Comparison of national and regional status assessments of amphibians and reptiles in Guatemala.

Rowland K. Griffin[1, 2], Joseph Tzanopoulos[1], Richard A. Griffiths[1]

[1]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Marlowe Building, Canterbury, Kent CT2 7NR, UK.

[2]Indigo Expeditions, 37 Chamberlain Street, Wells, England, BA5 2PQ

Corresponding author: Rowland K. Griffin (rowland@explorewithindigo.com)

Introduction

Guatemala is known as a mega-diverse country and is currently understood to contain around 388 species of amphibians (143 species) and reptiles (245 species) (Acevedo et al. 2010; Griffin and Powell 2014; Ariano-Sanchez and Campbell 2018). Like many countries in the tropics the herpetofauna of Guatemala is highly endemic with 27% of amphibian and 10% of reptiles only occurring in the country (Acevedo et al. 2010). As a consequence, much of the amphibian and reptile conservation focus has been centred on regions with high levels of endemism, including the Western and Central Highlands and the Motagua Valley (Duellman and Campbell 1992; Campbell and Frost 1993; Coti and Ariano-Sánchez 2008; Campbell et al. 2010). Although the northern region of Petén, the northernmost department of Guatemala, has been devoted to protected land in the form of the Mayan Biosphere Reserve (MBR) most conservation research has been focused on large enigmatic vertebrates (Wultsch et al. 2016; Lepe-López et al. 2018; Schmidt et al. 2020; Corado García et al. 2020; García-Anleu et al. 2007). but the study of terrestrial herpetofauna has been limited.

In order to assess the conservation status of amphibians and reptiles at such wide regional scales, a system known as Environmental Vulnerability Scores (EVS) has been employed. Studies have so far focused on employing EVS at country level for Central America and at state level for Mexico (Wilson et al. 2010; Johnson et al. 2015; Mata Silva et al. 2015; González-Sánchez et al. 2018; Ramirez Bautista et al. 2020). The EVS takes into account the distribution of a given species at both global and regional scales, whilst accounting for sensitivities in breeding ecology (frequently the case for amphibians) and vulnerability to human persecution (frequently a risk for reptiles) (Johnson et al. 2015). As a consequence, the EVS system of assessment is effective at revealing species in need of conservation attention at the regional scale in which it is used. A disparity between EVS assessments and the widely known IUCN Red List assessments is often reported, where there are far fewer species of conservation concern at the IUCN level in a given region (Acevedo et al. 2010; González-Sánchez et al. 2018). The reason for this disparity is due in part to the fact that the IUCN Red List only considers the status of a given species at a broader global scale. While the IUCN listings are undoubtably of key value, such lack of resolution at the regional scale can lead to misassigned conservation priorities when they are used to assess local conservation planning. Additionally, a national endangered species list (Lista de Especies Amenzadas or LEA) is compiled annually in Guatemala which places threatened species in one of three categories: 1) Critical Danger (PC) for species that are close to extinction; 2) Endangered (EP) for species that are nationally endemic and with restricted ranges that are threatened by habitat loss and often illegal trade; and 3) Vulnerable (VU) for species that are threatened by habitat loss or trade but where populations are such that regulated use of the species is possible (CONAP 2009). Using data from PNLT as a case study, this is the first attempt to use EVS to assess the conservation status of amphibians and reptiles in at a National Park level. The PNLT EVS scores

are then compared to existing global and national endangered species lists to assess the usefulness of EVS for conservation planning at a regional scale.

The objectives of this chapter were to: a) provide a comprehensive assessment of the amphibian and reptile diversity of PNLT and assess levels of amphibian and reptile diversity and endemism in PNLT; b) assess the conservation status of amphibian and reptile species in PNLT; and c) compare IUCN Red List and national LEA species with EVS assessments of amphibians and reptiles in PNLT.

Methods

Study Area

Parque Nacional Laguna del Tigre (PNLT) is located in north western Petén in Northern Guatemala and borders Mexico to the north and west. It is the largest of the core zones within the MBR, and covers approximately 289,000 hectares, and contains the largest protected wetland in Central America (Wallace 1997; Bestelmeyer 2000; Monzón-Alvarado et al. 2012). Northern Petén forms the southern limits of the Yucatán Platform and is characterized by a karst landscape, that is dominated by thin, fragile limestone soils (Monzón-Alvarado et al. 2012). The limestone that forms the platform was laid down during the Miocene and is typified by limestone cliffs along the few river courses that exist (Bestelmeyer 2000). The terrain of PNLT is mostly flat with undulations reaching a maximum of 300 m altitude (Bestelmeyer 2000; Monzón-Alvarado et al. 2012). PNLT is subject to distinct wet and dry seasons and receives, on average, 1600 mm of rain annually. The dry season lasts from January to April where temperatures may exceed 40˚ C (Bestelmeyer 2000). This high degree of seasonality may present significant challenges for the ecological communities of PNLT. The

vegetation of PNLT is dominated by corozo palm (*Attalea cahune*), ceiba (*Ceiba pentandra*), guarumo (*Cecropia* spp.) and ramón (*Brosimum alicastrum*) and is classed as Tropical Moist Forest under the classification system of Holdridge (1967) or Subtropical Moist Forest (warm) by Acevedo et al. (2010). The undulating limestone leads to variation in soil drainage and consequently two main forests types have developed (Bestelmeyer 2000). Over half of the forest cover in PNLT is classed as high forest (known locally as Bosque Altos) which is situated on the higher undulations (Monzón-Alvarado et al. 2012). High forest is characterized by well drained soils, a 30 m canopy with abundant leaf litter and little undergrowth (Bestelmeyer 2000; Monzón-Alvarado et al. 2012). A further 20% of PNLT is covered by seasonally flooded low forest (known locally as Bosque Bajo), which possess a lower canopy that is between 15 to 20 m, along with a dense understory (Bestelmeyer 2000; Monzón-Alvarado et al. 2012). The remaining area of PNLT is made up of wetlands (16%), seasonally flooded savannas (5%), and agriculture and pasture (9%) (Monzón-Alvarado et al. 2012).

Biological Records

Field data was collected in Parque Nacional Laguna del Tigre from 2013 to 2016 using adhoc and transect based surveys (Fig. 1). Estación Biológica las Guacamayas (EBG) is located in the south east of Parque Nacional Laguna del Tigre (PNLT) on the banks of the Rio San Pedro (Fig. 2). The Tropical Moist Forest (Holdridge 1967) of EBG consists of several habitat types including both primary and secondary forest, saw-grass swamp and thorn scrub. It is bordered to the east by concessional agricultural lands that belong to the nearby Quecchi Maya community of Paso Caballos. Transect surveys were conducted in four forest habitats, Agricultural Edge, High Forest, Low Forest and Natural Edge within the ownership of EBG (Fig. 2). Additional adhoc visual encounter surveys were conducted around the buildings of EBG

and the saw-grass swamp near the confluence of the San Pedro and Sacluc rivers (Fig. 2). Field data was augmented with information garnered from a search of primary literature using keywords (reptiles, amphibians, Northern Guatemala, Laguna del Tigre), known publications from PNLT (Lee 1996; Bestelmeyer and Alonso 2000) and from photographically verified personal communications with other fieldworkers in PNLT.

Field Methods

In each of the four habitats, 100 m transects were conducted both along existing trail systems and on transects cut sensitively into the forest away from the trails. Transects were placed to allow a representative sample of each habitat and promote heterogeneous sampling across microhabitats for efficient detection of herpetofauna (Crump and Scott 1994; Doan 2003; Marsh and Haywood 2010). The start points for each transect (Fig. 2) were positioned at least 50 m from the nearest forest edge to allow for any edge effects to be taken into account that may have risked biasing detection (Schlaepfer and Gavin 2001; Urbina-Cardona et al. 2006). Transects were marked every 25 m with flagging tape to indicate the path of the transect, and GPS waypoints were taken at the start and finish points using a handheld GPS device (Garmin^{TM} GPSMap 62s) to facilitate accurate survey replication. After setup, transects were left for a minimum of two days before surveying commenced to allow for animals to resume normal activity prior to survey (Crump 1994). All transects had negligible changes in altitude and were positioned to avoid passing through broad habitat types in order to satisfy assignment of habitat categorization (Babbitt et al. 2009). Surveys took approximately 45 minutes to one hour to complete and followed standardized protocols for Visual Encounter Surveys in tropical habitats (Rödel and Ernst 2004; Vonesh et al. 2009).

To maximize chances of detecting species with different autecology, each transect was surveyed three times, twice at night and once in the morning during each survey period (Heyer et al. 1994; McDiarmid et al. 2012). For the purposes of statistical analyses nocturnal and diurnal surveys were grouped. A minimum of two days was left between surveys of the same transect to maintain independence of sample survey periods. Surveys were conducted during seven fieldwork periods in May-June 2013, November-December 2013, June 2014, October 2014, June 2015, December 2015 and June-July 2016. A total of 86 transects were surveyed, comprising 17 in AE, 22 in HF, 23 in LF, and 24 in NE respectively. The order in which the four forest habitats were surveyed was randomized, as was the order of transects within each habitat. In some cases, fieldwork was hampered by inclement weather and surveys had to be abandoned, hence the non-equal survey effort.

Data Collection

Visual encounter surveys are a well-known method for surveying amphibians and reptiles (Crump and Scott 1994; Lovich et al. 2012). Surveys teams consisted of between two and eight people, and included one local guide, the principal author (RKG) and two to six field assistants. At the start of each field session, all guides and field assistants were trained in survey techniques, data collection, and species identification by RKG. All biometric and environmental data collection was overseen by RKG to avoid observer bias. Transects were walked at a suitably slow pace to allow detection of reptiles and amphibians by thorough examination of vegetation and refugia, such as leaf litter, fallen limbs and rocks (Crump and Scott 1994; Lovich et al. 2012).

Conservation Status Evaluations

Calculation of Environmental Vulnerability Scores (EVS) follows Acevedo et al. (2010) and included reassessments of five species that have been revised taxonomically, and one species that was recorded in Guatemala for the first time since the 2010 assessment. EVS scores are a popular method for assessing the regional conservation status of species (Wilson et al. 2010; Johnson et al. 2015; Mata Silva et al. 2015). Scores are calculated based on a species' geographic distribution, specialization of reproductive mode for amphibians, vulnerability to human persecution for reptiles, and ecological distribution based on the number 14 life-zones of Guatemala a given species occurs in as described by Acevedo et al. (2010) and summarized in Table 1. Scoring criteria are explained in more detail in Table 2. Each scoring criterion holds a value with the lowest scores being awarded for less specialized characteristics and higher scores awarded to those that are more highly specialized. After scores have been assessed for all characteristics of a given species, they are summed to give an overall EVS score. Following previous assessments of Guatemala herpetofauna (Acevedo et al. 2010), species with EVS scores between 3 to 9 were classed as of low vulnerability, those with scores between 10 to 13 of medium vulnerability, and those with scores between 14 to 19 of high vulnerability. Categorization of each species occurring in PNLT by the IUCN were obtained from the IUCN list of threatened species website (IUCN 2021) and cross-referenced with Acevedo et al. (2010). Distributional statuses were assessed using distribution records in Köhler (2008) for reptiles and Köhler (2011) for amphibians and using online resources (AmphibiaWeb and ReptileDatabase accessed 17/07/2021). They were defined as those restricted to the Yucatán Peninsula classed as Regional Endemic (RE), those that occurred

outside of Guatemala but that have restricted distributions with the country as Range Restricted (RR), and those that occurred widely outside of Guatemala as Non-Endemic (NE).

Results

Diversity and Endemism

During this study, fieldwork confirmed the presence of 92 species of amphibian and reptile in PNLT, including 20 species of amphibian (8 families / 17 genera), 27 species of lizard (10 families / 15 genera), 37 species of snake (4 families / 29 genera), seven species of turtle (3 families / 6 genera), and one species of crocodylian (1 family / 1 genus). Three additional species have been recorded by other workers in PNLT but had not yet been recorded during this study: the hylid frog species *Dendropsophus ebracattus,* hourglass treefrog, (Bestelmeyer and Alonso 2000) and *Agalychnis moreletii,* black-eyed treefrog (Tut pers. comms. and photograph verified), and the colubrid snake *Senticolis triaspis,* green ratsnake (Tut pers. comms. and photograph verified). Therefore, when these records are included, PNLT supports 95 species of which 22 are amphibian (8 families / 17 genera), 27 species of lizard (10 families / 15 genera), 38 species of snake (4 families / 30 genera), seven species of turtle (3 families / 6 genera), and one species of crocodylian (1 family / 1 genus).

No country endemics are found in PNLT, but 3 species of amphibian, 2 lizards, and 7 snakes are considered regionally endemic to the Yucatán Peninsula and are at the southernmost part of their range in northern Guatemala (Table 3). Several other species have highly restricted ranges, including the crocodylian *Crocodylus moreletii*, and 5 species of turtle, including *Dermatemys mawii* which is listed as Critically Endangered by IUCN, and 4 lizards (Table 3). No amphibian species were found to have restricted ranges in Guatemala, 9.1% were classified as regional endemics, with the remaining 90.9% being classified as non-endemic

(Table 4). Whereas 15.1% of reptile species were classified as range restricted, 10.1% were classed as regional endemic, and the remaining 73.9% were classified as non-endemic (Table 5). Although the colubrid snake *Tropidopdipsas fasciatus* has a wide range in Mexico, PNLT is currently the only location in Guatemala where the species has been recorded and so is considered range restricted in the country in this study (Griffin and Powell 2014). Two species of gekkonid lizard are non-native, having been introduced through human activities and both belong to the African-Eurasian genus *Hemidactylus* (Table 3).

Conservation Status

Environmental Vulnerability Scores (EVS) were calculated for all 22 amphibian and 71 reptile species that are currently known to occur in PNLT, the two non-native geckos were excluded from this analysis as they were only detected around human constructs and were not considered a threat to native fauna. Five species of reptile (1 crocodylian and 4 turtles) were found to have High EVS scores (Table 3). Four species of amphibians, 3 turtles, 8 lizards, and 20 snakes were found to have Medium scores. The remaining 18 amphibian, 19 lizard, and 18 snake species were found to have low scores. The seven species that were reassessed did not change their EVS status compared to Acevedo et al. (2010). A review of the IUCN Red List website identified 1 Critically Endangered turtle, 1 Vulnerable amphibian and 1 Vulnerable crocodilian, 4 Near Threatened turtles and 1 Near Threatened lizards, and 7 Least Concern amphibians, 2 Least Concern turtles, 9 Least Concern lizards, and 37 Least Concern snakes, and 1 Data Deficient snake (Tables 4 and 5). There is a disparity between EVS and IUCN assessments of the conservation status of amphibians and reptiles in PNLT. In the case of amphibians 18% of species are of conservation concern using EVS scores (High and Medium vulnerabilities), whereas only 4.5% are of conservation concern using IUCN statuses (CR, EN,

VU, NT). The disparity is more pronounced when reptiles are considered with 49.3% of species being of conservation concern using EVS scores, compared to only 9.5% using the same IUCN statuses.

A review of the latest national LEA (CONAP 2021) revealed that 112 of the 143 amphibians (78% of all species) present in Guatemala are considered to be threatened (PC 42; EP 44; VU 26), although only one species present in PNLT is included at Vulnerable level. This represents 4.5% of the amphibians present in PNLT. 150 reptiles (61% of all species) are currently considered endangered at a national level (PC 19; EP 59: VU 72), of these 17 are present in PNLT (PC 1; EP 3; VU 13), representing 23.9% of the total reptile fauna of the park. Again, national assessments of endangered amphibians and reptiles are more conservative than those of the EVS assessments.

Discussion

The herpetofauna of PNLT includes 93 native species, plus two non-native gekkonid lizards. The native species of PNLT represent 23.9% of Guatemala's total amphibian and reptile diversity. The nearby Sierra Lacandon mountains in Mexico that are contiguous with PNLT are reported to have a diversity of 124 species and includes 35 amphibians and 89 reptiles (Hernández-Ordóñez et al. 2014). Although the two regions are essentially part of the same biogeographical unit, Lacandon has a wider altitudinal gradient (100 - 1500 m) and receives nearly twice as much precipitation than PNLT, 2894 mm compared to 1500 mm annually (Bestelmeyer 2000; Hernández-Ordóñez et al. 2014). These distinct differences between PNLT and the Lacandon region may account for differences in assemblage structure and diversity. To the north of PNLT lies the wider Yucatán Peninsula region of Mexico, the region consists of three states (Campeche, Quintana Roo, and Yucatán itself), and covers an area of 126,742

km^2 compared to the 2.89 km^2 of PNLT. Recent assessments of the conservation status of the Yucatán Peninsula identified 145 species, of which 25 are amphibians and 120 are reptiles (González-Sánchez et al. 2018). The southern portion of the Yucatán Peninsula in Mexico includes the Calakmul Biosphere Reserve (CBR), which borders the Guatemalan Mayan Biosphere Reserve to the north and includes 723,000 ha of reserve and 384,000 ha of buffer zone (Colston et al. 2015). The herpetofaunal diversity of CBR is currently understood to contain 89 species, of which 20 are amphibians and 69 are reptiles (Colston et al. 2015). The herpetofauna of PNLT represents a significant proportion of the wider Yucatán diversity (65.5% represented in PNLT), compared to that of CBR (61.3%) which is similar to PNLT in terms of habitat classification but is two and half times the size.

Although many of the species that occur in PNLT are widely distributed throughout the lowlands of Guatemala, much of that distribution is unprotected land that is subject to a wide variety of land-uses and the majority of natural habitat has already been lost (Tolisano and Lopéz 2010). Regardless of the measure used, a higher proportion of reptile species were considered to be of a vulnerable conservation status than amphibians. As such PNLT could be considered a stronghold for the conservation of widespread Guatemalan herpetofauna, especially reptile species. This pattern is reversed when compared to the assessment of Acevedo et al. (2010) which found that a greater proportion of amphibians, compared to reptiles, were considered of vulnerable conservation status at a national level. Compared to EVS assessments both IUCN and LEA lists of endangered species underestimate the number of species of conservation interest in PNLT. This disparity between the IUCN and EVS assessments is consistent with other studies that employ the EVS methodology (Wilson et al. 2010; Johnson et al. 2015; Mata Silva et al. 2015). However, studies have shown that

perceived shortcomings in the use of IUCN Red List data at the regional level is often linked to the failure to use the Regional Assessment Guidelines provided by the IUCN (Miller et al. 2007). The regional guidelines suggest that species under assessment should first be considered endemic to the country or isolated from other populations, and then secondly, it should consider whether the population in question is in contact with other populations outside of the country of interest (Gärdenfors 2001). Correct use of the IUCN regional guidelines may decrease the disparity between IUCN and EVS assessments.

The EVS methodology has been successfully applied to the herpetofauna at various geographical scales including Country, State, and more recently regional levels (Wilson et al. 2010; Johnson et al. 2015; Mata Silva et al. 2015). This paper represents the first attempt to use the EVS methodology to assess the conservation status of the herpetofauna of a relatively small geographic unit such as a National Park and highlights the usefulness of EVS to assess the conservation status of amphibians and reptiles at various regional scales. Additionally, when considered without the use of EVS, the herpetofauna of PNLT represents relatively little conservation concern. The use of EVS however reveals that the herpetofauna of the region is of greater conservation interest than previously realized. While the herpetofauna of PNLT contains no species endemic to Guatemala itself, many are regional endemics to the Yucatán Peninsula and populations in Petén, Guatemala, represent their most southerly ranges. Due to under sampling of the region, these species are often represented by only a few specimens and their distribution and importance to the herpetofauna of the country is therefore poorly understood.

Acknowledgements

Fieldwork would not have been possible without the support of various individuals and institutions, not least of which are Asociación Balam and Estación Biológica las Guacamayas for providing access to the field site, the Petén and Central offices of Consejo Nacional de Áreas Protegidas for providing research permits (109-2013; 191-2014; 008-2015; DRP-01-2016). Thanks also must go to all the participants of Indigo Expeditions who helped collect data in the field.

Literature Cited

Acevedo, M., L.D. Wilson, E.B. Cano, and C. Vásquez-Almazán. 2010. Diversity and conservation status of the Guatemalan herpetofauna. In L.D. Wilson, J.H. Townsend and J.D. Johnson (eds.), Conservation of Mesoamerican Amphibians and Reptiles, pp 406-434. Eagle Mountain Publishing, Eagle Mountain, Utah.

Ariano-Sánchez, D., and J.A. Campbell. 2018. A new species of Rhadinella (Serpentes: Dipsadidae) from the dry forest of Motagua Valley, Guatemala. Zootaxa. 4442: 338–344.

Babbitt, K.J., J.S. Veysey, and G.W. Tanner. 2009. Measuring habitat. In C.K. Dodd (ed.), Amphibian Ecology and Conservation: A Handbook of Techniques, pp 299- 317. Oxford University Press, New York.

Bestelmeyer, B.T. 2000. Introduction to the RAP expedition to Parque Nacional Laguna del Tigre, Petén, Guatemala. In B.T. Bestelmeyer, and L.E. Alonso (eds.), A Biological Assessment of Parque Nacional Laguna del Tigre, Petén, Guatemala. RAP Bulletin of Biological Assessment 16, pp 20-25. Conservation International, Washington.

Bestelmeyer, B.T., and L.E. Alonso. 2000. A Biological Assessment of Parque Nacional Laguna del Tigre, Petén, Guatemala. RAP Bulletin of Biological Assessment 16. Conservation International, Washington. 221 pp.

Campbell, J.A., and D.R. Frost. 1993. Anguid lizards of the genus Abronia: Revisionary notes, descriptions of four new species, a phylogenetic analysis, and key. Bull. Am. Mus. Nat. Hist. 216. 121 pp.

Campbell, J.A., E.N. Smith, J. Streicher, M.E. Acevedo, and E.D. Brodie Jr. 2010. New salamanders (Caudata: Plethodontidae) from Guatemala: with miscellaneous notes on known species. Misc. Publ. – Mus. Zool., Univ. Mich. 200. 60 pp.

Colston, T.J., J.A.L. Barão-Nóbrega, R. Manders, A. Lett, J. Wllmot, G. Cameron, S. Hunter, E. Littlefair, R.J. Williams, A. Lopez Cen, and K. Slater. 2015. Amphibians and reptiles of Calakmul Biosphere Reserve, México, with new records. Check List. 11: 1759.

CONAP. 2009. Lista de Especies Emenzadas de Guatemala (LEA) 2009. Consejo Nacional de Áreas Protegidas, Guatemala. 35pp.

CONAP. 2021. Lista de Especies Emenzadas de Guatemala (LEA) 2021. Consejo Nacional de Áreas Protegidas, Guatemala.

Corado García, V.A., J.O. Cajas Castillo, and J.A. Benítez-Moreno. 2020. Estado poblacional y distribución del cocodrilo de pantano (Crocodylus moreletii) en regiones prioritarias de Petén, Guatemala. Rev. Latinoam. Herpetol. 3: 23-33.

Coti, P., and D. Ariano-Sánchez. 2008. Ecology and traditional use of the Guatemala black iguana (Ctenosaura palearis) in the dry forests of the Motagua Valley, Guatemala. Iguana. 15: 143-149.

Crump, M.L., and N.J. Scott. 1994. Visual Encounter Surveys. In W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L-A.C. Hayek, and M.S. Foster (eds.), Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians, pp 84-92. Smithsonian Institution Press. Washington.

Doan, T.M. (2003). Which methods are most effective for surveying rain forest herpetofauna? J. Herpetol. 37: 72-81.

Duellman, W.E., and J.A. Campbell. 1992. Hylid frogs of the genus Plectrohyla: Systematics and phylogenetic relationships. Misc. Publ. – Mus. Zool., Univ. Mich. 181. 32 pp.

Gärdenfors, Ulf. 2001. Classifying threatened species at national versus global levels. Trends Ecol. Evol. 16: 511-516.

González-Sánchez, V. H., J. D. Johnson, E. García-Padilla, V. Mata-Silva, D. L. DeSantis, and L. D. Wilson. 2017. The herpetofauna of the Mexican Yucatan Peninsula: composition, distribution, and conservation. Mesoam. Herpetol. 4: 264–380.

García Anleu, R., R.B. McNab, J.S. Shoender, V. Espejel, J. Moreira, G. Ponce, V.H. Ramos, F. Oliva, E. González, H. Tut, K. Tut, T. Xol, P. Xoc, M Córdova, F. Cordova, and L. Morales. 2007. Distribution and ecology of the Central American river turtle (Dermatemys mawii: Dermatemidae) in the lowland Maya forest, Guatemala. Wildlife Conservation Society. 28 pp.

Griffin, R., and G. Powell. 2014. Tropidodipsas fasciatus (Banded snail-sucker). Geographic distribution. Herpetol. Rev. 45: 467.

Heyer W R, M.A. Donnelly, R.W. McDiarmid, L.-C. Hayek, and M.S. Foster. 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institution Press, Washington, USA. 384 pp.

Hernández-Ordóñez, O, M. Martínez-Ramos, V. Arroyo-Rodríguez, A. González-Hernández, A. González-Zamora, D.A. Zárate, and V.H. Reynoso. 2014. Distribution and conservation status of amphibian and reptile species in the Lacandona rainforest, Mexico: an update after 20 years of research. Trop. Conserv. Sci. 7: 1-25.

Holdridge, L.R. 1967. Lifezone Ecology (Revised edition). San José Tropical Science Centre, Costa Rica. 149 pp.

IUCN. 2021. The IUCN Red List of Threatened Species. Version 2021-1. https://www.iucnredlist.org. Downloaded on18th July 2021.

Johnson, J. D., V. Mata-Silva, E. García-Padilla, and L. D. Wilson. 2015. The herpetofauna of Chiapas, Mexico: composition, physiographic distribution, and conservation status. Mesoam. Herpetol. 2: 272–329.

Köhler, G. 2008. Reptiles of Central America. Herpeton Verlag, Offenbach. 360 pp.

Köhler, G. 2011. Amphibians of Central America. Herpeton Verlag, Offenbach. 379 pp.

Lee, J.C. 1996. The Amphibians and Reptiles of the Yucatán Peninsula. Cornell University Press, Ithaca. 500 pp.

Schmidt, K.L., M.L. Aardema, and G. Amato. 2020. Genetic analysis reveals strong phylogeographical divergences within the Scarlet Macaw Ara macao. Ibis. 162: 735–748.

Lepe-López, M. R. García-Anleu, N.M. Fountain-Jones, G. Ponce, M. Gonzalez, and L.E. Escobar. 2018. Domestic horses within the Maya biosphere reserve: A possible threat to the Central American tapir (Tapirus bairdii). Caldasia. 40: 188-191.

Lovich, R.E., W.K. Hayes, H. Mushinsky, and G.H. Rodda. 2012. Transect Surveys, Including Line Distance. In R.W. McDiarmid, M.S. Foster, C. Guyer, J.W. Gibbons and N. Chernoff (eds.), Reptile Biodiversity: Standard Methods for Inventory and Monitoring, pp 227-234. University California Press. Berkeley, USA.

Marsh, D.M., and L.M.B. Haywood. 2010. Area-based Surveys. In C.K. Dodd Jr (ed.), Amphibian Ecology and Conservation: A Handbook of Techniques, pp 247-262. Oxford University Press. Oxford.

Mata-Silva, V., J. D. Johnson, L. D. Wilson, and E. García-Padilla. 2015. The herpetofauna of Oaxaca, Mexico: composition, physiographic distribution, and conservation status. Mesoam. Herpetol. 2: 6-62.

McDiarmid, R.W., M.S. Foster, C. Guyer, J.W. Gibbons, and N. Chernoff. 2012. Reptile Biodiversity: Standard Methods for Inventory and Monitoring. University of California Press, Berkeley, USA. 417 pp.

Miller, R.M., J.P. Rodríguez, T. Aniskowicz-Fowler, C. Bambaradeniya, R. Boles, M.A. Eaton, U. Gärdenfors, V. Keller, S. Molur, S. Walker, and C. Pollock. 2007. National Threatened Species

Listing Based on IUCN Criteria and Regional Guidelines: Current Status and Future Perspectives. Conserv. Biol. 21: 684–696.

Monzón-Alverado, C., S. Cortina-Villar, B. Schmook, A. Flamenco-Sandoval, Z. Christman, and L. Arriola. 2012. Land-use decision-making after large-scale forest fires: Appl. Geogr. 35: 43-52.

Ramírez-Bautista A, U. Hernández-Salinas, R. Cruz-Elizalde, C. Berriozabal-Islas, I. Moreno-Lara, D.L. DeSantis, J.D. Johnson, E. García-Padilla, V. Mata-Silva, and L.D. Wilson. 2020. The herpetofauna of Hidalgo, Mexico: composition, distribution, and conservation status. Amphib. Reptile Conserv. 14: 63–118.

Rödel, M.-O., and R. Ernst .2004. Measuring and monitoring amphibian diversity in tropical forests. I. an evaluation of methods with recommendations for standardization. Ecotropica. 10: 1-4.

Schlaepfer, M.A., and T.A. Gavin. 2001. Edge effects on lizards and frogs in tropical forest fragments. Conserv. Biol. 15: 1079-1090.

Tolisano, J., and M.M. López. 2010. Guatemala Biodiversity and Tropical Forest Assessment. USAID. 108 pp.

Urbina-Cardona, J.N., M. Olivares-Pérez, and V.H. Reynoso .2006. Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz. Biol. Conserv. 132: 61-75.

Vonesh J.R., J.C. Mitchell, K. Howell, and A.J. Crawford. 2009. Rapid assessments of amphibian diversity. In C.K. Dodd (ed.), Amphibian Ecology and Conservation: A Handbook of Techniques, pp 263-280. Oxford University Press, New York.

Wilson, L.D., J.H. Townsend, and J.D. Johnson. 2010. Conservation of Mesoamerican Amphibians and Reptiles. Eagle Mountain Publishing, Eagle Mountain, Utah. 812 pp.

Wultsch, C., A. Caragiulo, I, Dias-Freedman, H. Quigley, S. Rabinowitz, and G. Amato. 2016. Genetic diversity and population structure of mesoamerican jaguars (Panthera onca): implications for conservation and management. PLoS One. 11: 10.

Figures

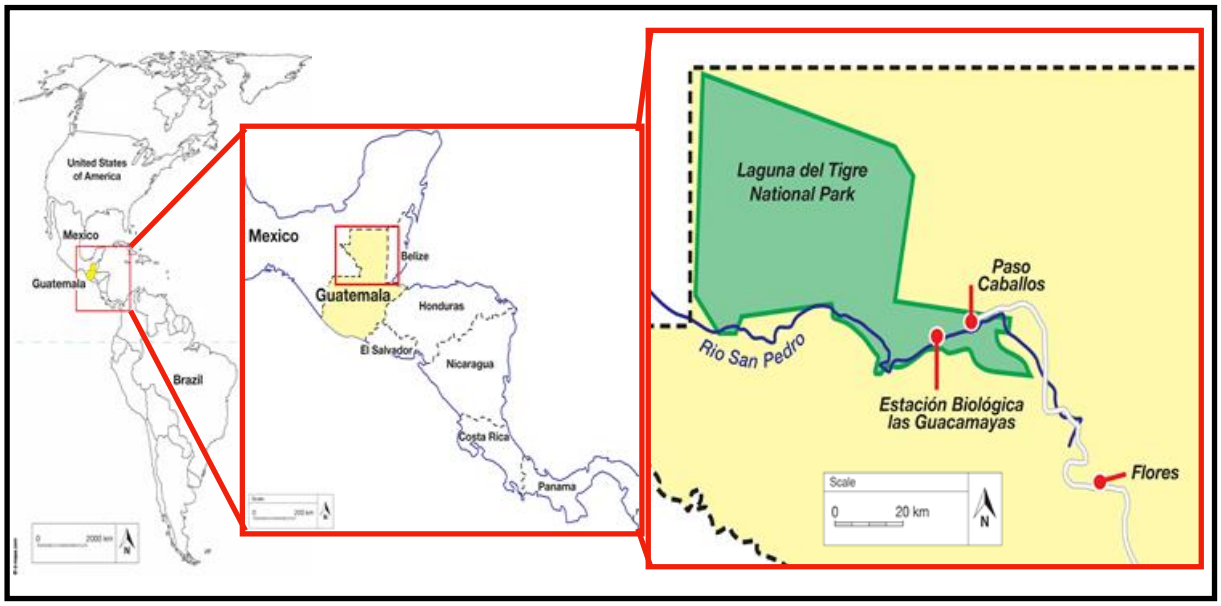

Fig. 1: Map of the Americas, showing the location of Parque Nacional Laguna del Tigre within Guatemala. Due to the curvature of the map the scale shown is representative of the scale at the equator. Map adapted from D-Maps.com

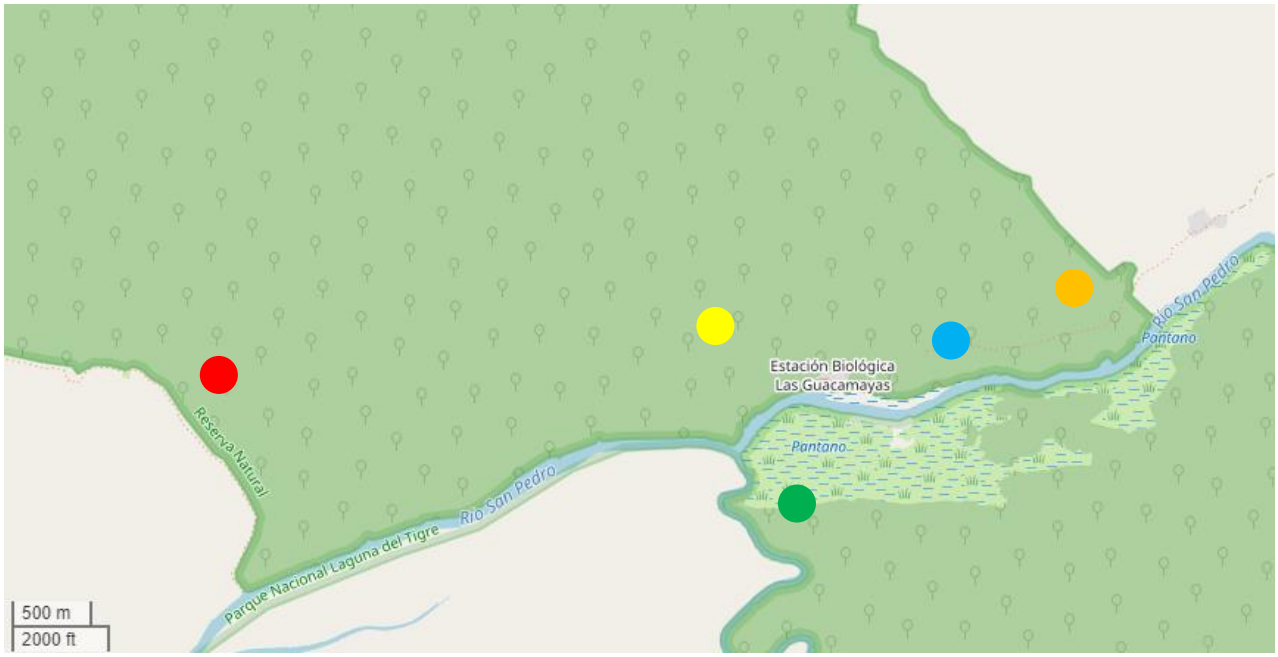

Fig. 2: Map of the southeast region of Parque Nacional Laguna del Tigre showing the location of survey sites indicated by colored dots: Orange = Agricultural Edge; Yellow = High Forest; Red = Low Forest; Blue = Natural Edge; Dark Green = Saw-grass swamp. The two rivers are the San Pedro River flowing east to west, and the Sacluc River flowing south to north. North of the San Pedro dark green areas indicate forest areas, grey indicates the concessional agricultural land of Paso Caballos. South of the San Pedro, green indicates a mixture of saw grass swamp (sabinal) and seasonally flooded thorn scrub. Map data from OpenStreetMap openstreetmap.org/copyright

Table 1: Description of Guatemalan life-zones adapted from Acevedo et al. (2010)

	Life-zone	Altitude (masl)	Annual Precipitation (mm)	Region in Guatemala
1	Tropical Wet Forest	0 - 1267	3600	Caribbean Coast
2	Tropical Dry Forest	440 - 600	1300	SE Guatemala around the area of Lago de Güila on the El Salvador border
3	Subtropical Rain Forest	460 - 1400	4410 - 6577	Sierra de las Minas in the E Guatemala and Sierra de Chamá
4	Subtropical Wet Forest (warm)	80 - 1600	1587 - 4327	Mainly in southern Petén and Izabal, Alta Verapaz, Quiché, and Huehuetenango. But also a small area in southwestern Guatemala near the Mexican border
5	Subtropical Wet Forest (cold)	1100 - 1800	2045 - 2514	Central highlands of Alta Verapaz
6	Subtropical Moist Forest (warm)	0 - 275	1160 - 2000	Northern Petén and extreme southern Guatemala
7	Subtropical Moist Forest (temperature)	650 -1700	1100 - 1349	A wide distribution acrosss moderate eleveations of central America
8	Subtropical Dry Forest	0 - 1200	500 - 1000	6 disjunct areas in central and south Guatemala
9	Subtropical Thorn Scrub Forest	180 - 400	400 - 600	Motagua Valley of eastern Guatemala
10	Subtropical Lower Montane Rain Forest	1500 - 1700	> 1400	Central highlands of Alta Verapaz
11	Subtropical Lower Montane Wet Forest	1800 - 3000	2065 - 3900	Western highlands of Guatemala
12	Subtropical Lower Montane Moist Forest	1500 - 2400	1057 - 1588	Southwestern Guatemala
13	Subtropical Montane Wet Forest	> 2800	2500	High elevations in Western Guatemala
14	Subtropical Montane Moist Forest	> 3500	1275	Limited to the very high elevations of the Sierra de Los Cuchumatanes in Western Guatemala

Table 2: Environmental Vulnerability Score (EVS) assessment criteria following Acevedo et al. (2010).

EVS Score	Geographic Distribution	Specialisation of Reproductive Mode (amphibians only)	Vulnerability to Human Persecution (reptiles only)	Ecological Distribution in Guatemala
1	Widespread in and outside Guatemala	Both eggs and tadpoles in large or small bodies of lentic or lotic water	Fossorial, typically escaping human notice	Occurs in 8 to 14 life-zones
2	Peripheral in Guatemala, widespread outside of Guatemala	Eggs in foam nests, tadpoles in small bodies of lentic or lotic water	Semifossorial, or nocturnal arboreal or aquatic, nonvenomous and usually nonmimicking, sometimes escaping human notice	Occurs in 7 life-zones
3	Restricted to Nuclear Central America	Tadpoles occur in small bodies of lentic or lotic water, eggs outside of water	Terrestrial and or arboreal or aquatic, generally ignored by humans	Occurs in 6 life-zones
4	Restricted to Guatemala	Eggs laid in moist situations on land or arboreally, direct development or viviparous	Terrestrial and or arboreal or aquatic, thought to be harmful (often mistakenly) and may be killed on sight	Occurs in 5 life-zones
5	Only known in the vicinity of the type locality in Guatemala	Eggs and/or tadpoles in water-retaining bromeliads or water-filled tree cavities	Venomous species or mimics thereof, usually killed on sight	Occurs in 4 life-zones
6			Species exploited by humans for their meat, eggs, or skin	Occurs in 3 life-zones
7				Occurs in 2 life-zones
8				Occurs in 1 life-zone

Table 3: Comparison of the conservation status of amphibian and reptile families in Parque Nacional Laguna del Tigre, Guatemala using Environmental Vulnerability Scores (EVS), IUCN Red List status, and distributional status. IUCN codes: CR = critically endangered; VU = Vulnerable; NT = Near threatened; LC = Least concerned; DD = Data deficient. Distributional status codes: RR = Range restricted; RE = Regional endemic; NE = Not endemic; NN = Non-native.

	EVS			IUCN status					Distributional Status			
	High	**Medium**	**Low**	**CR**	**VU**	**NT**	**LC**	**DD**	**RR**	**RE**	**NE**	**NN**
Amphibia												
Caudata												
Plethodontidae	0	1	0	0	0	0	1	0	0	0	1	0
Anura												
Rhinophryindae	0	0	1	0	0	0	1	0	0	0	1	0
Bufonidae	0	0	2	0	0	0	2	0	0	0	2	0
Leptodactylidae	0	0	3	0	0	0	2	0	0	0	3	0
Eleutherodactylidae	0	1	0	0	1	0	0	0	0	1	0	0
Hylidae	0	2	8	0	0	0	10	0	0	1	9	0
Microhylidae	0	0	2	0	0	0	3	0	0	1	1	0
Ranidae	0	0	2	0	0	0	2	0	0	0	2	0
Reptilia												
Testudines												
Dermatemidae	1	0	0	1	0	0	0	0	1	0	0	0
Kinosternonidae	2	2	0	0	0	3	1	0	3	0	1	0
Emydidae	1	1	0	0	0	1	1	0	1	0	1	0
Crocodylidae	1	0	0	0	1	0	0	0	1	0	0	0
Squamata												
Eublepharidae	0	1	0	0	0	0	1	0	0	0	1	0
Sphaerodactylidae	0	0	2	0	0	0	2	0	0	0	2	0
Gekkonidae	0	0	3	0	0	0	3	0	0	0	1	2
Corytophanidae	0	0	3	0	0	0	3	0	1	0	2	0
Iguanidae	0	1	0	0	0	0	1	0	0	0	1	0
Phrynosomatidae	0	2	0	0	0	0	2	0	1	1	0	0
Dactyloidae	0	2	6	0	0	0	8	0	0	1	7	0
Scincidae	0	1	3	0	0	0	4	0	1	0	3	0
Teiidae	0	0	2	0	0	0	2	0	0	0	2	0
Anguidae	0	1	0	0	0	1	0	0	1	0	0	0
Boidae	0	0	1	0	0	0	1	0	0	0	1	0
Colubridae	0	18	17	0	0	0	34	1	1	7	27	0
Elapidae	0	1	0	0	0	0	1	0	0	0	1	0
Viperidae	0	1	0	0	0	0	1	0	0	0	1	0

Table 4: Environmental Vulnerability Scores, IUCN statuses, and distributional statuses for amphibians occurring in Parque Nacional Laguna del Tigre. IUCN status categories are: CR = Critically endangered; VU = Vulnerable; NT = Near threatened; LC = Least concern; DD = Data deficient. Distributional Status categories are: RR = Range restricted; RE Regional endemic; NE = Non-endemic.

Species	Geographic Distribution	Reproductive Specialization	Ecological Distribution	EVS	IUCN Status	Distributional Status
MEDIUM						
Bolitoglossa mexicana	1	4	5	10	LC	NE
Eleutherodactylus leprus	1	4	6	11	VU	NE
Dendropsophus ebreccata	1	3	7	11	LC	NE
Triprion petasatus	3	1	7	11	LC	RE
LOW						
Incilius valliceps	1	1	5	7	LC	NE
Rhinella horribilis *	1	1	1	3	LC	NE
Agalychnis callidryas	1	3	5	9	LC	NE
Agalychnis moreletii	3	3	3	9	LC	NE
Dendropsophus microcephala	1	3	5	9	LC	NE
Scinax staufferi	1	1	5	7	LC	NE
Smilisca baudinii	1	1	1	3	LC	NE
Tlalocohyla loquax	1	1	5	7	LC	NE
Tlalocohyla picta	1	3	5	9	LC	NE
Trachycephalus typhonius	1	1	4	6	LC	NE
Engystomops pustulosus	1	2	4	7	LC	NE
Leptodactylus fragilis	1	2	2	5	LC	NE
Leptodactylus melanolotus	1	2	2	5	LC	NE
Gastrophryne elegans	1	1	6	8	LC	RE
Hypopachus variolosus	1	1	5	7	LC	NE
Rana brownorum	1	1	3	5	LC	NE
Rana vaillanti	1	1	4	6	LC	NE
Rhinophrynus dorsalis	1	1	5	7	LC	NE

* reassessed from Acevedo et al. (2010) due changes in taxonomy.

Table 5: Environmental Vulnerability Scores, IUCN statuses, and distributional statuses for reptiles occurring in Parque Nacional Laguna del Tigre. IUCN status categories are: CR = Critically endangered; VU = Vulnerable; NT = Near threatened; LC = Least concern; DD = Data deficient. Distribution Status categories are: RR = Range restricted; RE Regional endemic; NE = Non-endemic.

Species	Geographic Distribution	Vulnerability to Human Persecution	Ecological Distribution	EVS	IUCN Status	Distribution Status
HIGH						
Crocodylus moreletii	1	6	7	14	VU	RR
Dermatemys mawii	3	6	7	14	CR	RR
Rhinoclemmys areolata	3	6	6	15	NT	RR
Claudius angustus	2	6	7	15	NT	RR
Kinosternon acutum	3	6	7	16	NT	RR
MEDIUM						
Trachemys venusta *	1	6	4	11	NT	NE
Kinosternon leucostomum	1	6	5	12	LC	NE
Staurotypus triporcatus	1	6	6	13	NT	RR
Celestus rozellae	3	4	5	12	NT	RR
Coleonyx elegans	1	4	6	11	LC	NE
Iguana iguana	1	6	3	10	LC	NE
Norops rodriguezii	3	2	5	10	LC	RE
Norops sagrei	1	2	8	11	LC	RR
Sceloporus chrysostictus	3	2	7	12	LC	RE
Sceloporus teapensis	3	2	6	11	LC	RR
Mesoscincus schwartzei	3	1	7	11	LC	RE
Adelphicos quadrivirgatus	1	2	7	10	DD	NE
Clelia scytalina	1	4	8	13	LC	RR
Coluber mentovarius	1	4	5	10	LC	NE
Coniophanes schmidtii	3	2	8	13	LC	RE
Ficimia publia	1	2	7	10	LC	NE
Leptodeira frenata	1	2	7	10	LC	RE
Leptophis ahaetulla	1	4	5	10	LC	NE
Oxyrhopus petolarius	1	5	6	12	LC	NE
Pliocercus elapoides	1	5	4	10	LC	NE
Scaphiodontophis annulatus	1	5	7	13	LC	NE
Senticolis triaspis	1	4	6	11	LC	NE
Sibon dimidiata	1	4	5	10	LC	NE
Tantilla moesta	3	2	8	13	LC	RE
Tantillita canula	3	2	7	12	LC	RE
Thamnophis proximus	1	4	6	11	LC	NE
Tretanorhinus nigroluteus	1	4	6	11	LC	NE
Tropidodipsas fasciatus	2	2	8	12	LC	RR
Xenodon rabdocephalus	1	5	6	12	LC	NE
Micrurus diastema	1	5	6	12	NA	NE
Bothrops asper	1	5	5	11	LC	NE

(continued on next page)

Table 5 continued.

Species	Geographic Distribution	Vulnerability to Human Persecution	Ecological Distribution	EVS	IUCN Status	Distribution Status
LOW						
Sphaerodactylus glaucus	1	3	3	7	LC	NE
Sphaerodactylus millepunctatus	1	3	3	7	LC	NE
Thecadactylus rapicauda	1	2	5	8	LC	NE
Basiliscus vittatus	1	3	1	5	LC	NE
Corytophanes cristatus	1	3	5	9	LC	NE
Corytophanes hernandezii	1	3	5	9	LC	RE
Norops beckeri	1	2	6	9	LC	NE
Norops capito	1	2	5	8	LC	NE
Norops lemurinus	1	2	4	7	LC	NE
Norops welbornae *	1	2	4	7	LC	NE
Norops tropidonotus	1	2	6	9	LC	NE
*Norops uniformis**	1	2	5	8	LC	NE
Plestiodon sumichrasti	1	1	6	8	LC	NE
Marisora brachypoda *	1	2	3	6	LC	NE
Sphenomorphus cherriei	1	2	5	8	LC	NE
Holcosus festivus	1	2	5	8	LC	NE
Holcosus undulatus	1	2	1	4	LC	NE
Boa imperator	1	6	1	8	LC	NE
Coniophanes bipunctatus	1	2	5	8	LC	NE
Coniophanes imperialis	1	2	5	8	LC	NE
Drymarchon melanurus	1	4	1	6	LC	NE
Drymobius margaritiferus	1	4	2	7	LC	NE
Imantodes cenchoa	1	2	4	7	LC	NE
Lampropeltis abnorma *	3	5	1	9	LC	NE
Leptodeira septentrionalis	1	4	1	6	LC	RE
Leptophis mexicana	1	4	4	9	LC	NE
Mastigodryas melanolomus	1	4	4	9	LC	NE
Ninia diademata	1	2	4	7	LC	NE
Ninia sebae	1	5	1	7	LC	NE
Oxybelis aeneus	1	4	3	8	LC	NE
Oxybelis fulgidus	1	4	3	8	LC	NE
Pseudelaphe flavirufa	1	2	4	7	LC	NE
Sibon nebulatus	1	4	1	6	LC	NE
Spilotes pullatus	1	4	2	7	LC	NE
Tropidodipsas sartorii	1	5	3	9	LC	NE

* reassessed from Acevedo et al. (2010) due changes in taxonomy.