al*., 2012). Currently the whole cloud forest ecosystem is threatened in Mexico (Drobovolski *et al*, 2013; CONABIO, 2014). The IUCN Red List emphasizes that deforestation is ongoing on the species’ distribution area (Álvarez-Castañeda, *et al*., 2008a), a fact which is shrinking its already small distribution range.

This diagnosis is based in referenced information from peer review articles, published books, and government reports.

 Evaluation of current status of taxon’s habitat

*Habromys chinanteco* inhabits only in the cloud forest which sets the species in a high risk of extinction due to habitat loss, because it does not occur elsewhere rather Oaxaca’s cloud forest in the specific location where it was found.

The species scores 3 points in the Criterion B due to habitat is very demarcated for the species.

**Criterion C: intrinsic vulnerability**

 Life history

The Chinanteco deer mouse is a small rodent, the dorsal pelage is grayish-brown, the under parts are grayish-white. The pelage is soft and thick; meanwhile the tail is unicolor covered with long soft hair. The mean body length is 91.2 m. and the mean tail length is 110.3 mm (Robertson & Musser, 1976). Besides pine-oak and cloud forest, other flora elements that where associated to this rodent were orchids, ferns, and mosses that cover tree trunks (Robertson & Musser, 1976; Briones-Salas *et al*. 2012). Apparently this rodent has nocturnal activity, as all captures between 1969 and 1970 were at night (Robertson & Musser, 1976).

 Diagnosis of the currently species situation

Little is known about this species biology, and it is difficult to capture. It took about 33 years to get new specimens from the same area where it was first captured, but these new records confirm the continuing presence of *Habromys chinanteco* in the north slope of Cerro Pelón, Oaxaca (Briones-Salas *et al*., 2012).

This evaluation was performed by peer review articles, but the information is scant.

Evaluation of current species’ status

Little is known about the needs of *Habromys chinanteco*; however, the fact that this species is a cloud forest specialist tell us that it must be dependent on seeds and fruits from the area as well as for other environmental conditions. As this species habitat is highly threatened, its needs are threatened as well. Thus, we score this criterion with 3 points.

**Criterion D Human impact**

 Real and potential risk factors

The threat to *Habromys chinanteco* is deforestation of the cloud forest in Sierra de Juárez, Oaxaca. If habitat loss continues, this species will become extinct (CONABIO, 2014).

 Prediction analysis

The prediction of *Habromys chinantec’*s future is that deforestation will compromise the viability of the species; therefore conservation actions in short-term are urgent.

 Impact assessment

IUCN and many other authors present the same point of view regarding the impact of deforestation in cloud forest flora and fauna. *Habromys chinanteco* is endangered due to this activity, especially because of its very restricted range. Therefore the species was granted with the highest score for this criterion, 4 points in the Criterion D.

**MER total score**

Criterion A= 4

Criterion B= 3

Criterion C= 3

Criterion D= 4

MER = 14 points which would grant *Habromys chinanteco* the status of Endangered (P) in the NOM-059-SEMARNAT-2010.

Species relevance

*Habromys chinanteco* is a frugivorous species that provides important ecosystem services by dispersing seeds (MEA, 2005), and contributes to control the populations of plants (Forget *et al*, 2011), mammals, and insects (Hanksi, 1987).

Conservation actions suggested

Due to difficulty to capture this rodent, studies on its ecology and biology are complicated, whereas the urgency to conserve it is a priority. The conservation actions to protect the species should concentrate in conserving its habitat. We suggest some approaches to tackle the deforestation problems to give a better outcome for the survival of *Hanbromys chinanteco* and other cloud forest species:

1. Payment for ecosystem services: in Mexico this approach has provided good results (García-Amado *et al*., 2011; Rico García-Amado, Ruiz & Barrasa, 2013) in conservation actions.
2. Sustainable logging practices: Pine-Oak and other timber species inhabits in the range where *Habromys chinanteco* does. As logging seems to be inevitable in the short-term, having better practices could help to protect the ecosystem.

Summary

The assessment of *Habromys chinanteco* via the MER, grants this species a score of 14, which is equivalent to the endangered category. *Habromys chinanteco* must be included on the Mexican Red List NOM-059-SEMARNAT-2010.

Criterion A = 4. Very restricted, due to its very limited distribution (less than 5% of Mexico’s territory).

Criterion B = 3. Very limiting, habitat is very harsh for the species’ needs.

Criterion C= 3. High vulnerability, as it is only known from one locality for which it has a high affinity.

Criterion D = 4. High impact, deforestation is reducing its already small distribution range.

Due to difficulty to collect this rodent, studies of ecology and biology are complicated, and the urgency to conserve is a priority. Habitat protection should be the conservation action for this species, and we suggest at least these two approaches: a) payment for ecosystem services so that can local dwellers are willing to protect the habitat; b) Sustainable logging practices to sustainably use local resources.

**Evaluation of Risk of Extinction**

**Scientific name**

*Habromys delicatulus* (Carleton, Sánchez & Urbano Vidales, 2002)

**Common names**

Delicate Deer mouse

Ratón de Jilotepec

**Taxonomic classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Rodentia

Family: Cricetidae

**Rationale for the proposal**

*Habromys delicatulus* is an endemic rodent which inhabits the northern ridge of the Trans-Mexican Volcanic Belt, Mexico State (Carleton, Sánchez & Urbano Vidales, 2002). The delicate deer mouse has only been found in this one location in the cloud forest, a vegetation type under high anthropocentric pressure in Mexico (CONABIO, 2010; CONABIO, 2014), so its survival might be on risk. In addition *Habromys delicatulus* is listed on IUCN’s Red List of Threatened Species under the category of critical endangered (CR B1ab(iii)), due to its extent of occurrence of less than 100km2, all individuals are in one location and there is a continuing decline in the extent and of its habitat (Álvarez-Castañeda *et al*., 2008b).

**MER** (Risk of Extinction Assessment Method)

**Criterion A: distribution**

 Distribution

*Habromys delicatulus* has only been found in the northern ridge of the Trans-Mexican Volcanic Belt, Mexico State (Carleton, Sánchez & Urbano Vidales, 2002). In Cañada de Ermita, Municipality Dexcani Alto Jilotepec at elevations above 2000m asl (Álvarez-Castañeda *et al*., 2008b).

 Map construction and evaluation

The map shows the current known distribution of *Habromys delicatulus* (Figure. 1b main text). Coordinates for all recorded individuals were obtained from CONABIO’s databases (SNIB). We created the map with ArcMap V. 10.2 (ESRI, 2011) using Mexico’s Digital Map from the National Institute of Statistics and Geography (INEGI, acronym in Spanish) as base layer. To calculate the species’ distribution range we employed IUCN methodology (IUCN, 2012): a grill of 2 km (a cell area of 4 km2), which according to IUCN is more accurate for species with small distributions, and it allows taxa to be assessed by the criterion B and get into the critically endangered threshold (if it is required). Every record of *Habromys delicatulus* was set as a dot over the map and grid, posteriorly each occupied cell was sum to obtain the value of occupied territory. The use of this methodology helps to avoid overestimating values for this species distribution.

*Habromys delicatulus* got a score of with 4 points in the Criterion A, due to its very restricted distribution (less than 5% of Mexico’s territory).

**Criterion B: habitat**

Habitat

*Habromys delicatulus* inhabits the cloud forest of Estado de Mexico, Mexico. The climatological data from this area is as follows: temperate weather with summer precipitation; temperature range from 10°C to 16°C; precipitation range between 600 – 1000mm; vegetation type corresponds to cloud forest, the area was covered in its majority by oak (*Quercus* spp) mixed with small patches of oyamel (*Abies* spp). Orchids were present on the study area, especially in the branches of the trees. In addition tree species were indicative as cloud forest vegetation *Ilex tolucana*, *Garrya laurifolia*, and *Cornus disciflora*. *Arbutus* sp and *Buddleja americana* were present as well (Carleton, Sánchez & Urbano Vidales, 2002).

Diagnosis of the present habitat situation

*Habromys delicatulus* is only known from one location in the cloud forest. More research is needed to have a better diagnosis, but as a frugivore species, this rodent surely has an association with plants that only occur in this cloud forest. Deforestation is the biggest threat to this species (Álvarez-Castañeda *et al*., 2008b).

This diagnosis is based in peer review articles and published books.

 Evaluation of the current status of the taxon’s habitat

The habitat of *Habromys delicatutlus* is very restricted, it only occurs in the cloud forest on northern ridge of the Trans-Mexican Volcanic Belt in Mexico State. Due to species affinity to this habitat, and to its endemism, the taxon will be at risk if the habitat is loss and that can occur soon.

The species scored 3 points in the Criterion B as its habitat is very restricted

*Criterion C: intrinsic vulnerability*

 Life history

*Habromys delicatulus* is an arboreal rodent, like all the species within *Habromys* it inhabits the highlands of Mesoamerica (León-Paniagua *et al*., 2007), and is the smallest rodent of this genus. Specimens of this rodent were captured by traps on trees from 0.9 m to 4.3 m above the ground; most of the specimens obtained were at *Ilex tolucana* trees (Carleton, Sánchez & Urbano Vidales, 2002). It is also known that *Habromys delicatutlus* is a rare species, like all the others within *Habromys*, and therefore poorly understood and represented in scientific collections (León-Paniagua *et al*., 2007).

Diagnosis of the current situation of the species

The critical situation of its habitat along with its limited distribution place *Habromys delicatulus* species in a vulnerable situation. Furthermore, little is known about its biology, but Carleton, Sánchez & Urbano Vidales, (2002) and León-Paniagua *et al*., (2007) found that *Habromys delicatulus* is an arboreal rodent, so deforestation is the major threat to this species (Álvarez-Castañeda *et al*., 2008b).

The evaluation was performed through peer review articles, but the information is scant.

Evaluation of the current status of the species

*Habromys delicatulus* status according to IUCN (IUCN, 2012) is critical, and its population is decreasing, furthermore this species is close related to its habitat. Even though it exists a gap on the biology and ecology of this species, the fact that it only occurs in one area of the Cordillera Neovolcanica points to the affinity of this rodent to specific either habitat (Carleton, Sánchez & Urbano Vidales, 2002; León-Paniagua *et al*., 2007). Because of this affinity and the restricted area it occupies *Habromys delicatulus* scored 3 points for its high vulnerability.

**Criterion D: human impact**

 Real and potential risk factors

Deforestation is the real and potential risk factor to *Habromys delicatulus*. The risk that this species faces is shared by all Mexico´s cloud forests (Drobovolski *et al*, 2013). Specifically, almost 61% of the northern ridge of the Cordillera Neovolcánica, at Jilotepec Municipality, is used for agriculture according to the National Institute of Statics and Geography (INEGI, 2010b).

Prediction analysis

If deforestation continues on the area, the viability of *Habromys delicatulus* will be compromised; therefore conservation actions in short-term directed toward the habitat are due.

Impact assessment

Deforestation is the major threat for this species. Several authors such as Pardini *et al*, (2005), Sullivan *et al*, (2013), and Drobovolski *et al*, (2013) mention that the cloud forest ecosystem in Mexico and Mesoamerica is endangered by this threat. In addition percent of land that is used for agriculture in the municipality where this rodent inhabits is very high. For these reasons as well as the species’ reduced distribution range; the species scored 4 points in criterion D

**Final MER score**

Criterion A= 4

Criterion B= 3

Criterion C= 3

Criterion D= 4

MER total is 14 points. This score places *Habromys delicatulus* as Endangered (P) and so it must be included in the NOM-059-SEMARNAT-2010.

 Relevance of the species

As a frugivore species *Habromys delicatulus* has a very important role in providing ecosystem services as it contributes with seed dispersal (MEA, 2005) in the cloud forest, provides biocontrol of plant (Forget *et al*, 2011) and insect communities (Hanksi, 1987) and serve as prey for upper mammals that inhabit the cloud forest. The absence of this species will cause a loss of equilibrium to the habitat, especially to the plant community structure and dynamics.

 Conservation actions suggested

Due to difficulty to capture this rodent, studies on its ecology and biology are complicated, whereas the urgency to conserve it is a priority. The conservation actions to protect the species should concentrate in conserving its habitat. We suggest some approaches to tackle the deforestation problems to give a better outcome for the survival of *Hanbromys delicatulus* and other cloud forest species:

1. Payment for ecosystem services: in Mexico this approach has provided good results (García-Amado *et al*., 2011; Rico García-Amado, Ruiz & Barrasa, 2013) in conservation actions.
2. Sustainable logging practices: Pine-Oak and other timber species inhabits in the range where *Habromys delicatulus* does. As logging seems to be inevitable in the short-term, having better practices could help to protect the ecosystem.

Summary

The assessment of *Habromys delicatulus* by the MER grants this species the category of endangered (P). *Habromys delicatutulus*, must be included in the NOM-059-SEMARNAT-2010.

Criterion A = 4. Very restricted, due to its very limited distribution (less than 5% of Mexico’s territory).

Criterion B = 3. Very limiting, habitat is very harsh for the species’ needs.

Criterion C= 3. High vulnerability, as it is only known from one locality for which it has a high affinity.

Criterion D = 4. High impact, deforestation is reducing its already small distribution range.

We suggest taking care of its habitat, as this action will keep the species protected.

**Evaluation of risk of extinction**

**Scientific name**

*Habromys ixtlani* (Goodwin, 1964)

**Common names**

Ixtlán Deer mouse

Ratón de Ixtlán

**Taxonomic classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Rodentia

Family: Cricetidae

**Rationale for the proposal**

*Habromys ixtlani* is a small mouse from the genus *Habromys,* endemic to Mexico. This species only occurs on Cerro Machín, in Sierra de Juarez, Oaxaca (Carleton, Sánchez & Urbano Vidales, 2002), in San Pablo Macuiltianguis municipality. The vegetation type of this area is the cloud forest, which is in risk due to deforestation (COANBIO, 2010; CONABIO, 2014).

*Habromys ixtlani* is listed on IUCN’s red list under the category Critical Endangered (CR B1ab(iii)), as its extent of occurrence is less than 100km2, all individuals are in a single location, and there is continuing decline in the extent and quality of its habitat (Álvarez-Castañeda *et al*., 2008c). However this species is not either currently listed in the NOM-059-SEMARNAT-2010.

**MER** (Risk of Extinction Assessment Method)

**Criterion A: Distribution**

 Distribution

*Habromys ixtlani* has only been collected in one location at Cerro Machín in Sierra de Juárez, Oaxaca, in San Pablo Macuiltianguis municipality at elevations between 2500 to 3000m asl. (Carleton, Sánchez & Urbano Vidales, 2002; Álvarez-Castañeda *et al*., 2008c).

Map construction and evaluation

The map shows the currently known distribution of *Habromys ixtlani* (Figure. 1c main text), records were obtained from CONABIO’s databases (SNIB). We created the map with ArcMap V. 10.2 (ESRI, 2011) using Mexico’s Digital Map from the National Institute of Statistics and Geography (INEGI, acronym in Spanish) as base layer. To calculate the species’ distribution range we employed IUCN’s methodology (IUCN, 2012), using a 2 km grill (a cell area of 4 km2), as this scale is more accurate for species with small distributions. Every record of *Habromys ixtlani* was set as a dot over the map and grid, posteriorly each occupied cell was sum to obtain the value of occupied territory. The use of this methodology helps to avoid overestimate values for this species distribution.

*Habromys ixtlani* scored 4 points in the Criteria A, due to its very restricted distribution (less than 5% of Mexico’s territory).

**Criterion B: Habitat**

Habitat

*Habromys ixtlani* inhabits the cloud forest of Sierra de Juárez, Oaxaca. The vegetation type of this area is mostly pine-oak (Carleton, Sánchez & Urbano Vidales, 2002). The weather is temperate humid with abundant rains in the summer, temperature in Cerro Machín is between 14°C to 16°C, and precipitation range varies from 600 to 2000mm (INEGI, 2010c).

Diagnosis of the present habitat situation

*Habromys ixtlani* only occurs in this habitat in one single location. Therefore, for this rodent this specific habitat is essential for its survival. The only thing that is known about this species’ habits is that is an arboreal rodent (León-Paniagua *et al*., 2007).

This diagnosis was extracted from peer review articles and government publications.

 Diagnosis of the present habitat situation

The cloud forest in Mexico is the most threatened habitat in Mexico, with many endemic species such as *Habromys ixtlani* (Carleton, Sánchez & Urbano Vidales, 2002). The close relationship of this species with its very specific habitat elevates the stakes of the species if the habitat is loss.

*Habromys ixtlani* was scored with 3 points in the criterion B due to its habitat restriction and the threat that the cloud forest faces.

**Criterion C: Intrinsic vulnerability**

 Life history of the species

*Habromys ixtlani* is a small arboreal rodent which inhabits the highlands of Mesoamerica. The male total length and tail size ranges from 217 - 260mm and 126 – 141 mm respectively, while females range between 215 – 266mm and 107 – 143mm (Goodwin, 1966, León-Paniagua *et al*., 2007). Dorsal coloration cinnamon, mixed with brownish black; mid-dorsal region is predominantly black, sides and shoulders cinnamon, ears blackish brown, ventral parts creamy white. It is

Frugivore, but apart from this little is known.

Diagnosis of the current situation of the species

*Habromys ixtlani* is not a well-studied species with only some basic features known. It is arboreal and frugivore, and only occurs in the cloud forest of Sierra de Juárez, Oaxaca (Carleton, Sánchez & Urbano Vidales, 2002; León-Paniagua *et al*., 2007). The species is dependent of this cloud forest to survive, so it is highly vulnerable. IUCN’s Red List assessment classifies its population as decreasing due to habitat destruction (Álvarez-Casatañeda *et al*., 2008c).The diagnosis was performed with peer review articles.

Evaluation of the current status of the species

*Habromys ixtlani* population is decreasing (Álvarez-Casatañeda *et al*., 2008c), whereas little is known of its biology and ecology. More research on biology, ecology and demographics is needed to have a better assessment.

Due to its dependence to only one location and one type of habitat which is highly endangered, *Habromys ixtlani* was granted with 3 points on the Criterion C.

**Criterion D Human impact**

Real and potential risk factors

Habitat loss by deforestation is the major threat to this species (Álvarez-Casatañeda *et al*., 2008c). Even though agriculture only occupies around 11% of San Pablo Macuiltianguis municipality, Cerro Machín is close to the deforestation area (INEGI, 2010c). In addition there is a federal highway that crosses Cerro Machín. Studies like those of Stephen *et al* (2013) demonstrate that roads can affect the genetic composition of mice populations, even if they are walking paths or big roads. So it is a chance the road is affecting the population in Cerro Machín. Furthermore this can be addressed as a potential risk in the future, as we do not have genetic structure analyses to this species.

Prediction analysis for the species

*Habromys ixtlani* is in risk of extinction if uncontrolled logging continues in its distribution area. Conservation for the species must be performed via habitat protection, because of the lack of information and studies of biology, ecology and demography.

Impact assessment

*Habromys ixtlani* is in great risk of extinction due to its habitats loss (Pardini *et al*, 2005; Sullivan *et al*, 2013; Drobovolski *et al.*, 2013).

*Habromys ixtlani* was scored with 3 points due to the moderate logging of the area; however, if logging is not controlled it will soon the impact the species.

Final MER score

Criterion A= 4

Criterion B= 3

Criterion C= 3

Criterion D= 3

MER total is 13 points. This score places *Habromys ixtlani* as endangered (P), and must be included in the Mexican list of threatened wildlife species NOM-059-SEMARNAT-2010.

 Relevance of the species

*Habromys ixtlani*as a frugivore rodent has a very important role as ecosystem services provider, it contributes with seed dispersal (MEA, 2005), as biocontrol by competition of plant communities in the area it inhabits like other several rodents (Forget *et al*, 2011), it can also be prey for upper mammals that inhabit the cloud forest, and as insect pest control (Hanksi, 1987). For all these features, this rodent is important for the cloud forest ecosystem, and its absence might cause problems to the habitat and specially the plant structure and dynamics.

 Conservation suggestions

Conservation actions suggested

Due to difficulty to capture this rodent, studies on its ecology and biology are complicated, whereas the urgency to conserve it is a priority. The conservation actions to protect the species should concentrate in conserving its habitat. We suggest some approaches to tackle the deforestation problems to give a better outcome for the survival of *Hanbromys delicatulus* and other cloud forest species:

1. Payment for ecosystem services: in Mexico this approach has provided good results (García-Amado *et al*., 2011; Rico García-Amado, Ruiz & Barrasa, 2013) in conservation actions.
2. Sustainable logging practices: Specific vegetation on the area is unknown (maybe *Pinus* spp. or *Quercus* spp.), but logging is a practice which occurs in the area. As logging seems to be inevitable in the short-term, having better practices could help to protect the ecosystem.

Summary

The assessment of *Habromys ixtlani* grants the species as endangered (P) with an score of 13 and must be included in the NOM-059-SEMARNAT-2010.

Criterion A = 4. Very restricted, due to its very limited distribution (less than 5% of Mexico’s territory).

Criterion B = 3. Very limiting, habitat is very harsh for the species’ needs.

Criterion C= 3. High vulnerability, as it is only known from one locality for which it has a high affinity.

Criterion D = 3. High impact, deforestation is reducing its already small distribution range.

**Evaluation of risk of extinction**

**Scientific name**

*Habromys lepturus* (Merriam, 1898)

**Common names**

Ratón trepador cola larga

Zempoaltepec Deer Mouse

Slender Tailed Deer mouse

**Taxonomic classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Rodentia

Family: Cricetidae

**Rationale for the proposal**

*Habromys lepturus* is small endemic rodent from Mexico which only inhabits the highest zones of the cloud forest of Cerro Zempoaltepec (Carleton, Sánchez & Urbano Vidales, 2002; Lamoreux, McKnight & Cabrera, 2015), in Zempoaltepec, Oaxaca. This mouse is threatened by deforestation throughout its distribution range, and it is listed in IUCN’s red list of threatened species under the category of Critical Endangered (CR B1ab (iii)) because its extent of occurrence is less than 100km2, all individuals are in a single location and there is continuing decline in the extent and quality of its habitat (Álvarez-Castañeda *et al*., 2008d). Despite being in IUCN red list, *Habromys lepturus* is not listed in the Mexican list of threatened wildlife species NOM-059-SEMARNAT-2010.

 **MER** (Risk of Extinction Assessment Method)

**Criterion A: Distribution**

 Distribution

*Habromys lepturus* only inhabits the highest regions of Cerro Zempoaltepec, Oaxaca. At elevations between 2500 to 3000m asl (Álvarez-Castañeda *et al*., 2008d; Léon & Romo, 2005).

Map construction and evaluation

The map shows the current known distribution of *Habromys lepturus* (Figure. 1d main text). Coordinates for all recorded individuals were obtained from CONABIO’s databases (SNIB). We created the map with ArcMap V. 10.2 (ESRI, 2011) using Mexico’s Digital Map from the National Institute of Statistics and Geography (INEGI, acronym in Spanish) as base layer. To calculate the species’ distribution range we employed IUCN methodology (IUCN, 2012): a grill of 2 km (a cell area of 4 km2), which according to IUCN is more accurate for species with small distributions, and it allows taxa to be assessed by the criterion B and get into the critically endangered threshold (if it is required). Every record of *Habromys lepturus* was set as a dot over the map and grid, posteriorly each occupied cell was sum to obtain the value of occupied territory. The use of this methodology helps to avoid overestimating values for this species distribution.

*Habromys lepturus* scored 4 points in Criterion A, due to its very restricted distribution (less than 5% of Mexico’s territory).

**Criterion B: Habitat**

Habitat

*Habromys lepturus* inhabits the cloud forest of Sierra Zempoaltepec, Oaxaca. The vegetation type of this habitat is compound of pines (*Pinus* spp), oaks (*Quercus* spp) and ferns. Trees are covered by bromeliads, mosses, lichens, and several other epiphytes, and this mouse uses bromeliads as shelter (León & Romo, 2005). According to INEGI (2010d), the climate is temperate humid with summer rains, mean temperature of Cerro Zempoaltepec is 14°C, and precipitation is around 1200mm per year.

Diagnosis of the present habitat situation

*Habromys lepturus* is an arboreal rodent (León-Paniagua *et al*., 2007), using bromeliads as shelter. Like all other cloud forests in Mexico, *Hambromys lepturus’* habitat is in risk due to deforestation (CONABIO, 2014). The survival of this species depends on habitat condition.

The diagnosis was performed by peer review articles and government publications

 Evaluation of the currently status of taxon’s habitat

*Habromys lepturus* is highly dependent on its habitat. It does not occur in any other region of Sierra Zempoaltec rather than Cerro Zempoaltepec, or in any other cloud forest in Mexico (Carleton, Sánchez & Urbano Vidales, 2002; Paniagua & Romo, 2005; Álvarez-Castañeda *et al*., 2008d). For this reason the habitat is very specific for the species, and due to the degree of disturbance it presents, we scored the species with 3 points for the Criterion B.

**Criterion C: Intrinsic vulnerability**

 Life history of the species

*Habromys lepturus* is arboreal, inhabiting humid environments (Léon & Romo, 2005; León-Paniagua *et al*., 2007) and using bromeliads as shelter. This species is frugivorous, and includes seeds in its diet. This rodent has a medium (between 207 to 262 mm total length), and a weight of 32g. The coloration of the back is dark with brown blackish and cinnnamon hairs, ventral area is bicolor, thin ears covered by tiny brown hairs; long tail, almost as long as the head and body (Léon & Romo, 2005). Its reproduction is seasonal, taking place in the beginning of rain season (May and June), and the average litter of the species is 1.9 individuals (León & Romo, 2005).

Diagnosis of the current situation of the species

Despite the gaps of information for *Hambromys lepturus*, we know that the population trend is decreasing (Álvarez-Castañeda *et al*., 2008d), due in part to its seasonal breeding, as this species can only have one reproductive event per year and in average litter is less than 2 pups (Léon & Romo, 2005). For this reason, the species has a high biological vulnerability.

Evaluation of the current status of the species

*Habromys lepturus* population is decreasing (Álvarez-Castañeda *et al*., 2008d), as a result to its low reproduction rate (Léon & Romo, 2005). Moreover, climate change will directly impact further its reproductive success. For these reasons, we scored the species with 3 points for criterion C.

**Criteria D Human impact**

Real and potential risk factors

Deforestation within *Habromys lepturs’* distribution range is high. INEGI (2010d) reports that agriculture occupies almost de 29% of the municipality area where the species is found. Moreover, induced grassland as a product of deforestation is about 2% of municipality’s territory, and these grasslands are located next to the species’ collection site. Finally, climate change is also a potential risk to this mouse as changes in the periodicity of the rainy season could impact the reproductive season.

Prediction analysis for the species

*Hambromys lepturus* will become extinct if deforestation throughout its distribution range continues. Moreover, this species has small litters and a reproductive cycle that is highly dependent on climatic conditions, so the prediction for its survival is not good with the current conditions of severe anthropogenic pressure.

Impact assessment

*Habromys lepturus* is in high risk of extinction due to human impact to its environment. Thus, the species scored 4 points in the Criterion D.

Final MER score

Criterion A= 4

Criterion B= 3

Criterion C= 3

Criterion D= 4.

MER total is 14 points. This score places *Habromys lepturus* as endangered (P), and must be included in the Mexican list of threatened wildlife species NOM-059-SEMARNAT-2010.

Species relevance

*Habromys lepturus* is an endemic species of Sierra Zempoaltepec, Oaxaca, it is only found at Cerro Zempoaltepec in the cloud forest, at elevation between 2500 to 3000 m asl. It is a frugivore rodent, which provides essential ecosystem services to its habitat (MEA, 2205), including the regulation of competition between plant communities (Forget *et al*, 2011).

Conservation suggestions

Little is known about *Habromys lepturus* biology, ecology, and population biology, so conservation actions targeted towards this species should be directed towards the habitat.

1. Payment for ecosystem services: in Mexico this approach has provided good results (García-Amado *et al*., 2011; Rico García-Amado, Ruiz & Barrasa, 2013) in conservation actions.
2. Sustainable logging practices: Specific vegetation on the area is unknown (maybe *Pinus* spp. or *Quercus* spp.), but logging is a practice which occurs in the area. As logging seems to be inevitable in the short-term, having better practices could help to protect the ecosystem.

 Summary

The assessment of *Habromys lepturus* grants the species the category of endangered (P) with 14 total points and must be included in the NOM-059-SEMARNAT-2010.

Criterion A = 4. Very restricted, due to its very limited distribution (less than 5% of Mexico’s territory).

Criterion B = 3. Very limiting, habitat is very harsh for the species’ needs.

Criterion C= 3. High vulnerability, as it is only known from one locality for which it has a high affinity.

Criterion D = 4. High impact, deforestation is reducing its already small distribution range.

**Evaluation of risk of extinction**

**Scientific name**

*Habromys schmidlyi* (Romo-Vázquez, León-Paniagua & Sánchez, 2005)

**Common names**

Ratón

Schmidly’s Deer Mouse

**Taxonomic classification**

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Rodentia

Family: Cricetidae

**Rationale for the proposal**

*Habromys schmidlyi* is a small mouse endemic to Mexico that only inhabits one location at Sierra de Taxco, a mountain range which encompasses the states of Guerrero and Mexico (Romo-Vázquez *et al*., 2005). *Habromys schmidly* is threatened by deforestation, as the cloud forest is the most threatened in the country (CONABIO, 2010; CONABIO, 2014). IUCN´s Red List of threatened species has listed the species as critically endangered (CR B1ab(iii)), because its extent of occurrence is less than 100km2, all individuals are in a single location, and there is a continuous decline in the extent and quality of tis habitat (Álvarez-Castañeda *et al*., 2008e). Unfortunately, despite these facts, *Habromys schmidlyi* is not listed in the Mexican list of threatened wildlife species NOM-059-SEMARNAT-2010.

**MER** (Risk of Extinction Assessment Method)

**Criterion A: distribution**

 Distribution

*Habromys schmidlyi* is known from 3 localities in Sierra de Taxco in the Trans-Mexican Volcanic Belt. 2 localities are from Almoloya de Alquisiras municipality at 1870 and 1800 m asl. The last locality is known in Guerrero State, Cerro Huizteco, at 2300m asl.

Map construction and evaluation

The map shows the current known distribution of *Habromys schmidlyi* (Figure. 1e main text). Coordinates for all recorded individuals were obtained from CONABIO’s databases (SNIB). We created the map with ArcMap V. 10.2 (ESRI, 2011) using Mexico’s Digital Map from the National Institute of Statistics and Geography (INEGI, acronym in Spanish) as base layer. To calculate the species’ distribution range we employed IUCN methodology (IUCN, 2012): a grill of 2 km (a cell area of 4 km2), which according to IUCN is more accurate for species with small distributions, and it allows taxa to be assessed by the criterion B and get into the critically endangered threshold (if it is required). Every record of *Habromys schmidlyi* was set as a dot over the map and grid, posteriorly each occupied cell was sum to obtain the value of occupied territory. The use of this methodology helps to avoid overestimating values for this species distribution.

*Habromys schmidlyi* scored 4 points in the Criteria A, due to its very restricted distribution (less than 5% of Mexico’s territory).

**Criterion B: habitat**

Habitat

*Habromys schmidlyi* inhabits Sierra de Taxco, a 360km long mountain range. It is found within the cloud forest, with temperate with rains all year-round (INEGI, 2008f). The dominant tree species were the species was collected were *Quercus affinis*, *Q. seyatophila*, *Q. laurina*, *Q. castanea*; these trees are often covered with epiphytes like orchids, ferns or bromeliads (Romo-Vázquez *et al*., 2005). Mean temperatures are between 16°C-18 with 1200mm of annual precipitation (INEGI, 2010e; INEGI, 2010f). One observation suggests *Habromys schmidlyi* uses bromeliads as shelter (Romo-Vázquez *et al*., 2005).

Diagnosis of the present habitat situation

The cloud forest is the most threatened habitat in Mexico, and this species is dependent on this habitat (Romo-Vázquez *et al*., 2005). Changes in land use are causing hardship for the species throughout its distribution.

The diagnosis was performed with peer review articles and government publications.

Evaluation of the present habitat status

*Habromys schmidlyi* is highly specific to the cloud forest, a habitat that is considered the most endangered in Mexico, hence the species extreme vulnerability; it has only been recorded in the cloud forest of Sierra de Taxco at 3 localities along its 360km range. Therefore changes in the habitat affect directly the species’ survival. Moreover, it uses specific types of tress for shelter and feeding.

Due to this tight association with its habitat and microendemism, the species was granted 3 points in Criterion B, because the very harsh conditions of its habitat relative to its needs.

**Criterion C: intrinsic vulnerability**

 Life history of the species

*Habromys schmidlyi* is an arboreal or partially arboreal rodent which only occurs in Sierra de Taxco, between 1800 and 2300m asl in the cloud forest (Romo-Vázquez *et al*., 2005). This mouse uses bromeliads as shelter; feeds on seeds of trees and observations suggest that feeds on mushrooms as well (Romo-Vázquez *et al*., 2005).

This species has a small body size (total length ranges between 216 and 262 mm), bicolored tail, black above, white below, which is long relative to body length (about 103-137 mm, and covered with long hairs; dorsal pelage is chestnut brown, with a narrow dusky area mid-dorsally; ventral coloration is white, with a narrow yellow collar, and a pale lateral line (Romo-Vázquez *et al*., 2005).

Diagnosis of the current situation of the species

Schmidly’s deer mouse is endemic to Mexico, with a restricted distribution range within the cloud forest. There is a gap of information for this species in terms of ecology and biology alike, however, with the little information available it is possible to know that its situation is precarious. IUCN considers that the population trend is decreasing (Álvarez-Castañeda *et al*., 2008e), due to deforestation. In addition this is a rare species to collect, Romo-Vázquez *et al* (2005), mentioned that in 737 trap nights they only captured 9 Schmidlyi deer mice. In another similar effort with 627 trap nights they only captured two mice.

The diagnosis was performed with peer review articles.

Evaluation of the current status of the species

The species is threatened and the information gap makes it even more difficult to assess however due to its endemism to Sierra de Taxco, and because of its rareness it has been granted with 3 points in the Criterion C.

**Criterion D: human impact**

Real and potential risk factors

The major threat to *Habromys Schmidly* is habitat lost by deforestation, which is decreasing its population (Álvarez-Castañeda *et al*., 2008e). Agriculture in its area of distribution is extensive. In Almoloya de Alquisiras municipality, agriculture occupies around 34.5% of the territory. Moreover, fragmentation is another threat as collection localities are close to a federal road (INEGI, 2010e), and Stephen *et al* (2013) found that even small paths inside the forests, not only big roads can directly affect the demography of rodent species and their genetic diversity. If deforestation and fragmentation increase the species probably will get extinct.

Prediction analysis for the species

*Habromys schmidlyi* will become extinct if uncontrolled logging keeps going on Sierra de Taxco, as most probably its population size is small, with low reproduction rates.

Impact assessment

*Habromys schmidlyi* is endangered as its habitat is being lost as logging, extensive agriculture, and fragmentation are prevalent in its distribution area. Thus, the species scored 4 points in criterion D, due to the high anthropogenic pressure it endures.

Final MER score

Criterion A= 4

Criterion B= 3

Criterion C= 3

Criterion D= 4

MER total is 14 points. The value grants *Habromys schmidlyi* the status of endangered (P) and must be included in the NOM-059-SEMARNAT-2010.

Species relevance

*Habromys schimidlyi* is a frugivore rodent which inhabits the cloud forest of Sierra de Taxco, between the states of Guerrero Mexico. As a frugivore, it provides essential ecosystem services (MEA, 2005) and plays an important role in plant communities by dispersing seeds far from the parental plant (Forget *et al*, 2011).

Conservation suggestions

Little is known about *Habromys schmidlyi* biology, ecology, and population biology, so conservation actions targeted towards this species should be directed towards the habitat.

1. Payment for ecosystem services: in Mexico this approach has provided good results (García-Amado *et al*., 2011; Rico García-Amado, Ruiz & Barrasa, 2013) in conservation actions.
2. Sustainable logging practices: Specific vegetation on the area is unknown (maybe *Pinus* spp. or *Quercus* spp.), but logging is a practice which occurs in the area. As logging seems to be inevitable in the short-term, having better practices could help to protect the ecosystem.

 Summary

Criterion A = 4. Very restricted, due to its very limited distribution (less than 5% of Mexico’s territory).

Criterion B = 3. Very limiting, habitat is very harsh for the species’ needs.

Criterion C= 3. High vulnerability, as it is only known from three localities in the cloud forest of Guerrero and Mexico states.

Criterion D = 4. High impact, deforestation is reducing its already small distribution range.

**References**

Álvarez-Castañeda, S.T., Castro-Arellano, I., Lacher, T. & Vázquez, E. 2008a. *Habromys chinanteco*. The IUCN Red List of Threatened Species 2008: e.T9608A13004362. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T9608A13004362.en . Downloaded on **14 October 2015**.

Álvarez-Castañeda, S.T., Castro-Arellano, I., Lacher, T. & Vázquez, E. 2008b. *Habromys delicatulus*. The IUCN Red List of Threatened Species 2008: e.T136683A4327272. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T136683A4327272.en . Downloaded on **14 October 2015**.

Álvarez-Castañeda, S.T., Castro-Arellano, I., Lacher, T. & Vázquez, E. 2008c. *Habromys ixtlani*. The IUCN Red List of Threatened Species 2008: e.T136582A4313474. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T136582A4313474.en . Downloaded on **14 October 2015**.

Álvarez-Castañeda, S.T., Castro-Arellano, I., Lacher, T. & Vázquez, E. 2008d. *Habromys lepturus*. The IUCN Red List of Threatened Species 2008: e.T9609A13004502.http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T9609A13004502.en . Downloaded on **14 October 2015**.

Álvarez-Castañeda, S.T., Castro-Arellano, I., Lacher, T. & Vázquez, E. 2008e. *Habromys schmidlyi*. The IUCN Red List of Threatened Species 2008: e.T136616A4318725.http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T136616A4318725.en . Downloaded on **14 October 2015**.

Briones-Salas, M., Hernández-Allende, A., Coronel, M. M., & Pérez, G. G. (2012). New Records of the Endemic Chinanteco Deermouse Habromys chinanteco (Rodentia: Cricetidae) in the Sierra Madre de Oaxaca, Mexico. *The Southwestern Naturalist*, *57*(2), 221–222. http://doi.org/10.1894/0038-4909-57.2.221

Carleton, M. D., Sanchez, O., & Vidales, G. U. (2002). A New Species Of Habromys (Muroidea : Neotominae) From Mexico, With Generic Review Of Species Definitions And Remarks On Diversity Patterns Among Mesoamerican Small Mammals Restricted To Humid Montane Forests. *Proceedings of The Biological Society of Washington*, *115*, 488–533. Retrieved from http://biostor.org/reference/81388

CONABIO. (2010). *El Bosque Mesófilo de Montaña en México: Amenazas y oportunidades para su conservación y manejo sostenible* (p. 196). México: CONABIO.

CONABIO. (2014). *Bosques Mesófilos de Montaña de México diversidad, ecologia y manejo*. (M. Gual-Díaz & A. Rendón-Correa, Eds.) (p. 345). México.

Dobrovolski, R., Loyola, R. D., Guilhaumon, F., Gouveia, S. F., & Diniz-Filho, J. A. F. (2013). Global agricultural expansion and carnivore conservation biogeography. *Biological Conservation*, *165*, 162–170. http://doi.org/10.1016/j.biocon.2013.06.004

ESRI. (2011). ArcGis Desktop. Redlands CA: Environmental Systems Research Institue.

Forget, P.-M., Jordano, P., Lambert, J. E., Böhning-Gaese, K., Traveset, A., & Wright, S. J. (2011). Frugivores and seed dispersal (1985–2010); the “seeds” dispersed, established and matured. *Acta Oecologica*, *37*(6), 517–520. http://doi.org/10.1016/j.actao.2011.09.008

García, E. (1998). *Modificaciones al sistema de clasificación climática de Köppen*. México: Instituto de Geografía. Universidad Nacional Autónama de México.

García-Amado, L. R., Pérez, M. R., Escutia, F. R., García, S. B., & Mejía, E. C. (2011). Efficiency of Payments for Environmental Services: Equity and additionality in a case study from a Biosphere Reserve in Chiapas, Mexico. *Ecological Economics*, *70*(12), 2361–2368. http://doi.org/10.1016/j.ecolecon.2011.07.016

Goodwin, G. G. (1964). A new Species and a New Subspecies of Peromyscus from Oaxaca, Mexico. *American Museum Novitates*, *2183*, 1–8.

Hanski, I. (1987). Pine sawfly population dynamics: patterns, processes, problems. *Oikos1*, *50*, 327–335.

INEGI. (2010a). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: Ixtlán de Juárez, Oaxaca. Clave geoestadística 20042*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

INEGI. (2010b). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: Jilotepec, Estado de México. Clave geoestadística 15045*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

INEGI. (2010c). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: San Pablo Macuiltianguis, Oaxaca. Clave geoestadística 20296*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

INEGI. (2010d). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: Santiago Choápam, Oaxaca. Clave geoestadística 20460*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

INEGI. (2010e). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: Almoloya de Alquisiras, Estado de México. Clave geoestadística 15004*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

INEGI. (2010f). *Compendio de infromación geográfica municipal de los Estados Unidos Mexicanos: Taxco de Alarcón, Guerrero. Clave geoestadística 12055*. Retrieved from http://www.inegi.org.mx/geo/contenidos/Topografia/Compendio.aspx

IUCN. 2012. *IUCN Red List Categories and Criteria: Version 3.1* (Second Edi, p. 32PP). Gland, Switzerland and Cambridge, UK: IUCN.

León-Paniagua, L., Navarro-Sigüenza, A. G., Hernández-Baños, B. E., & Morales, J. C. (2007). Diversification of the arboreal mice of the genus Habromys (Rodentia: Cricetidae: Neotominae) in the Mesoamerican highlands. *Molecular Phylogenetics and Evolution*, *42*(3), 653–64. http://doi.org/10.1016/j.ympev.2006.08.019

León-Paniagua, L., & Romo, E. (2005). Habromys lepturus. In G. Ceballos & G. Oliva (Eds.), *Los Mamíferos Silvestres de México* (pp. 673–674). México: CONABIO.

MEA. (2005). *Millenium Ecosystem Assessment. Ecosystems and Human Well Being. Biodiversity Synthesis*.

Merriam, C. H. (1898). Descriptions of twenty new species and a new subgenus of Peromyscus from Mexico and Guatemala. *Proceedings of the Biological Society of Washington*, *12*, 115–125.

Pardini, R., de Souza, S. M., Braga-Neto, R., & Metzger, J. P. (2005). The role of forest structure, fragment size and corridors in maintaining small mammal abundance and diversity in an Atlantic forest landscape. *Biological Conservation*, *124*(2), 253–266. http://doi.org/10.1016/j.biocon.2005.01.033

Rico García-Amado, L., Ruiz Pérez, M., & Barrasa García, S. (2013). Motivation for conservation: Assessing integrated conservation and development projects and payments for environmental services in La Sepultura Biosphere Reserve, Chiapas, Mexico. *Ecological Economics*, *89*, 92–100. http://doi.org/10.1016/j.ecolecon.2013.02.002

Robertson, P. B., & Musser, G. G. (1976). A NEW SPECIES OF PEROMYSCUS (RODENTIA: CRICETIDAE), AND A NEW SPECIMEN OF P. SIMULATUS FROM SOUTHERN MEXICO, WITH COMMENTS ON THEIR ECOLOGY. *Occasional Papers of the Museum of Natural History, the University of Kansas.*, *no.47*, 1–8. Retrieved from http://www.biodiversitylibrary.org/item/26111

Romo-Vázquez, E., León-Paniagua, L., Sánchez, O., & Graves, G. R. (2005). A new species of Habromys (Rodentia: Neotominae) from México. *Proceedings of the Biological Society of Washington*, *118*(3), 605–618. http://doi.org/10.2988/0006-324X(2005)118[605:ANSOHR]2.0.CO;2

STEPHENS, H. C., SCHMUKI, C., BURRIDGE, C. P., & O’REILLY-WAPSTRA, J. M. (2013). Habitat fragmentation in forests affects relatedness and spatial genetic structure of a native rodent, Rattus lutreolus. *Austral Ecology*, *38*(5), 568–580. http://doi.org/10.1111/aec.12001

Sullivan, T. P., Sullivan, D. S., Lindgren, P. M. F., & Ransome, D. B. (2013). Stand structure and small mammals in intensively managed forests: Scale, time, and testing extremes. *Forest Ecology and Management*, *310*, 1071–1087. http://doi.org/10.1016/j.foreco.2013.02.025