FINAL REPORT

Project: Status and population trends of amphibians in relation to microenvironment at a montane forest, southern Mexico

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We present here the results of our Project which consisted in an intense field, laboratory and local community work. The present report is separated in two parts, the Part I contains the results of the social and environmental education activities while the second part includes the results of our scientific ecological research in the way of a scientific paper that we will submit soon to a specialized journal after reviewing by the CLP pertinent staff.

Study site, background and justification:
Our field work was conducted at the town El Molote, Municipality of Atoyac de Alvarez, Guerrero, Mexico (Figure 1). The project was initially conceived to study the dynamics of the amphibian communities in a fragmented cloud forest and to know the local interest of the people about the very interesting fauna of amphibians in the region. In this area we conducted four field seasons (8 to 10 days in duration) sampling eight selected sites throughout a large area of Tropical Mountain Cloud Forest (TMCF). We established a close relationship with the local people; we taught children everyday about diversity and natural history of amphibians and reptiles and coordinated scientific activities with them. A previous visit to the town and vicinities were made during April 2007 in order to select the study sites and to establish the pertinent contacts with the people. All permits and advices were made by that time. The field work team was composed of five persons each time. We defined eight study sites, named and numbered Ecotones 1-8 each one comprising three representative habitats: anthropogenic matrix (coffee and corn plantations), forest edge and forest interior. Sampling was performed only by night, due to the previously observed

activity of the amphibians in the field. In the first sampling period we were advocated to prepare the study sites measuring and marking the transect distances to the forest edge in each ecotone, this method will be explained in the second part of this report.

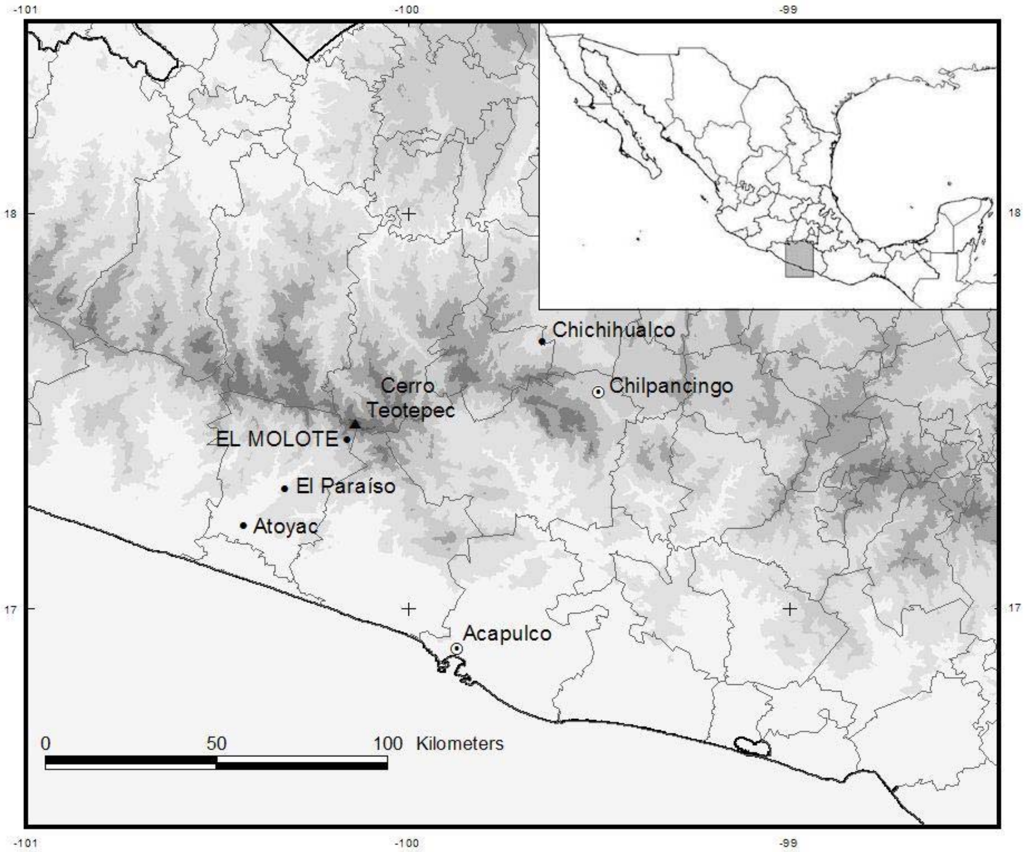

Figure 1. Location of the TMCF at El Molote town, Guerrero, México

PART I

From the beginning of this research we had talks with the town commissary and with the school teachers to let them know about our intend to celebrate a scientific workshop to show the results of the research and to share knowledge and experiences about the consequences of deforestation, contamination and some concepts such natural services and climate change. The idea was kindly received so we rely upon the support of the community and an enthusiastic response to our project. The main goal of our research was to study amphibian communities focusing on threatened species inhabiting a priority area of TMCF, their relation with the microhabitat and the role of the local people to the future expectative for conservation of this group. The practical objectives in our proposal were:

1) To know the current knowledge of natural history and possible uses of the TMCF amphibian species by interviewing local farm workers, farmer landowners and managers.

2) To organize workshops, talks, symposia and poster presentations to sensibly local people about the amphibian natural services and their potential extinction risk.

3) To identify important stake holders and in general local communities' priorities and perceptions in relation with the ecosystem in order to identify potential management and conservation actions for the future.

4) To collaborate, participate and attend to scientific, social and political meetings to share and discuss the results of our research.

All the above objectives were fully achieved; details of the activities are described below:

1) We standardize, with the advisory of Shannon Earle (CI), an interview about people's perception on biodiversity, and specifically about amphibians and reptiles at the TMCF. A format of the original interview can be seen in the Appendix 1. We implemented the interview with 28 persons inhabiting only at El Molote, these interviews represent the different age structure of the population, being the youngest a little boy of 6 and the oldest a woman of 74 years old. A relevant feature from the El Molote community is that this is a

small town composed mainly of children, women and old men. In the last decade the majority of the young men in age to work abandoned the cultivation lands to move to the USA as illegal immigrants. As a general depict of the people perceptions we summarize some important results of these interviews. The responses reveal that in spite of living adjacent to the main forest, most of the people have a poor knowledge of the herpetofauna inhabiting there, in example, the persons who know more species are kids studying in the basic school, the most species recognized are 18 from a stock of 20. Almost all the people interviewed say that the first reaction to a herpetozoan encounter is to ignore the animal or to kill it and running away, 88% of the interviewers responded that all the snakes are venomous, even when they do not know any person affected by a snake bit. In the area inhabits only three species of venomous snakes and they clearly confound one species of false coral snake (genus *Lampropeltis*, a coluber snake) with the true ones (genus *Micrurus*), and the majority of the interviewers never have seen a rattle snake and just few reported to have seen the copperhead (*Agkistrodon*). One interesting result from the interview is that the adult interviewers (50%) have observed that some amphibian species have decreased and/or disappeared from the area in last years. Finally, only 21% know some human use for the snake species, this is mainly for manufacturing belts or for traditional medicine. The amphibians are considered as not beneficent for humans by these persons. These results clearly expose that intense work with children in the school and with the adults is necessary to contribute to eliminate some myths and misperceptions about the herpetofauna and to expand the knowledge about the natural services which can mean benefits for human. This is not an impossible mission considering the advances reached with this research.

2) We celebrate a workshop at the main auditory of the town by mid August, 2008. We wrote and published the book “Diviértete y aprende conociendo la naturaleza en El Molote, Guerrero, México” (English translation: Enjoy and learn knowing nature at El Molote, Guerrero, Mexico) which was distributed to the 100 attendants at the end of the workshop (Figures 2 and 3). We designed a poster that talks about the herpetofauna of El Molote, the importance of amphibians and reptiles to the forest and to their own town and how to differentiate a venomous snake from a non-venomous one (Figure 4).

We left eight posters to be distributed at the town's church, schools and main auditory. At the entrance of the event we tagged everyone with a sticker written with their names to get a familiar and relaxed atmosphere. Along the talks we presented information on several topics such as biodiversity, natural services, extinction, present threats and future of the biodiversity, climatic change, sustainable development, reusing and recycling and conservation (Figures 5 and 6). At the end of the talks we organized games and didactic activities with the children to evaluate the lessons learned and to distribute diverse gifts, toys, notebooks, other scholar supplies, and candies to the winners of the concourses like "Drawing the biodiversity" (Figure 7).

3) Adults were also welcomed to the workshop, they participated by making questions (Figures 8 and 9). The TCMF of the reserve is not a private area, it is a communal land spanning (in Spanish "terreno ejidal") and any decision about logging or land use changes must be discussed by the community. However, it is possible to see selective logging of large trees into de forest that are supposedly used to construct houses. We identified some aspects that should be treated in the future such as garbage management, the commercial use of some species of trees and exploitation and cultivation of alternative products since agriculture is being increasing because of weakening of extensive traditionally used plantations. The most interesting issue for the adult audience was the great potential of the batteries to contaminate water bodies in surroundings El Molote use of the batteries; we made the announcement with a great response of the people that we could collect used batteries and transport them to the center of recycling at the University of Mexico thus avoiding contamination since they don't have specific garbage management (Figure 10).

4) We were very active in attending to scientific meetings; first we presented preliminary results of our research at the **Congreso de la Sociedad Mesoamericana para la Biología y la Conservation** helded in Oaxtepec, Morelos, Mexico from 26 to 30 November, 2007 with the talk: "Poblaciones de anfibios en un bosque fragmentado de la sierra Madre del Sur, Guerrero, México". A second participation was the **Student Conference on Conservation Science** in Cambridge University, England from 25 to 27 March, 2008 with the poster: "Matrix use determines edge effect in amphibian diversity

in montane forests, Southern Mexico". We keep in contact with other groups investigating the flora and fauna at the Sierra Madre del Sur de Guerrero in the expectation to collaborate; we have had some feed-back with other ecologists to conclude the publication of one or two scientific papers and one book on natural history, inventory of species and ecology of amphibians in the area.

We had a wonderful interaction with children, throughout the field work we had the chance to indirectly teach scholars the role of amphibians in the ecosystem and to refuse the ancient myths about the risk of the Guerreran species of amphibians by illustrating the true venomous reptiles inhabiting in the forests surrounding El Molote. However, we think that the greatest success was the preparation and engaging of a young girl from the town into the study and conservation of the herpetofauna at El Molote, her name is Leticia Barragán Valladares, she was born 15 years ago in a bigger town west ward El Molote. She was always very interested in the research to the point to become part of the crew; she was also an excellent guide in the forest, she intensively sampled for amphibians in the field with us, some pictures of Leticia, and the rest of the team can be seen at the end of the book.

Figure 2. Announcement inviting community to the workshop to be held at the main auditory at El Molote, Guerrero.

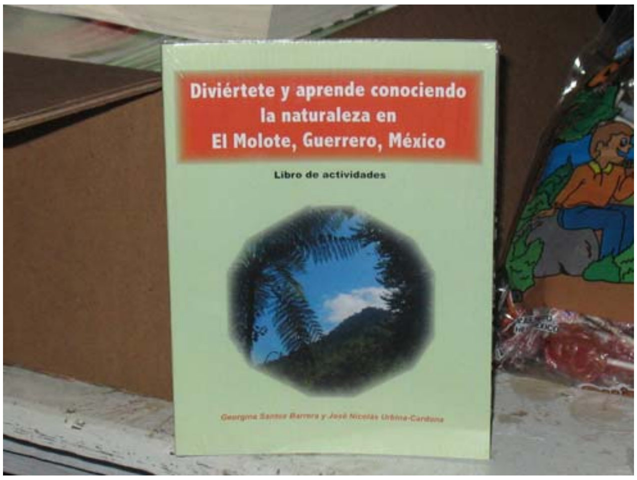

Figure 3. Cover of the book about nature at El Molote, distributed during the workshop in August 2008

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Figure 4. Poster presented during the workshop in August 2008, talking about the amphibians and reptiles of El Molote.

Figures 5 and 6. Nicolas Urbina (left) and Georgina Santos (right) during the lectures on biodiversity at El Molote.

Figure 7. Children drawings made during the workshop celebrated in El Molote. Drawings illustrate different topics explained during the talks as correct reuse of batteries and oils (both top and bottom right drawings), climate change, and diversity of amphibians (bottom left).

Figures 8 and 9. Children (top) and adult (bottom) audience in the workshop at El Molote, August, 2008.

Figures 10. Designed containers to collect used batteries (bag on the left) and garbage (black bag at the right).

PART II

A choice for amphibians in fragmented forests: the role of the matrix for amphibian conservation in a montane forest, Guerrero, Mexico

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1. Background

An irrefutable fact resulting from the development of human beings, is the negative impact that this development has caused to the natural environments. The challenge for new conservationists is to learn how to deal with these new country side landscapes which are composed mainly of patches of original vegetation commonly adjacent to human impacted or managed areas and settlelments (Daily, 2001). This is a common view in countries like Mexico, where the rate of deforestation has increased in last years with a 0.4% per year (Conafor, 2008). We were interested especifically in the case of the Tropical montane cloud forest (TMCF); this ecosystem is considered as one of the most threatened worldwide, even when it has been declared in priority for conservation by the Government of Mexico (Challenger, 1998; Arriaga et al., 2000). The distribution of the TMCF in Mexico is clearly dispersed forming a kind of archipielago of truly small pieces. Even with this distribution it is still recognized as one of the most diverse ecosystem in terms of plant and vertebrate species in Mexico (Rzedowski, 1996). This is might be the reason of its disaster, the overexploitation of the vast diverse of resources still present in this small areas (Challenger, 1998; Luna Vega et al., 1999). Concernign the amphibians, a characteristic group of the TMCF, most of the 50% of the known species are endemic of this kind of forests in Mexico. However this diversity is now facing the collateral effects from the global biodiversity crisis with possibly more severe results. The combination of several factors acting in synergy is causing enigmatic and non enigmatic declines in amphibians worldwide. The major identified threats are related with anthropogenic activities such as habitat loss, fragmentation, deforestation, pollution of water and ground, introduction of invasive exotic species and lately, two possibly related factors: the emergent infectious diseases such as viruses and fungi and the global warming (Collins and Storfer, 2003; Pounds, et al., 2006; Stuart et al., 2008).

Concerning the state of conservation in Mexico, the state of Guerrero has been one of the most impacted in the country, poverish and richness coincide in the same areas as a result of non efficient political and social strategies, natural resources have been traditionally exploited for local and large scale human comsuption and vast extensions of forests have dissapeared. This is one of the main causes for the amphibian populations declines in the mountains along the Sierra Madre del Sur de Guerrero (SMSG) and in other Mexican states (Santos & García, 2006) . The state of Guerrero accounts for an important diversity of herpetofauna reaching 321 species, 70 of them are amphibians, and 48% are endemic of Guerrero. Significant records of amphibians at the Guerrero montainous area include recent descibed species mainly Plethodontid salamanders and intresting records of Hylid frogs (Hanken, 1999; Adler, 1996; Pérez-Ramos et al., 2000) most of these species are currently classified as endangered or data defficient (IUCN, 2008). One interesting and yet poorly known area in the SMSG is the northward Atoyac mountains. The inventory of species of herpetozoans of this area is still in progress (Cristian Blancas, pers. Comm., 2008), most of the biological research in the area has been focused on systematics of trees and non vascular plants (Lozada et al., 2003). Since some extended areas of forest have been transformed into flowering plants, coffee and corn plantations, the preserving isolated patches of original forest are now inmersed in a matrix of cultivated areas. It is expected that the dynamics of the amphibian commuties have changed mainly because of fragmentation and the subsequent occurrence of the edge effect. The role of the edge effect on the amphibian species has been barely evaluated in Mexico, the dyanamics of amphibians in tropical rain forests fragments was studied by Urbina Cardona et al. (2006), however just few studies consider the TMCF as a target study ecosystem in Mexico (e. g. Pineda & Halftter, 2004; González Romero y Murrieta-Galindo, 2008). However, it is very common to see that agricultural practices of coffee in Mexico include the preservation of small to medium patches of TMCF adjacent to a coffee plantation, the presence of original elements from the forest that the farmers leave to use as natural shadow for the coffee plants is also frequent. On the other hand, corn plantation is a monocultive that have a dynamic rotation that includes clearing parcels, the dried debries is burned, planting of corn, harvesting corn (February) and abandon of the parcel which is colonized mainly by the fern *Pteridium aquilinium*, a dominant species in clear cutting areas until is time to begin the cycle again. All this cuting-burning-planting process is repeated two times along the year. Some times the people cultivate there flowering ornate species and/or beans.

We studied the dynamics of the amphibian communities in a countryside area of TMCF named El Molote at the state of Guerrero, Mexico. This area has been disturbed for logging and cultivation of coffee and corn from about 30 years. The main intend of this study was to determine the role of the matrix type in supporting amphibian fauna since several endangered and endemic species of amphibians occurs along the SMSG sytem. Considering the lack of Federal Natural Protected Areas in this region an evaluation of the conservation status of the herpetofauna in this countryside area is not only necessary but urgent in order to predict the future of the biodiversity in these impacted areas might be by planning to propose new conservation areas.

1.1 Study area

El Molote is a communal or cooperative land spanning of about 8411 ha located in the Municipality of Atoyac de Alvarez, State of Guerrero, Mexico. The area is part of the mountain system SMSG located at the southern slope of the mountain system and to the south to the highest peak of the area, the Teotepec Mountain (3,500 m elevation). Extreme coordinates are: 17° 24’ 50’’, 17° 27’ 30’’ N and 100° 09’ 40’’, 100° 12’ 20’’ W (Figure 1 in Part I). The area was originally covered with tropical montane cloud forest (TMCF), pine and pine-oak forest, the human settlements in the area date from the end of the 60’s, since then the forest has been intensively used for human profit. The remnant forest patches of TMCF cover an extension of about 700 ha along an elevation interval from 1500 to 2000 m. Characteristic elements of this kind of forest are several species of Lauraceae and the tree *Alfaroa costaricencis* which occurs at the foothills forming forests that are gradually replaced with *Quercus* (Lozada et al., 2003). El Molote town is a small settlement with no more than 450 inhabitants. Other human settlements are remote from El Molote from about 60 km. During the last 30 years, extensive areas of TMCF at El Molote were deforested to convert into cultivation lands, especially for coffee and corn. These are the main productive activities at the town, the cultivation of coffee, corn in conjunction with flowering plants and the commerce of these products at El Paraiso, a bigger town located in the tropical region of the SMSG. Just recently, the authorities and people from El Molote decided to assign part of the communal land for protection thus creating a non Federal declared area but a common land area where non exploitation of resources is permitted, this is common land tenure in Mexico known as “ejido”.

2. Methods

2.1 Field sampling

We selected eight parcels comprising three habitats (anthropogenic plantation-forest edge-forest interior) located north to the town that were associated or adjacent to a coffee (four ecotones) or corn plantation (four ecotones). The ecotones were previously identifying with the inspection of digital aerial photographs and then verified at the field. We chose the matrix-forest ecotones that fulfill the following criteria: 1) the forest edge have not been extensively managed or disturbed for more than 15 years, 2) each forest edge was associated to a cultivated land, 3) close to the surveyed ecotone we identified at least one stream and/or pool to standardize the relationship of this variable for the amphibian species with aquatic reproduction. Each ecotone was geograpically referred and labeled with a number (Ecotone 1, Ecotone 2, etc.) and then divided into three habitat types: plantation (corn or coffee), forest edge (delimited within the first 20 m of forest), and forest interior (beyond the first 50 m of forest from the edge until 150 m) (following Williams-Linera et al. 1998, Urbina-Cardona et al. 2006). On each of these habitats we set up three permanent transects of 50 m in length chosen randomly and set at predetermined distances from the forest edge (Figure 2). The whole study included 8 Ecotones representing three habitat typeswith a total of 72 permanent transects. We surveyed for four consequitive seasons covering two of dry (May 2007 and February 2008) and two of rainy seasons (September 2007 and August 2008). The transects were conducted using visual encounter surveys (VES) (Heyer, et al., 1994), searching for amphibians from all possible microhabitats within 1 m on both sides of the transect and up to 2 m in height. All transect surveys were standardized for time and distance to 20 minutes with the same capture effort and by the same four observers. Replication along habitats and ecotones controls for the pseudoreplication biases on amphibians and environmental variables that could be introducing due to habitat heterogenity (Urbina-Cardona et al. 2006). The total survey effort was of 192 man/hours. Identification of amphibian individuals was made directly in the field, non collection was made with the exception of an unidentified salamander that requiered at least one individual as a voucher reference, this individual was deposited at the Herpetological Collection of the Museo de Zoología, Facultad de Ciencias, UNAM (MZFC). After identification, the organisms were released to reduce invasive practices and negative effects over the populations. For each organism found (n=58) along the transect six variables that represent the microhabitat were measured in the way of Urbina Cardona et al. (2006): temperature, relative humidity, leaf litter depth, height from forest floor, herbaceous cover and leaf litter cover. The temperature and humidity were obtained with a remote sensor Thermohygrometer. Leaf litter depth was directly measured by using a scaled rule. The herbaceous and leaf litter coverage were estimated with a plastic 4 X 4 nylon divided quadrat. Other variables were measured per each transect (n=72) such as distance to the edge, altitude, distance to the town, distance to the streams, canopy cover and slope. All distances were calculated by using the geographic references of a GPS from the transects to the nearest forest edge, stream and town; altitude was measured with an altimeter; slope with a clinometer; and the canopy cover was estimated with a spherical densiometer, counting the number of filled cuandrants with canopy vegetation reflected in a convex mirror and calculating the formula: multiplying the total count by 1.04 to obtain percent of overhead area not occupied by canopy. The difference between this and 100 is an estimation of overstory density in percent. The process was repeated three more times (facing north, east, south an west).

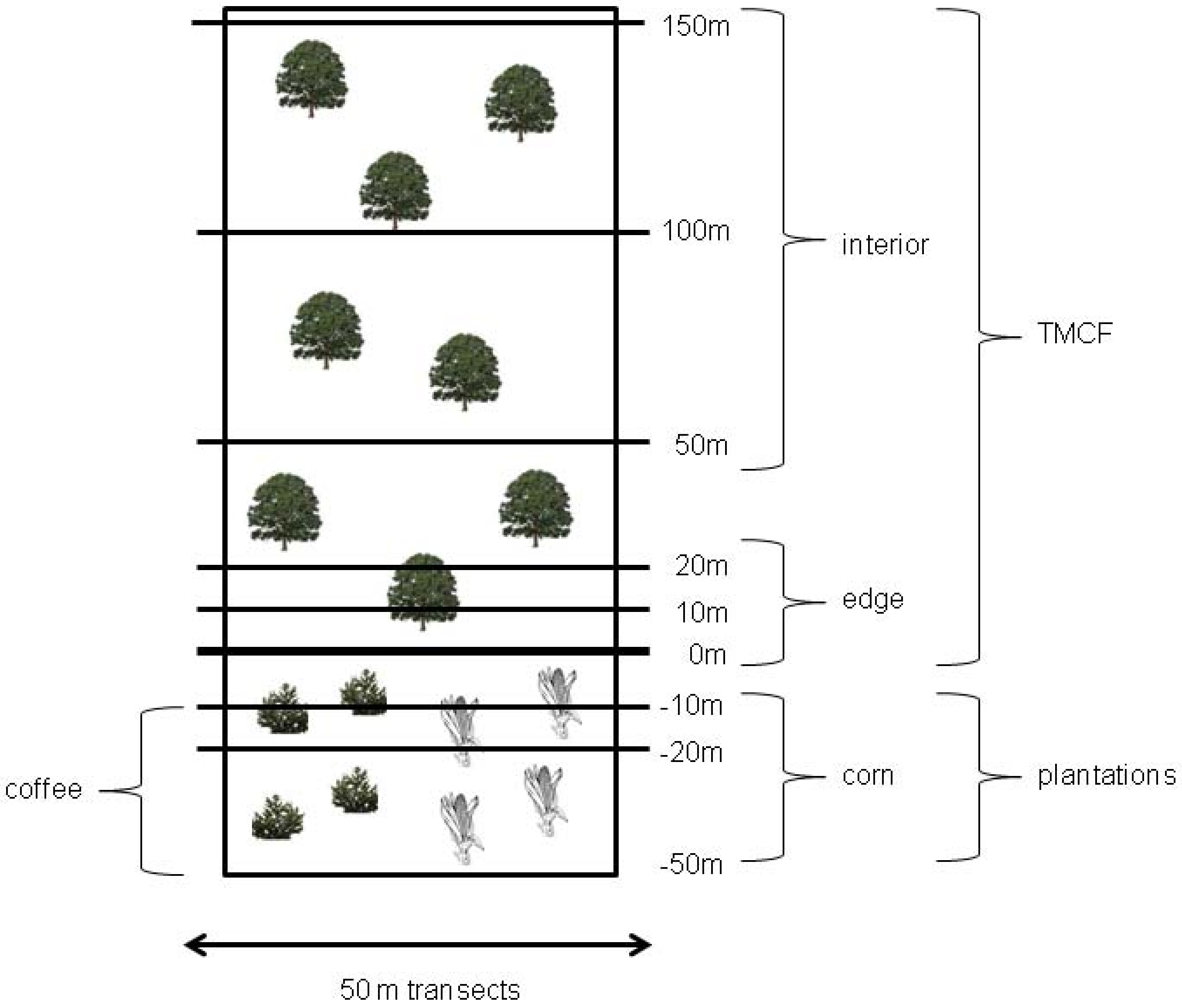

Figure 2. Sampling design to study amphibian communities in the ecotones matrix (coffee or corn)-edge-interior in the TMCF in El Molote, Guerrero, Mexico

2.2. Data analysis

To compare species richness among study habitats with an equal sampling effort, we made a prediction of species richness using three non-parametric estimators Bootstrap, Chao1 and Chao2 in the EstimateS 8 program (Colwell, 2005). The function of expected richness (Sobs) is the accumulation function of species along transects per habitat (n = 72) (Colwell et al., 2005). We compare abundance and species composition patterns between habitats by plotting the number of individuals of each species on each of the six habitats.

To describe the composition and structure of amphibian species at the microhabitat level we used the number of species (specific richness) and the proportional distribution of the importance value of each species in the community (evenness, Magurran, 1988). The evenness was calculated using the natural logarithm based Shannon Diversity index (H'), with values ranging between zero and the logarithm of maximum richness when all species are represented by the same number of individuals (Magurran, 2004). The Shannon index expresses the uniformity of the important values throughout all found species (Magurran, 1988) and measures the degree of uncertainty to predict to which species an individual of the collection would belong (Pielou, 1977; Magurran, 1988), thus raising the importance of rare species in the sample (Brower et al., 1998). This index assumes that all species are represented in a homogeneous sample and that all individuals are randomly sampled (Magurran, 1988; Pielou, 1975; Zar, 1999). A Bootstrap analysis was used to calculate Shannon indexes variance to directly detect differences in diversity index among habitats, transects, and seasons.

We also conducted a non-linear regression to determine the relationship between some species abundance and the coffee-edge-interior gradient. To evaluate the effects of seasonality, habitat type and distance from edge effects on amphibians we analyzed amphibian abundance per transect (n = 72) per season (n = 2) by analysis of variance. When analyzing the models, all residuals accomplished normality and homoscedasticity of variance. To test for differences between factors we used the Shapiro Wilk test. All analyses were performed using the Statistica software (StatSoft 2001).

Pearson correlation coefficients were used to determine correlations among microhabitat variables and to identify non-correlated variables. All measured 12 variables (n = 58 data for each variable) accomplished normality and homoscedasticity of variance. All data were analyzed with Statistica 6.0 software (StatSoft, 2001).

Backward stepwise multiple regressions were used to detect the relationship between measured environmental variables as predictors and the species presence in their microhabitats as the response variable. The variables with non significant F test result (p>0.05) were eliminated from the model. We tested for normality of regression residuals with the Shapiro–Wilk (W) test using Statistica 6.0 software (StatSoft, 2001).

3. Results

3.1 General aspects

After 192 man/hours of sampling effort, 58 individuals of seven amphibian species were captured. For the entire area, the total amphibians predicted in the inventory were 87.5% (Table 1). The forest edge and interior were expected to have more additional species (1 and 4, respectively), if the survey effort was increased. Based on the non-parametric richness estimators the survey represented all the expected amphibian species in coffee and corn plantations (Table 1).

Table 1. Abundance age structure, species diversity, and observed and estimated species richness for habitats and the entire landscape in the TMCF of El Molote,Guerrero, Mexico

	Landscape	Coffee	Edge	Interior	Corn Edge
Abundance	58	11	25	18	4
Adult/Juvenile/ froglets	16/23/19	2/8/1	8/8/9	6/6/6	0/1/3
H´ (variance)	1.39 (0.014)	0.69 (0.005)	1.34 (0.034)	1.47 (0.04)	0.56 (0.087)
Sobs	7	2	6	6	2
Chao1	8	2	7	9	2
Chao2	8	2	7	10	2
Bootstrap	8	2	7	7	2

3.2. Species diversity and composition among habitats

The ensemble of species in the TMCF of El Molote was dominated by the leaf litter frogs *Craugastor mexicanus* and *C. pygmaeus* with 39.6 and 38% of the total captures, respectively (Figure 3, Table 2). Along the corn plantation-forest edge-forest interior there were no amphibian captures excepting for four individuals in the forest edge belonging to two species (Table 1, 4). Eighty-six percent of all amphibian species were captured at forest edge and interior habitats and 28.5% at coffee and corn plantations (Table 1). The greatest percentage of amphibian individuals was captured in the forest edge (43%) and on the forest interior (31%), whilst only 4% were captured in the corn plantations. At the forest edge and forest interior habitats, 32-33% of the individuals were adults, 32-33% were juveniles and 33-36% froglets. At the coffee, 18% of the individuals were adults, 72% were juveniles and 9% were froglets (Table 1).

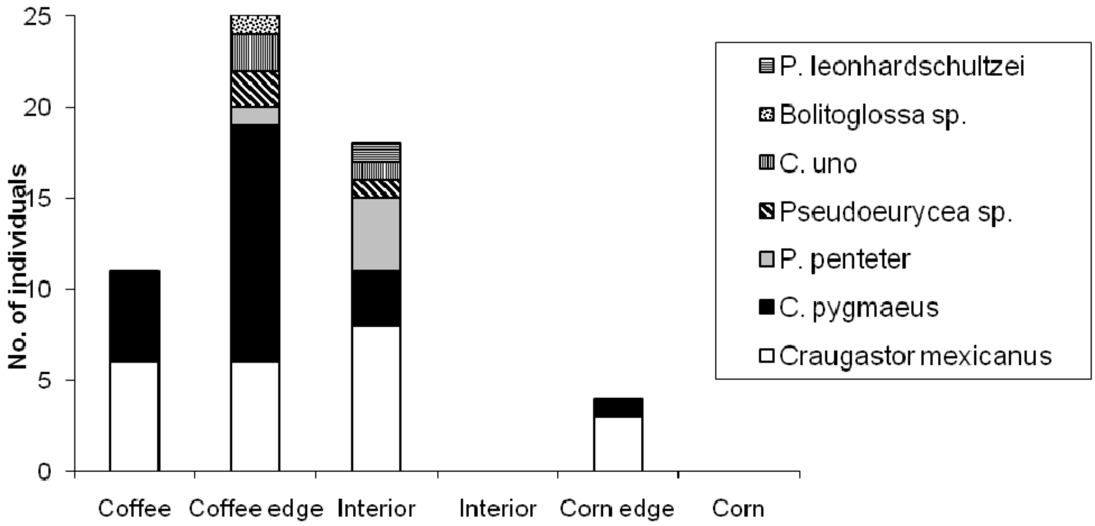

Figure 3. Abundance of seven amphibian species collected at El Molote TMCF, Guerrero, Mexico according to the ecotone matrix-edge-forest gradient.

Species diversity was higher in the forest interior and forest edge (Table 1); one exclusive species inhabit in these habitats (Table 2). All habitats showed a mean complementarity of 49% being the coffee-corn plantations and the forest edge-interior the ones that showed the lowest complementarity index, which means that had similar species composition (Table 2). The surrounding coffee matrix was equally dominated by *Craugastor mexicanus* and *C. pygmaeus* (Figure 3, Table 2). Forest edge limiting with corn plantations was dominated by *C. mexicanus,* the forest edge limiting with coffee plantations was dominated by *C. pygmaeus* and the forest interior was dominated by *C. mexicanus* (Figure 3, Table 2).

Table 2. Species complementarity values between habitats along the ecotones in the TMCF of El Molote, Guerrero, Mexico*

	Coffee	Edge	Interior	Corn Edge
Coffee	**0**	2	2	2
Edge	0.66	**1**	5	2
Interior	0.66	0.28	**1**	2
Corn Edge	0	0.66	0.66	**0**

*Bold values in the diagonal correspond to the number of unique species for each habitat. Values up of the diagonal correspond to the number of shared species between two habitats. Down the diagonal are the complementarity values that ranges from 0 when species composition are identical between two habitats and 1 when species composition is totally different between two habitats.

3.3. Amphibians along edge distance gradient

The abundance of two species changed significantly along the coffee-edge-interior gradient: the tree-frog *Plectrohyla penteter* increased linearly into the forest interior (R2=84%, p=0.004) and the leaf litter frog *Craugastor pygmaeus* abundance increased in the forest edge showing a non-linear shape curve (R2=87%, p=0.02; Table 3). Species richness and diversity showed the same pattern along forest edge distance gradient: the greatest species richness and diversity were found at 20 m from the forest edge that limits with coffee plantations reducing its values in both directions to the forest interior and to the forest edge (Figure 4, Table 2).

Table 3. Simple regression models for two frog species found along the matrix-edge-interior gradient in the TMCF of Guerrero, Mexico

	Regression model	R2 (%)	F	p
Craugastor pygmaeus	y = 8.53 - 0.94 * (LOG x)	87	20.8	0.02
Plectrohyla penteter	y = 0.17 + 0.84 * x	84	17.6	0.004

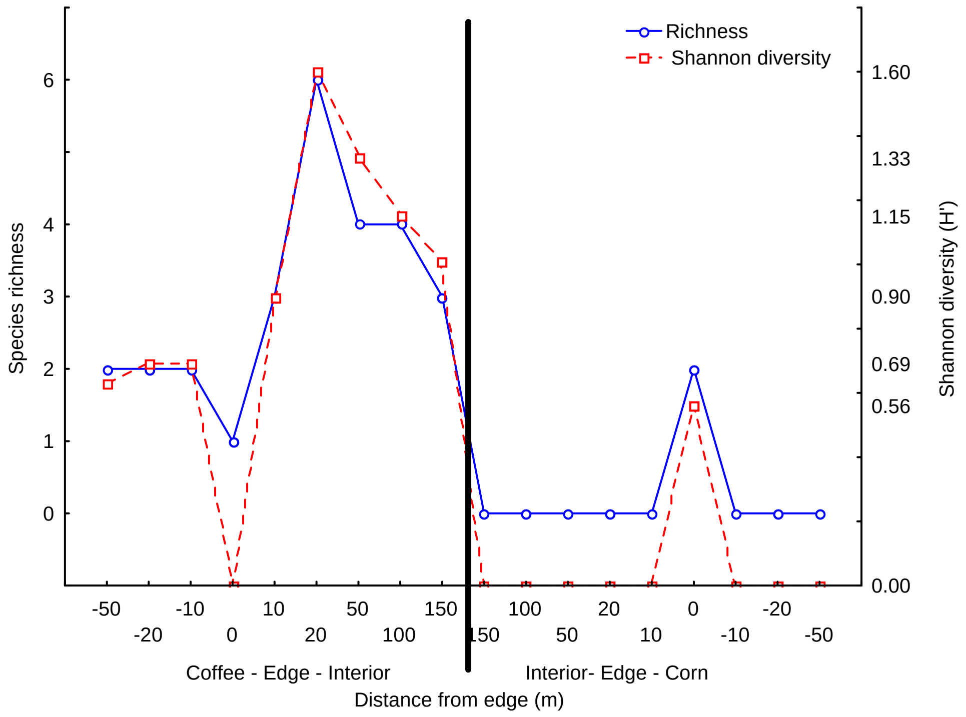

Figure 4. Species richness and diversity along the matrix-edge-interior gradient of amphibian species in El Molote, Guerrero, Mexico

3.4. Seasonality in edge effects

During wet season there were more amphibian richness (86%) and abundance (64%) than in dry season. *Craugastor pygmaeus* was more abundant during the dry season whilst *Plectrohyla pentheter* and *C.mexicanus* were more abundant in the wet season (Table 4).

Table 4. Richness and species abundance across wet and dry seasons in two ecotones limiting with coffee and corn matrices, respectively at the TMCF of El Molote, Guerrero, Mexico.

	Cofee-TMCF ecotone						Corn-TMCF ecotono					
	Coffee		Edge		Interior		Corn		Edge		Interior	
	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY
Bolitoglossa sp.	0	0	1	0	0	0	0	0	0	0	0	0
Pseudoeurycea sp.	0	0	2	0	1	0	0	0	0	0	0	0
Caugastor pygmaeus	0	5	2	11	1	2	0	0	1	0	0	0
Craugastor uno	0	0	1	1	1	0	0	0	0	0	0	0
Craugastor mexicanus	5	1	6	0	8	0	0	0	3	0	0	0
Plectrohyla penteter	0	0	1	0	4	0	0	0	0	0	0	0
Ptychohyla leonhardschultzei	0	0	0	0	0	1	0	0	0	0	0	0
Total abundance	5	6	13	12	15	3	0	0	4	0	0	0
Species Richness	1	2	6	2	5	2	0	0	2	0	0	0

3.5. Correlation among environmental variables

Many of the environmental variables were strongly correlated (Table 5). There was a high, direct positive correlation between distances to river in relation to slope. Relative humidity was negative correlated with temperature, distance to river, and positive correlated with canopy cover. Microhabitat use altitude from the soil and herbaceous cover were not correlated with other variables (Table 5).

The matrix–edge–interior distance gradient was positive related to relative humidity, leaf litter cover, and canopy cover; and negative related with slope and distance to stream (Table 5). Understory density was greatest on the edge of the forest and the percentage of canopy cover was greatest in the forest interior (Table 5).

Table 5. Pearson correlation coefficients among 12 environmental variables measured at the TMCF of El Molote,Guerrero, Mexico

Variable	edge	Temp	RH	LL depth	H	%grass	%leaf lit	Altit	Dis town	Dis stream	%canopy
Distance to edge	1										
Temperature	-0.18	1									
Relative humidity	0.36b	-0.35b	1								
Leaf litter depth	0.18	0.23	-0.01	1							
h from floor	0.22	0.1	0.003	0.1	1						
Grass cover	0.06	0.12	0.09	-0.05	-0.11	1					
Leaf litter cover	0.31b	-0.1	0.1	0.4b	0.006	0.01	1				
Altitude	-0.09	-0.07	-0.03	0.2	-0.2	-0.14	0.16	1			
Distance to town	-0.1	0.13	0.05	-0.3a	-0.06	0.08	-0.2	-0.35b	1		
Distance to streams	-0.7c	0.15	-0.56c	-0.15	-0.06	-0.11	-0.1	0.25	-0.13	1	
Canopy cover	0.34b	-0.27a	0.26a	-0.01	0.1	-0.2	0.06	-0.28a	0.25	-0.48c	1
Slope	-0.56c	0.002	-0.21	-0.1	-0.15	-0.13	-0.07	0.22	0.12	0.51c	-0.31a

p Values a <0.05, b <0.01, c <0.001.

Altitude did not correlate significantly with the pasture–edge–interior distance gradient (Table 5), demonstrating that the effect of this variable was adequately controlled by the sampling design in this study. Although relationship between edge distance gradient with slope and distance to stream could have some alienated effects on topography and water availability with edge effects.

3.6. Relationship of some species with the coffee–edge–interior microhabitats

The presence of *Craugastor pygmaeus* in their microhabitats was negatively correlated with leaf litter cover, relative humidity, distance to river and temperature. The presence of *C. mexicanus* in their microhabitats was positively correlated with temperature, leaf litter cover, relative humidity, distance to streams, distance to forest edge and slope; and negatively correlated with microhabitat use of altitude from the floor. The presence of *Plectrohyla pentheter* in their microhabitats was positively correlated with altitude from the floor and distance to forest edge (Table 6).

Table 6. Multiple regression models for three frog species found in the TMCF at Guerrero, Mexico

	Regression model	R2 (%)	F	p
Craugastor pygmaeus	y = 5.9 -0.36*g - 0.71*c - 0.49*b -0.32*j	80.5	8.66	<0.001
Craugastor mexicanus	y = -7.27 + 0.57*b + 0.27*g + 0.6*c + 0.52*j - 0.21*e + 0.33*a + 0.24*l	74.5	8.9	<0.001
Plectrohyla penteter	y = 0.07 + 0.61*e + 0.25*a	76.4	18.5	<0.001

a, distance to edge; b, temperature; c, relative humidity; d, leaf litter depth; e, altitude from floor; f, grass cover; g, leaf litter cover; h, altitude; i, distance to town; j, distance to streams; k, canopy cover; l, slope.

4. Discussion

Species diversity and abundance

The inventory of species in the Tropical Mountain Cloud Forest (TMCF) at el Molote and surroundings is incomplete, however the species richness expected is not considerable different from our results as can be seen with the results obtained from three estimators (Table 1). The TMCF interior, when limiting with coffee plantations, is expected to support the highest amphibian richness and diversity in the whole region than the remaining areas. The area supports a natural low abundance and might be a low diversity of amphibians when compared with other TMCF adjacent to coffee plantations like the ones from the Atlantic versant of Mexico (e. g. Pineda et al., 2005; Gonzalez-Romero and Murrieta-Galindo, 2008). In some preliminary visits to the area we noted that two leaf litter species (*Craugastor mexicanus* and *C. pygmaeus*) were the most abundant in the area, this notion was confirmed with this study. But, the other two salamanders and three frogs most be carefully studied because of its high degree of endemism and threat. Urbina-Cardona and Loyola (2008) determined that *Plectrohyla pentheter* and *Ptychohyla leonhardschultzei* might be require additional conservation areas because of its limited protected distribution which include only the periphery (4.7% and 1.9% respectively) with its core distribution outside some protected area. Other species of amphibians like the Pine toad (*Incilius occidentalis*) are also present in the area but were recorded in this study far from the cultivation lands and close to the town, suggesting that this species could be more related with the urban areas than with the forest.

Distribution of amphibians across the habitats

It can also be noted that the edge-forest habitat is the one preferred by the amphibians. Although corn and coffee plantations had similar species composition and diversity in this study we demonstrate that coffee plantations represent an important habitat to reduce the edge effects on amphibian species in the TMCF, while the corn plantations affect negatively amphibian´s habitat quality in the remaining forest. The bulk of species observed in this study were captured at the wet season, the activity of amphibians decrease during the dry season which extends for no more than three months. Some species, like the tree-frog *Plectrohyla pentheter* was only recorded at the edge and forest interior during the wet season (Table 4), this is an endangered endemic species. During our field work we suffered the transformation of one transect at the forest interior, two of the most mature trees were cut down and the habitat and microhabitat completely changed, this was identified as the main centre of *P. pentheter* populations. On the other hand, none studies have developed to specifically figure out the role of climate change, (in the way of global warming), and the amphibian phenology in Mexico as has been suggested with temperate amphibians in Europe and the US (Walther et al., 2002). Any change in the pattern of rainfalls could affect the amphibian dynamics. The global warming is a present threat to amphibians that added to the existed problems identified can seriously affect the populations inhabiting these forests.

Final considerations

Although the TMCFs of El Molote are immersed in one of the priority regions for conservation in Mexico, the Sierra del sur de Guerrero (Number 117, Arriaga et al, 2000) that no means that it has a developed program for management of the area. This inclusion is due to the richness of several vertebrate and plant species observed in the area but more importantly to the high endemism observed. In fact, overexploitation, pollution, deforestation and changes in the land use are common and increasing every day. However, our results demonstrate that these small fragments of land having human influence can provide suitable habitats to maintain regional diversity (Daily, 2001). The shadow coffee plantations can considerably moderate the edge effects in the TMCF by increasing habitat quality in the forest interior (Urbina-Cardona et al. 2006). This idea can be contrasted with the poor value of the secondary forest to preserve reptile species in a tropical rain forest (Luja et al., 2008) thus revealing the need to increase the study of the spatial and environmental variable gradient related with the amphibian and reptile ecological requirements when including the matrix context in the landscape. Traditionally the edge effect studies in tropical mountain amphibians have been a one-side approach ignoring the matrix influence in edge effects (Marsh and Pearman 1997, Schlaepfer and Gavin 2001) and riskily concluding that the edge effect may be of far less concern than the habitat loss and fragmentation effects (Toral et al. 2002). Gascon et al. (1999) demonstrated that the matrix context has an influence in the dynamics and composition of rainforest frogs having important implications for the management of fragmented landscapes. This study is an approach to the role of edge effects and taking into account the matrix context for the TMCF for amphibian conservation.

The old discussion about development versus conservation of biodiversity should be gone. In the scope of this new scenario of human dominated landscapes any effort to preserve the biodiversity should be welcomed, especially in countries where scarce or non economic resources are addressed to conservation. This is the case of some regions in Mexico where many species now occur in small, isolated subpopulations due to habitat fragmentation and loss and where conservation efforts should be focused in sitescale (e.g. reproduction sites) and landscape-scale (e.g. the establishment of additional conservation areas) actions to buffer the extinction-driven process (Urbina-Cardona and Loyola 2008).

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